2018 Semi-Annual Report

Prepared for: Katherine Swanson

Prepared by: Bret Ericson, Project Director

bret@pureearth.org, +1 212 870 3481

Period Covered by the Report: 1 October 2017 to 1 April 2018

Project: Reducing the Threats of Toxic Chemical Pollution to Human Health in Low- and Middle-Income Countries

Cooperative Agreement No. AID-OAA-A-16-00019

Cover Photo: Theater performance on lead risk mitigation at a community event in Patna, Bihar, India.

Table of Contents

ACRONYMNS

ASGM – Artisanal Small-scale Gold Mining
BAT – Benchmarking Assessment Tool
BLL – Blood Lead Level
ChemObs – Chemicals Observatories
DENR – Department of Environment and Natural Resources (Philippines)
DSA – Detailed Site Assessment
DPV – Direction de la Protection des Vegetaux
GAHP – Global Alliance on Health and Pollution
GEF – Global Environment Facility
GoJ/P/V – Government of Jamaica/ Philippines/ Vietnam
IEED – Institute for Environment and Eco Development Institute for Environment and Eco Development
IRB – Institutional Review Board
ISS – Initial Site Screening
LMIC – Low and Middle Income Countries
MONRE – Ministry of Natural Resources and Environment (Vietnam)
PE – Pure Earth
PSA – Preliminary Site Assessment
TSIP – Toxic Sites Identification Program
ULAB – Used Lead Acid Battery
UNE – United Nations Environment
UNDP – United Nations Development Program

ANNEXES

Annex A – List of Assessed Sites
Annex B – Draft Manuscripts
Annex C – Colombia Annual Report
Annex D – *The Lancet* Commission on Pollution and Health media coverage
Annex E – *The Lancet* Commission on Pollution and Health
Annex F – Meetings Held

Annex G – La Dolores Report (Colombia)

Annex H – Benchmarking Assessment Tool training report (Colombia)

Annex I – HPAP manual

Annex J – Vietnam Background Survey

Annex K – Vietnam Workshop Report

Annex L – Vietnam Workshop Survey

Annex M – Community Education Materials examples

Project Background

Project Summary

The overall goal of the project is to assist governments and communities heavily impacted by toxic pollution in poor countries to take locally led action to mitigate health exposures by breaking pollution exposure pathways and preventing future toxic emissions. The project is executed by Pure Earth (PE) in eight countries (Bangladesh, Colombia, India, Jamaica, Mongolia, the Philippines, Senegal, Vietnam) and contains three broad objectives, each with its own set of activities and outputs. The three objectives of the project are as follows:

1. Improve existing knowledge and gather critical data about the scope of toxic pollution and its human health impacts by expanding the Toxic Sites Identification Program;
2. Encourage national and international decision-makers to mainstream the issue of toxic pollution, chemicals and wastes and associated impacts on human health and the environment into development agendas through awareness raising, presentation of scientifically-based evidence and encouraging action; and
3. Assist decision-makers and communities in five countries to mitigate the impacts of toxic pollution, chemicals and wastes on human health and the environment through training and capacity building, and provision of technical expertise and support, for specific interventions that produce measurable reductions in exposure risk.

Summary of Progress

Good progress has been made on key indicators, including the assessment of sites, pilot projects and outreach. Major accomplishments of the reporting period include:

- 38 sites putting the health of an estimated 159,000 people at risk were assessed in 5 countries. These sites are in addition to the 300 assessed to date by the project affecting more than 600,000 people.
- Cleanup projects to mitigate exposures were executed in Bangladesh, Colombia, India, and the Philippines. Each of these projects received significant in-kind or cash support from local governments and/or other international donors.
- The world's premier medical journal, *The Lancet*, dedicated an entire issue to a report authored with the support of this project. The Lancet Commission on Pollution and Health gained immense international media attention.
- Additional support from the Pollution Management and Environmental Health program of the World Bank was leveraged (USD 509,992) to improve the Initial Site Screening (ISS) protocol and database, resulting in a cleaner and more robust interface. The project will also build on site assessment work conducted under this project in Bangladesh.
- National level coordination on pollution and health issues began in Colombia, Bangladesh and the Philippines as part of the Health and Pollution Planning (HPAP) under Objective 2: Mainstreaming.

PROGRESS AGAINST KEY INDICATORS

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
1	Objective One: Toxic Sites Identification Program (TSIP)					
1.1	TSIP Trainings conducted	Trainings held	0	0	3	9
		Number of investigators trained (goal 50% female)	0	0	15	95
		# women		0		46
		# men		0		49

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
		Number of government staff trained (goal 50% female)	0	0	15	145
		# women		0		74
		# men		0		71
1.2	Site Screenings	Site Visit	50	38	200	300*
		Number of samples taken per site	5	7.5	5	9.5
		Number of samples taken total	250	292*	1,000	2,646*
		Number of Stakeholders interviewed per site	2	3.8	2	3.1
		Number of Stakeholders interviewed total	100	145	400	888**
		# women		39		239
		# men		106		658
1.3	Research and Analysis	Reports published	1	1	2	1
		Papers published	0	2	2	3
2	Objective Two: Mainstreaming					
	International and national awareness about toxic pollution	Number of organizations	2	0	5	9

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
2.1	Sharing Data	Number of final workshops	0	0	3	0
		Number of Country Data Reports Shared	1	0	3	0
		Number of stakeholders participating in final workshops	9	0	18	0
		# women		0		0
		# men		0		0
		Number of government agencies engaging in final workshops	3	0	6	0
2.2	Action Planning	Number of planning workshops held	1	1	3	1
		Number of government agencies engaging in the planning process	12	12	6	12
		Number of government participants attending	14	14	18	14
		# women	6	6		6
		# men	8	8		8

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
		Number of strategy, policy or program plans drafted	1	0	3	0
2.3	Donor Meetings	Number of international presentations on TSIP data	3	2	6	24
		Number of national presentations on TSIP data	0	0	4	6
		Number of meetings held with donor agencies/international organizations	2	28	10	143
		Percentage of survey respondents demonstrating an increased interest in toxic pollution as a result of meetings	0.6	0	0.6	0
3	Outcome 3: Pilot Projects					

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
	Local and national capacity to reduce health risks from toxic pollution, prevent future emissions and replicate pollution mitigation projects is enhanced	Number of countries planning or implementing interventions to mitigate exposure risks at contaminated sites	2	4	5	4
		Number of people (m/f) estimated to benefit from reduced health risks at pilot project sites or because of interventions	2000	2100	5000	2100
		# women		1050		1050
		# men		1050		1050
3.1	Five Sites Selected	Number of pilot interventions selected	2	5	5	5
3.2	Stakeholder Involvement	Number of stakeholder meetings held	2	12	5	15
		Number of stakeholders (m/f) participating in stakeholder groups	12	5057	30	5181
		# women		2552		2628
		# men		2505		2553

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
		Percentage of survey respondents with a positive view of participation in project design and implementation	0.7	0	0.5	0
3.3	Five in-depth site reviews conducted.	Number of DSAs conducted;	2	0	5	6
		Number of people (m/f) estimated impacted by interventions	2000	900	5000	900
		# women		450		450
		# men		450		450
		Number of persons (m/f) trained to conduct in-depth site characterizations at contaminated sites	10	4	25	42
		# women		2		20
		# men		2		22
3.4	Pilot Project Design	Number of pilot intervention projects or programs designed	2	5	5	5

	Performance Indicator	Units	Reporting Period Target	Reporting Period Result	Total Project Target	Total Result to Date
3.5	Pilot Project Execution	Number of clean up, prevention or other pollution intervention site projects initiated as a result of USAID assistance (activities under Outputs 3.1-3.4)	2	4	5	5
		Number of persons trained (m/f) in pollution mitigation strategies and interventions, and number of those assisting in the implementation of the pilot projects (goal 50% female)	20	43	50	86
		# women		15		46
		# men		28		40
3.6	Contamination reduced	Number of samples taken before and after intervention, ensuring that contamination levels are accurately measured.	200	714	500	1475
3.7	Guidance Documents Produced	Number of guidance tools/documents produced	1	0	2	0

*205 Sites were reported in the previous semi-annual report, while 38 are reported for this period. However, in total 300 sites have been assessed during the project (greater than the sum of 209 and 38). The reason for this discrepancy is a lag time in when sites

are assessed (which is tracked) versus when they are entered into the database (which is not tracked). Annex A lists all sites assessed to date.
** Number of Samples Collected reflects only those samples manually entered into the database. In reality additional samples are often collected and analyzed. These results are recorded on a sample log and included in site entries as attachments only. In addition, the tracking issue mentioned above also affects the number of samples reported semi-annually. Thus the amount given here (2,646) is greater than the sum of previous reports (1,543) and the total for the reporting period (292).
*** Some gender breakdowns do not sum to the total for each site due to QA/QC issues related to the new data field.

PROGRESS AGAINST OBJECTIVES

Objective One: Toxic Sites Identification Program (TSIP)

Initial Site Screenings and the TSIP Program

Progress continued to be made against this objective during the period covered by this report. Currently the number of completed assessments exceeds the amount targeted by the work plan. The reasons for this are detailed in the country-specific sections. Going forward, the targets will be re-evaluated and adjusted as needed in the next award modification. As part of the objective, site investigators are hired and trained in contaminated site assessment.

The Toxic Sites Identification Program (TSIP) began in 2007 with support from the European Commission and the United Nations Industrial Development Organization (UNIDO). Since that time the program has identified more than 4,000 contaminated sites in LMICs. Of those, nearly 3,000 sites in 51 countries have been visited by investigators trained and supported by the program. USAID began supporting the effort in 2016.

The TSIP is unique in that it is the first global effort to assess contaminated sites in LMICs. Importantly, there have been other similar efforts carried out under the auspices of different conventions. For instance, FAO maintains a database of pesticides stores known as the pesticides stock management system (PSMS), executed primarily with support leveraged by the Stockholm Convention. Similarly, the Minamata Convention obligates signatories to develop lists of ASGM sites in their respective countries. The TSIP is both broader in that it is not restricted to one chemical (or class of chemicals) and more specific, in that it focuses only on those sites where human health is at risk. This means that investigators have a reasonable suspicion of the presence of a receptor (human beings), a known human exposure pathway (air, water, soil) and a contaminant above recommended levels[1] in that pathway at all sites assessed. As such, the TSIP serves a key role in understanding the scope and

[1] http://www.pureearth.org/wp-content/uploads/2014/12/Maximum-Recommended-Levels-Sheet1.pdf

severity of a broad set of pollution issues not being reviewed elsewhere. By focusing specifically on sites where human health is at risk, the TSIP can help national governments and international donors prioritize sites or thematic areas for action. In this way, the TSIP acts both as an advocacy instrument and a practical tool to deal with sites resulting in serious health outcomes for millions of people.

Site assessments executed under the TSIP fall into two broad categories: rapid or detailed. With regard to rapid assessment, a tailored protocol, the Initial Site Screening (ISS) is utilized. The ISS represents a compromise between cost and comprehensiveness and was developed specifically for use in LMICs. As part of the ISS, 5-10 samples are collected, photographs are taken and a basic site history is recorded. Completed assessments are entered into an online database (int.dbisa.org) where they are searchable by a range of criteria and checked for quality control and assurance.

The ISS has gone through significant refinement since the program began. ISSs (previously ISAs) carried out earlier in the program were markedly less robust, relying on fewer samples and less questionnaire requirements. The current protocol, while much improved, is still not a perfect instrument. Given the challenge presented by multiple contaminants in multiple geographies, the ISS will likely continue to evolve. This is true as new technologies are developed (e.g. data collection and storage), new chemicals are released into the environment (e.g. PFOS), or the data needs of governments change (e.g. in response to new conventions). With support of the World Bank PMEH program, the ISS went through a stringent peer-review exercise in the second half of 2017. Surveys were conducted of more than 150 previous and current users of the database to identify improvements. More than 20 international experts in site assessment were engaged in a 5 hour workshop in Washington DC with USAID participation in June 2017 to discuss and suggest improvements. In response an improved protocol and database were developed and is currently being trialed in Tanzania under that program. After an evaluation period, the revised database (hosted at tsipdatabase.org) will replace the existing portal and all data will be stored in that format. The transition is currently planned for August 2018 and will be supported by the European Commission, though will benefit this project.

Once ISSs are carried out a prioritization exercise takes place with local and/or national governments. This happens both informally and formally, through meetings, workshops and discussions. The TSIP database includes an integrated prioritization mechanism known as the Blacksmith Index for the process of ranking the relative severity of sites. This index, as well as a number of less quantitative inputs, is used to prioritize sites for detailed assessment. In some cases, detailed assessments are followed by interventions, elsewhere they are not, typically because of limited funding. In some cases affordable technologies, like the portable X-Ray Fluorescence (pXRF) instrument purchased by this project, are available in-country and greatly reduce analytical costs. By way of example, a skilled operator can analyze approximately 150 samples in the field in a single day with a pXRF and record immediate results with no incremental increase in cost. As stated above, the ISS protocol only requires 5-10 samples. Depending on analyte, laboratory analysis can cost USD 50-120/ sample. Additionally these samples can takes weeks to months to process, depending on local capacity. Thus in those countries where a pXRF is accessible, more detailed assessments are sometimes carried out under the TSIP program and labelled as an ISS.

In the period covered by the report, 38 ISSs putting the health of an estimated 159,000 people at risk were assessed in 5 countries. These sites were in addition to the 300 assessed to date by the project affecting more than 600,000 people. The table below summarizes the number of ISSs carried by country and includes an exposed population column to capture the scale of problem identified in each country.

Table 1: ISS by country and key pollutant

Country	1 Oct 16 – 30 Sep 17	As	Cd	Pb	Hg	Other	Pesticides	Period Total	Project Total
Bangladesh	128							0	128
Colombia	17	1		3	4	1	1	10	27
India	65		1	6		1		8	73
Jamaica	0			4				4	4
Mongolia	17	5						5	22
Philippines*	9							0	9
Senegal	28			3			8	11	39
Vietnam**	0							0	0
	237	6	1	16	4	2	9		300

*Extensive site assessment work has been carried out in the Philippines under a new pilot program to develop a complementary protocol to the ISS.

**60 Sites have been identified in Vietnam. Of these 18 have been visited and qualitatively assessed. An additional 2 have been assessed using the ISS protocol and have not been entered into the TSIP database.

Peer-reviewed Research

Two peer-reviewed journal articles were published during this reporting period. A third is currently under review at *Environment International*. Articles are drafted by PE staff jointly with other institutions. With the exception of the *Lancet* report described below, no payments are made to consultants or partner organizations. USAID financing supports the salaries of PE authors and costs associated with primary data collection. Each paper is co-financed with support from the European Commission or other donors.

Table 2: Peer-reviewed Papers

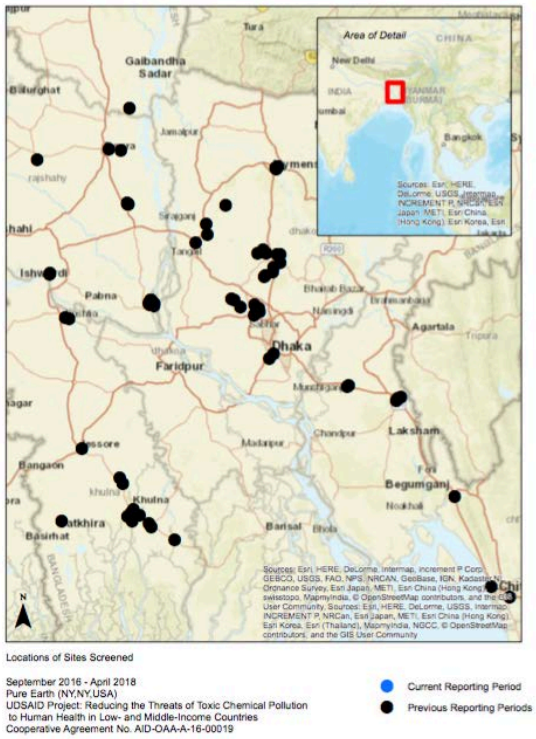
Citation	*DOI*
Ericson, B., Landrigan, P., Taylor, M. P., Frostad, J., Caravanos, J., Keith, J., & Fuller, R. (2016). The Global Burden of Lead Toxicity Attributable to Informal Used Lead-Acid Battery Sites. *Annals of Global Health*, *82*(5), 686-699.	10.1016/j.aogh.2016.12.005
Ericson, Bret, Jack Caravanos, Conrado Depratt, Cynthia Santos, Mishelle Gomez Cabral, Richard Fuller, and Mark Patrick Taylor. "Cost Effectiveness of Environmental Lead Risk Mitigation in Low-and Middle-Income Countries." *GeoHealth* 2, no. 2 (2018): 87-101.	10.1002/2017GH000109
Ericson, Bret, Thi To Duong, John Keith, Trong Cuu Nguyen, Deborah Havens, William Daniell, Catherine J. Karr et al. "improving human health outcomes with a low-cost intervention to reduce exposures from lead acid battery recycling: Dong Mai, Vietnam." *Environmental research* 161 (2018): 181-187.	10.1016/j.envres.2017.10.042
A Meta-Analysis of Blood Lead Levels in India and the Attributable Burden of Disease	Under review at *Environment International*

The first published paper assesses the cost effectiveness of environmental remediation through a single case study in the Dominican Republic was completed jointly with New York University and Macquarie University (Sydney, Australia). The study found that the cost of one averted DALY in this case was USD 400-3,238. The project was therefore very cost effective according to WHO thresholds. This paper was published in *Geohealth.*

The second described the environmental intervention executed in Dong Mai Village, Vietnam and subsequent drop in biological lead levels. This intervention resulted in 70% declines in blood lead levels over a period of one year. The study was completed jointly with the University of Washington (USA) and the National Institute of Occupational and Safety and Health (Vietnam). The paper was published *Environmental Research.*

A third conducts a meta-analysis of available blood lead data from all sources of exposure in India. This paper was produced jointly with the Public Health Foundation of India. The key finding is that that current disease burden estimates do not account for pediatric exposure to environmental lead. We calculate that 5 million DALYs (or 1% of the disease burden) result from IQ decrement attributable to environmental lead exposure. This paper is currently under review by *Environment International.*

Current drafts of all three articles are attached as Annex B.



Bangladesh

Local Executing Partner
Geology Department, University of Dhaka
Nilkhet Rd, ঢাকা 1000, Bangladesh
Primary Contact: Dr. Aziz Hasan (aziz.hasan@yahoo.com)

Local Government Contact
Dr. Sultan Ahmed (sultan.doe@doe.gov.bd)
Department of Environment, Ministry of Environment and Forests

Focal Area
Legacy and active sites resulting from informal battery processing

TSIP work in Bangladesh under this project paused in September when work shifted to pilot work under Objective 3. The data resulting from that work are currently being aggregated into a national report to be presented to Department of Environment in the 3rd or 4th quarter of 2018. In addition, TSIP results will be included in forthcoming high level planning activities to be carried out under Objective 2: Mainstreaming.

Efforts in Bangladesh have followed immediately upon work supported by the European Commission (EC) under a parallel project. Under that effort, our partner organization (Department of Geology, University of Dhaka) was identified and investigators trained. As such, work in Bangladesh (along with India) proceeded more quickly than other countries. As part of this project 128 site entries have been fully completed. Nearly all sites are informal Used Lead Acid Battery (ULAB) processors. These include informal battery breaking and smelting operations as well as battery repair workshops. These sites are regularly located in residential areas and result in severe exposures to surrounding residents. Lead is a neurotoxicant with a range of other related health effects and particularly affects the developing brains of children. Under the previous effort (funded by the EC) assessments of ULAB processors were carried out in the Dhaka region only. Under this project work was expanded to other regions (Chittagong, Khulna and Rajshahi) while also continuing to make the inventory more robust in Dhaka. The 128 sites visited are estimated to result in elevated exposures to nearly 160,000 people, indicating that ULAB processing in Bangladesh is an urgent and under-reported problem. Work in Bangladesh has benefitted from having a long-standing partnership with the University of Dhaka (first established in 2008 as part of an earlier EC project). The University has access to a portable X-Ray Fluorescence (pXRF) instrument for the rapid assessment of metals in soil. This has greatly reduced analytical costs and improved the detail of rapid assessments. In addition investigation teams have identified a higher prevalence of accessible ULAB sites than were expected. These two factors (ability to rapidly assess) and the high number of sites, resulted in more assessments executed in greater detail than were anticipated. ULAB sites are highly prevalent in LMICs yet notoriously difficult to identify and assess. While PE has been active in Bangladesh since 2010, we were unaware of the extensive contamination resulting from ULAB recycling. The number of sites in Dhaka alone far exceeds anything we have been able to identify anywhere else in the world, indicating that the country is a high priority in this area.

Colombia

<u>Local Executing Partner</u>
Primary Contact: Alfonso Rodriguez (arodriguez@pureearth.org)
PE locally hired consultant

<u>Local Government Contact</u>
Dr. Sultan Ahmed (sultan.doe@doe.gov.bd)
Department of Environment, Ministry of Environment and Forests

<u>Focal Area</u>
Lead and pesticides contaminated sites

During the period covered by this report, 10 additional site assessments were conducted at sites contaminated with lead, pesticides, PCBs and mercury. This activity was carried out in addition to pilot activities under Objective 3 and high-level coordination under Objective 2. Also during this period, an annual report for 2017 was prepared and submitted to the Ministry of Environment and Sustainable Development in December 2017. The report presented summary results of all major activities and is attached as Annex C.

PE had not worked in Colombia prior to this project. Priority areas include pesticide and lead contaminated sites in the states of Cundinamarca, Atlantico, Bolivar and Valle de Cauca. The USAID mission has an ongoing project called Oro Legal focused on mercury-contaminated land resulting from Artisanal Small-scale Gold Mining (ASGM) in 20 municipalities in the departments of Antioquia and Choco. Thus, while this issue is a clear priority for the Colombian government, this project initially elected to focus on other areas to avoid overlap. The team began site assessments in January and has visited and assessed 27 sites in 4 states (Atlantico, Bolivar, Cundinamarca and Valle de Cauca). Altogether these 27 sites potentially affect the health of 117,000 people.

Based on conversations with the USAID Oro Legal project, PE offered to support the assessment of mercury exposures from gold processing shops with the use of a portable mercury analyzer (Jerome). While this joint work has not yet materialized, this equipment remains in Colombia and has been used for the assessment of 4 mercury contaminated sites during the period covered by this report.

India

<u>Local Executing Partner</u>
Blacksmith Institute for a PE (local registered PE office)

Blacksmith Institute for PE
3rd Floor, 28B/7/1, Jia Sarai
Near IIT, Hauz Khas, New Delhi- 110016
Primary Contact: Promila Sharma (promila@blacksmithinstitute.org)

<u>Local Government Contact</u>
Prof. Subhash Chandra Singh (email_scsingh40@yahoo.com)
Pollution Control Board, Bihar State

<u>Focal Area</u>
Legacy and active sites resulting from informal battery processing

During the period covered by this report, 8 sites were assessed, primarily in the Delhi area. TSIP work was then halted as efforts shifted to pilot work carried out under Objective 3 in December 2017. A summary report is currently being prepared on India TSIP work and will be submitted to Ministry of Environment and Forests in the 3rd or 4th quarter. In addition a Bihar specific report will be submitted to state level Pollution Control Board.

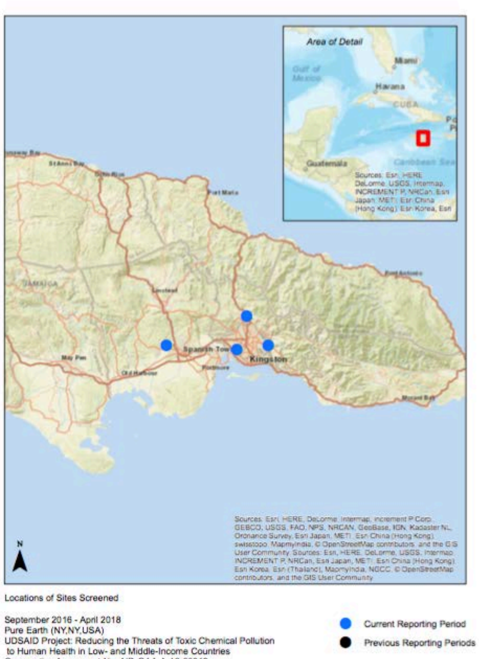
Work in India, like Bangladesh, was preceded by a parallel EC-funded site assessment effort. Also like Bangladesh, PE has operated in India for an extended period (since 2004) and has access to a pXRF. Thus the infrastructure for the project was well in place before execution began. Under the project 73 sites in 5 states have been visited and assessed. Of the 73 sites 48 are in the state of Bihar, where informal ULAB processing is ubiquitous. It is estimated that these 48 sites in Bihar pose a risk to 125,000 residents.

Within the state of Bihar, the project supported a local NGO, the Institute for Environment and Eco Development (IEED). IEED had initially approached PE through an open call for funding under a previous EC supported project. Their proposal dealt with the issue of informal ULAB recycling. While compelling the proposal did not demonstrate sufficient technical capacity for the execution of the proposed project and was accordingly not supported. Under the current award PE experts worked with IEED staff to identify and improve key aspects of the proposal. In particular, sites were quantitatively assessed and prioritized using the ISS and the Blacksmith Index. High priority sites were then assessed in detail and one such site, Karmalichak was identified for risk mitigation work under Objective 3 of this project. This arrangement allowed for the best use of IEED's significant community engagement capacity (discussed under the Objective Three: Pilot Projects section below) while the support of PE's staff to assured adequate technical execution.

Jamaica

Local Executing Partner
International Centre for Environment and Nuclear Science (ICENS) at the University of the West Indies
Primary Contact: Mitko Voutchkov, (mitko.voutchkov@gmail.com)

Local Government Contacts:



Gillian Guthrie (emfmohe@yahoo.com)
Col. Oral Khan (oral.khan@megjc.gov.jm)
Ministry of Economic Growth and Job Creation

Focal Area
Legacy and active sites resulting from informal battery processing

PE had not executed substantial work in Jamaica before this project. Efforts in Jamaica took taken longer than anticipated to initiate as concurrence was assured with GoJ. PE signed an MOU with GoJ on October 17th, 2017 allowing the project to proceed. As part of the agreement a steering committee was formed, comprised of representative from the Ministry of Economic Growth & Job Creation, Ministry of Health, Environmental Health Unit, National Environment Planning Agency, Planning Institute of Jamaica, Pesticides Control Authority, National Solid Waste Management and USAID was formed. Priority sites were identified by PE's partner, ICENS, and proposed the steering committee for approval. Sites were then visited by a trained team of investigators.

To support the execution of TSIP in Jamaica, a two-day training was held in Kingston, Jamaica with participation of the mission and 5 government representatives. A total of 8 investigators (all PhD students) were trained in the ISS protocol during the event, which included a site visit to a lead contaminated site for the purposes of demonstrating the protocol.

To date only 4 sites have been entered into the database, while 12 have been visited and assessed by the team. A number of issues have inhibited the adequate completion of the additional 8 sites in the database, many of which are implicit with initiating the program in a new country. Specifically these relate to the quality of the information entered. Training of new investigators to successfully complete site entries can sometimes be an iterative process with data entry prone to errors. This has been the case in Jamaica. A mission is planned for the 3rd quarter to provide further assistance to the local team with identification and assessment of sites.

Mongolia

Local Executing Partner
Environment and Security Center of Mongolia (ESCM)
Suite R314, Mongolia Youth Federation's Building, Baga toiruu St 42, Sukhbaatar District, Ulanbaatar, Mongolia,
Primary Contact: Erdenesaikhan Naidansuren (erdene@environ.mn)

Local Government Contact
Battulga Sosorbaram (battulga@mram.gov.mn)
Mineral Resources Authority of Mongolia

Focal Area
Areas contaminated from mining operations nationally. Primary contaminants of concern include mercury, lead and arsenic.

At the close of the previous reporting period, 21 sites had been visited and assessed, though only 7 had been fully entered into the database. Accordingly, work during the period covered by this report focused primarily on improving the quality of site entries in the database. At the close of the reporting period 22 sites, including 5 new site entries, were fully entered into the database. These sites pose a risk to an estimated 50,000 people. Target areas included leather tanneries and ASGM sites. In the leather tanning process chromium is added to improve texture. In some cases, hexavalent chromium, a known carcinogen, is used, though more commonly trivalent chromium, a nutrient, is selected. In either case, the common practice of overloading chromium to the leather results in high concentrations in effluent. In the context of informal operations, effluent is typically poorly managed and often discharged to the surrounding areas. In the environment, hexavalent and trivalent chromium can pick up or lose valance electrons, switching between nutrient and carcinogenic forms. Thus during site assessment work, total chromium is measured in human exposure pathways – typically dried sediment downstream.

In the case of ASGM, significant investment by the EC over recent years has resulted in dramatic declines of mercury usage in Mongolia. However, as will other mining locations (both industrial and small scale) the processing of alluvial soils and ore results in the excessive discharge of elements normally bound up in the earth's crust. In the case of ASGM in Mongolia, high naturally occurring levels of arsenic, a human carcinogen and the chemical responsible for arsenicosis, result in high bioavailable levels of this element in residential areas. Thus at these sites, investigators assess both mercury and arsenic.

TSIP work in Mongolia halted in the 3rd quarter of 2017 due to the onset of winter. A summary report is currently being prepared. TSIP work will resume under the expansion of the award.

Philippines

<u>Local Executing Partner</u>
PE, Philippines (local registered PE office)
3rd Floor Vega Center, Lopez Avenue, Los Baños, Laguna 4031
Primary Contact: Larah Ortega Ibanez, *National Coordinator* (larah@pureearth.org)

<u>Local Government Contact</u>
Undersecretary for Environment and International Environment Affairs, Atty. Jonas R. Leones, Department of Environment and Natural Resources (DENR) (jonasrleones@gmail.com)

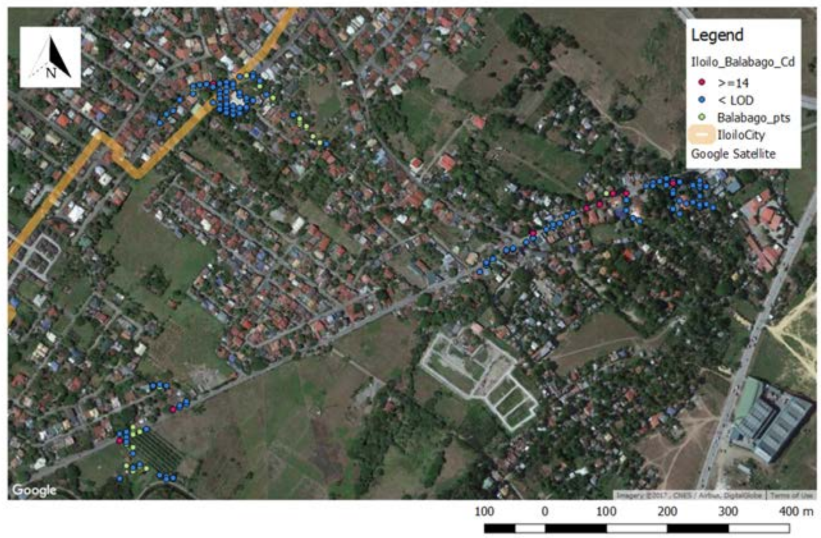
Locations of Sites Screened
September 2016 - April 2018
Pure Earth (NY,NY,USA)
UDSAID Project: Reducing the Threats of Toxic Chemical Pollution to Human Health in Low- and Middle-Income Countries
Cooperative Agreement No. AID-OAA-A-16-00019
Current Reporting Period
Previous Reporting Periods

<u>Focal Area</u>
ISS activities have focused on lead, mercury, and other pollutants in residential areas and in particular in the fish ponds within the Meycauayan, Marilao, Obando river systems (Manila Metropolitan Area and Bulacan province). In addition to ISS activities, an innovative approach to the comprehensive assessment of a given geography is currently being piloted.

Two separate TSIP trainings have been held in the Philippines. The first, in March 2017, covered the standard TSIP approach and ISS protocol. The second, in August 2017, was held to introduce a pilot approach to site identification. As part of the ISS, sites are identified through a range of means, including formal and informal networks, the peer reviewed literature and the news media. In the piloted approach, investigators are tasked with sample collection along a predefined grid in a predefined area. In the case of the Philippines, teams randomly selected a representative sets of barangays (the smallest administrative unit; akin to a neighborhood) within a given a municipality. Those barangays were then assessed comprehensively with pXRF samples taken in increments of one hundred meters. The approach has the benefit of identifying contaminated areas that might have otherwise remained undetected. This is particularly relevant given the common siting of informal industries within residential areas. In this regard the approach has already provided some insight. For instance, in the case of previously unknown releases of cadmium, new sites have been identified (note the hotspots in the map below of a single barangay). These will be revisited under the project and ISSs will be conducted. A second benefit is that, when conducted in a systematic way, the approach is amendable to statistical modeling allowing researchers to make predictions. These might include for instance the total number of contaminated sites in the city, the number of people at risk, and possible associations with poverty. The Philippines was well suited to pilot this exercise for several reasons. One is PE's operational structure and capacity in the country. PE maintains a close relationship with the University of the Philippines, Los Baños with students often engaged in site assessment work. As a result, we have a disproportionately large number of trained investigators in the Philippines. The large number of trained staff is a benefit as the effort requires a large amount of fieldwork. The office also has its own portable analytical equipment (pXRF), which eases sample collection and planning. Finally the World Bank possesses detailed barangay level poverty data in the Philippines and has indicated a willingness to use TSIP data for the purposes of associating poverty and contamination. Geocoded demographic data of this kind is rarely available in LMICs. Thus, pending approvals from the World Bank and their constituents (i.e. GoP) this data could be used jointly with site assessment information to identify linkages between poverty and contamination.

To date the comprehensive assessment exercise has been conducted in the city of Iloilo. More than 70 different barangays were assessed and more than 1,000 measurements have been taken. A challenge has been storing the large amount of data generated in a format amenable to aggregation and use. The current TSIP database was not developed to hold the sort of data generated by the project, which is not organized around a contaminated site, as such. Under the expanded award the possibility of modifying the existing database structure to usefully accept this data will be explored. Both this activity and additional ISS work are currently on hold pending the expansion of the award. A challenge has arisen in determining how best to integrate this new type of data into the existing structure of the TSIP database. Under a parallel World Bank supported effort, a new database for the hosting of TSIP data has been designed and is currently being piloted. With the support of the EC this database will be introduced globally in August 2018. The revised platform is more amenable to geographically organized data. Currently the data collected as part of the Philippines effort is organized primarily in spreadsheets hosted by Google Docs. This format does not facilitate broader use and access beyond the immediate staff executing the project. A formal report will be prepared pending the expansion of the award that presents the key findings, however the use of the new database is anticipated to vastly improve the user experience and usefulness of the data.

Profile of Cadmium (Cd) concentrations in soil at Barangay Balabago, Jaro, Iloilo City (XRF Reading from September 4, 2017 Site Assessment)



With regard to traditional ISS work the PE local office has coordinated with the Department of Environment and Natural Resources (DENR) and the USAID mission to identify priority areas. Three provinces were targeted: Luzon, Visayas and Mindanao. Within these 3 provinces, efforts have focused on 4 different program areas: revisiting sites assessed by PE in previous efforts; sites in municipalities identified under USAID Cities Development Initiative; sites requested by DENR; and finally in barangays identified through the exercise described above. 22 sites have been assessed to date, 9 of which have been fully entered in the TSIP database.

Senegal

Local Executing Partner

Primary Contact: Khadidiatou Sy Djigo (khadidiatou@pureearth.org)

PE locally hired consultant

Local Government Contact

Aita Seck (aitasec@yahoo.fr)

Biologiste environnementaliste Direction de l'Environnement et des Etablissements Classés

Chef de la Division Pollution et Nuisance

Focal Area

Obsolete pesticide storages and legacy ULAB processing sites

At the close of the previous reporting period only 6 sites had been fully entered into the TSIP database, while 29 had been visited. Accordingly significant effort was placed on completing those site entries as well as visiting new sites. At the close of the current reporting period, 38 sites putting the health of perhaps 100,000 people at risk had been identified and assessed. Of these half (n=18) were ULAB processing sites, 7 were contaminated with obsolete pesticides and 6 were mercury contaminated sites resulting from small scale artisanal gold mining.

Locations of Sites Screened

September 2016 - April 2018
Pure Earth (NY,NY,USA)
UDSAID Project: Reducing the Threats of Toxic Chemical Pollution to Human Health in Low- and Middle-Income Countries
Cooperative Agreement No. AID-OAA-A-16-00019

● Current Reporting Period
● Previous Reporting Periods

Pesticide site assessment work was executed jointly with the Plant Protection Directorate (Direction de la Protection des Vegetaux). These sites were identified by the Ministry of Environment and assessed with portable immunoassay test kits. The number of kits procured by the project exceeded the total number used for those site assessments. The balance was transferred to DPV after training. Assessment work of other sites was coordinated with Aita Seck of the Ministry of Environment.

A separate UN Environment (UNE) executed, Global Environment Facility (GEF) supported effort is currently begin carried out in 9 African countries including Senegal. Among the project's aims is the development of Chemicals Observatories (ChemObs) for the aggregation of chemicals data in each target country. PE is coordinating with UNE to facilitate the use of TSIP data in the ChemObs. This effort is encouraging as it assures utility of the results of this project in a broader international effort.

Vietnam

Local Executing Partner
Centre for Environment and Community Development (CECoD)
No. 23, Alley 1004, De La Thanh Street, Ngoc Khanh Ward, Ba Dinh District, Hanoi
Primary Contact: Duong Thi To (duyto2007@gmail.com)

Local Government Contact

Vinh Thanh Hoang (vinhtinh@gmail.com)
Vietnam Environmental Administration (VEA)

Focal Area
Heavily industrialized “Craft Villages” and mining areas. Possible contaminants of concern include lead and cadmium.

The TSIP training was held in Vietnam in March 2017. Progress has been very slow on TSIP work, with only 20 assessments having been carried out and none yet fully entered into the TSIP database. Delays here are attributable to a number of factors, including our small staff focusing on mission requested work (described below), continued mechanical failures of the pXRF unit in country, and bureaucratic issues implicit with working closely with local government partners. Following the technical workshop in March described below we began to put a renewed focus on assessing sites in Vietnam, including utilizing the new pXRF unit procured under this project and conducting additional in country training by senior management. A mission is scheduled jointly with USAID in the 3rd or 4th quarter of 2018.

With regard to the bureaucratic issues implicit with working closely with government agencies, the specific delay has been associated with a failure to acquire government approval to upload data into the online database. Formal support would be necessary to assure a continued productive working relationship with GoV. Specifically, PE will draft a proposal for the Vietnam Environment Administration (VEA) outlining the

The current project follows on a successful risk mitigation project executed jointly with VEA in a specific village heavily impacted by lead pollution (described in the attached peer reviewed publication from *Environmental Research*). Leadership within the Department of Natural Resources and Environment (like VEA, within the Ministry of Natural Resources and Environment) has recently communicated to our local partners that site assessment work should be explicitly linked to the execution of similar projects. Because the intention of the ISS is not necessarily as the basis of risk mitigation projects, it is not the appropriate instrument in this case. The ISS is intended to rapidly assess multiple sites and objectively prioritize them based on health impact. Prioritized sites are then assessed in detail and these assessments form the basis of further prioritization and possible risk mitigation work. DONRE has encouraged us to skip over the ISS stage and pursue more detailed assessments directly. In this case PE would partner directly with provincial Departments of Natural Resources and Environment (DONREs) to conduct the work. These DONREs would provide lists of high priority sites (based on their own protocols) for detailed assessment. PE would then assist DONRE staff in executing the detailed assessment. One such assessment will be carried out in the 4th quarter of 2018 as part of this project.

Under the expanded award, budget would be allocated toward the execution of a limited set of Preliminary Site Assessments (PSAs), which would in turn be prioritized for Detailed Site Assessments (DSAs). Both protocols represent a more in depth assessment than the ISS but represent a compromise as the process would still allow for prioritization based on objective criteria, albeit from a more limited number of sites.

Objective Two: Mainstreaming

Summary

Objective Two includes outputs related to engaging both the governments of the target countries and those of donor countries. With regard to the former (target countries) the key outputs rely on data collected during the TSIP process. Sites are identified and assessed and summary reports are presented to country governments for use in action planning. TSIP work began in most countries covered by this project in the third quarter of 2016, while it began in others in the first quarter of 2017. Once sufficient data has been collected on the status of hazardous waste sites, this data will be presented to country governments for the purpose of action planning. Progress is expected on this indicator by the end of the third quarter of 2018 through formal meetings and continue for the duration of the project. This work had initially been planned for the first quarter of 2018, however in part a focus on other aspects of the project, little activity has yet taken place. The singular exception is Colombia where an annual report with summary results was presented to government counterparts.

With regard to engaging donor countries, activities focused primarily on events and meetings related to the Commission on Pollution and Health report. On 19 October 2017 *The Lancet* published a report by the Commission (10.1016/S0140-6736(17)32588-6), a multi-organizational research effort lead by PE and Mount Sinai School of Medicine. The report was substantially covered by major media outlets globally being covered by more than 3,000 unique media stories and reaching more than 2 billion people. Major stories on the report were produced by leading global media outlets such as the BBC, CNN, New York Times and the Times of India. In addition, within the period covered here, the report had been cited 96 times in the peer-reviewed literature. A full summary of media coverage is attached as Annex D.

The report found that 9 million deaths are attributable to pollution annually, with 92% of that morbidity falling In LMICs. These results were higher than those presented previously, but perhaps more importantly gained unprecedented media coverage. The report's second author and president of PE, Richard Fuller, was invited to present on pollution issues at the World Economic Forum in Davos Switzerland as a result of his role in the report. Thus the impact of the report has been significant and is anticipated to increase. In addition to support from this project, its development was supported by the EC, UNIDO, the Swedish Ministry of Environment and Energy, the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Royal Norwegian Ministry of Health and Care Services, the US National Institute of Environmental Health Sciences, the Icahn School of Medicine at Mount Sinai, and PE. The full report is attached as Annex E and can be accessed at the following link: http://www.thelancet.com/journals/lancet/article/PIIS0140-6736(17)32345-0/abstract

Meetings were also with multiple agencies within donor countries to discuss the scope and severity of pollution issues in LMICs outside of the context of *the Lancet* report. These meetings (n=28 during the period covered by the report) focused on the health risks posed by pollution, the lack of sufficient knowledge of its extent, and cost effective approaches to beginning to deal with the problem. Moving forward these meetings will focus on supporting work in the 8 target countries of this project, including soliciting support for remediation projects and pollution planning.

The dates and purpose of all meetings as well as contact information for whom was met with are attached as Annex F. Meetings were held with the following organizations:

Meetings Held to Discuss the Commission Report

- Asian Development Bank
- Brazil, Permanent Mission to UN
- Canada, Permanent Mission to UN
- European Commission
- European Union
- Finland, Ministry of Environment
- France, Ministry of Environment and Ecology
- France, Permanent Mission to UN
- South Korea, Permanent Mission to UN
- Sweden, Ministry of Environment and Energy
- Sweden, Ministry of Foreign Affairs
- Sweden, Swedish International Development Agency (SIDA)
- Switzerland, Swiss Development Cooperation
- The Department for International Development (DFID, UK)
- United Nations Environment
- United Nations Development Program (UNDP)
- United Nations Industrial Development Organization (UNIDO)
- United Nations International Children's Emergency Fund (UNICEF)
- United States Agency for International Development (USAID)
- United States Department of State
- World Bank
- World Economic Forum
- World Health Organization

Meetings Held to Discuss Pollution in LMICs

- African Development Bank
- Agence Francaise de Development
- Asian Development Bank
- China Development Forum 2018
- European Commission
- European Union
- Food and Agriculture Organization of the United Nations
- Global Chemicals Outlook
- Global Green Growth Institute
- United Nations Environment
- US Environment Protection Agency
- United States Agency for International Development
- World Bank

Health and Pollution Action Planning

The HPAP program promotes collaboration between agencies that may not typically work together to identify practical short to medium actions to protect environmental health.

The HPAP program is the successor to an earlier effort known as National Toxics Action Plans (NTAP). NTAPs focused specifically on the issue of contaminated sites. They were designed to utilize the TSIP database and other related sources of information to identify high priority locations or themes for intervention. In some cases this process resulted in document production at the national level. Under an EC-funded program, Azerbaijan and Armenia for instance, both authored robust technical documents reviewing the issue and identifying actionable steps forward. Other countries held a series of NTAPs workshops but opted not to produce significant documentation. Vietnam and Uruguay, for instance, both held multiple NTAP workshops to promote interagency action on contaminated sites. In Uruguay, this work resulted in the development of a municipal lead remediation program in the city of Montevideo. Under that program, more than 10 hotspots were remediated in the frame of the previous project. In Vietnam, the workshops resulted in the clean-up of a single high priority location. The village of Dong Mai was the site of decades of informal ULAB processing that resulted in severe community wide lead poisoning. That clean-up in turn led to the development of a national blood lead monitoring program carried out at hazardous waste sites by the National Institute for Occupational and Environmental Health (NIOEH).

Despite these successes, the NTAP program failed to gain significant support in most countries. The narrow focus on contaminated sites was likely insufficiently tied to existing programs and funding streams to be taken up in a sustainable way. The HPAP program, by contrast, is much broader in scope. Air, water and soil pollution issues from a range of point and non-point sources are discussed and prioritized. Where possible, priority issues are aligned with existing government programs. The HPAP is therefore more government driven than the NTAP and more responsive to national priorities. Additionally, the HPAP encourages more involvement from other member of the Global Alliance on Health and Pollution (GAHP), a network of international and national organizations that regularly convene to discuss pollution issues that is a project of PE. The NTAP, with its focus on contaminated sites, had at least a de facto bias on PE to support execution. The broader scope of the HPAP program, compared to that of the NTAPs, is the result of increasing consensus among GAHP members and the international community that pollution challenges should be viewed through the lens of public health, and that health impacts should serve as a key prioritization metric when allocating resources and designing interventions. As such, the idea of limiting the scope of the HPAP to, for example, soil contaminated by chemicals, contradicts the message that pollution issues should be viewed as a whole and then prioritized by health impacts. Limiting the scope of the HPAP to specific pollution issues pre-establishes those issues as priorities without first analyzing their relative impacts on public and occupational health.

In 2017, a handbook was developed by Pure Earth outlining the HPAP process (attached as Annex I). The handbook is designed to provide a general over view of the process in accessible and clear language. It provides a general background on the issues of health and pollution globally to provide context for decision makers from disparate backgrounds. It then describes five very broad “phases” through which an action plan is developed and eventually disseminated. Importantly the guide is not overly prescriptive. The HPAP process is intended to catalyse action within national governments, while allowing the specific methods and plans to be determined by those governments themselves.

Under the period covered by this report, significant activity was carried out on HPAP work in Colombia, while work began in the Philippines and Bangladesh. In Colombia, the Ministry of Environment and Sustainable Development (MESD) requested assistance from GAHP to help prioritize pollution challenges and develop plans to reduce pollution’s impacts. MESD agreed to participate in a national HPAP program with facilitators from Pure Earth. The HPAP development process in Colombia has followed the five-step process outlined in the HPAP Manual. The process in Colombia is being supported, in part, by UNIDO, through a grant from the European Commission.

With assistance from MESD and other national agencies, GAHP facilitators (primarily PE and UNIDO) developed a background report summarizing the national pollution situation to help inform the HPAP process and its participants.

In July of 2017, Pure Earth facilitators began contacting relevant national stakeholders in Colombia and international stakeholders with development programs in Colombia to describe the HPAP process, solicited inputs, and invite such stakeholders to two HPAP Inception Meetings to be held in the fall of 2017. The collaborative HPAP process began in Colombia in October 2017, with the convening of a multi-stakeholder Technical Workshop and High-Level Inception Meeting in Bogota on October 18 and 20, respectively.

The purpose of the Technical Workshop was to invite inputs from technical staff from relevant ministries, non-governmental organizations, and international development agencies. The invitees were chosen based on their familiarity and expertise working on specific pollution issues relevant to Colombia. The output of this meeting was an initial list of priority pollution challenges and potential solutions for Colombia. Following the Technical Workshop, Pure Earth facilitators created a presentation summarizing the outcomes from the Technical Workshop for further discussion during the High-Level Inception Meeting.

A subsequent High-Level Inception Meeting was held with decision-makers from key national ministries. The results of the Technical Workshop were shared with the participants, who agreed that Colombia should pursue the HPAP program as designed and focus on the identified priority pollution issues.

Since the Inception Meetings, PE and UNIDO have assembled a team of four consultants to gather and analyze information, continue meeting with stakeholders, and draft sections of the HPAP document.

In June 2018, the HPAP team will co-host a mid-term HPAP meeting with CONASA—an inter-ministerial technical committee established to coordinate environmental health initiatives. One of CONASA's primary responsibilities is to draft a National Environmental Health Plan. The scope of this plan is broader than that of the HPAP, but includes pollution issues. This drafting process is underway currently. The HPAP will not only feed into this National Plan, but will also serve as the roadmap to implement some of the goals established in the National Plan. PE anticipates completing a draft HPAP and hosting a validation meeting by the fourth quarter of 2018.

Objective Three: Pilot Projects

Summary

As part of this project 6 sites were identified through the TSIP program for intervention. The project supported significant components of risk mitigation projects including the design of activities and execution of community education campaigns. However the project did not support execution of construction work, thus alternative sources of funding were required for the completion of this objective. In some cases domestic sources of funding were identified (either cash or in-kind) for the execution of risk mitigation projects, elsewhere funding came wholly from international sources. In all cases some portion of funding was required from international donors. A parallel project supported by the EC included some resources for these types of projects. To best utilize these funds, project teams carried out a series of detailed site assessments (DSAs) at high priority sites. These DSAs formed the basis of proposals that were in turn reviewed by a project review committee in the second quarter of 2017. Summaries of the DSAs selected during that meeting were provided in the previous reporting period.

In total twelve proposals were developed for clean-up projects in 11 countries, with 5 of the proposed projects falling in countries covered by this award. The balance fell in countries covered by the EC project. All proposals were based on work conducted jointly by PE technical advisors and staff, local partners and local and/or national governments. Previous similar efforts by PE relied almost entirely on submissions assembled by country governments and local partners, with much less involvement from PE staff and technical advisors. These earlier proposals were then submitted to the Global Alliance on Health and Pollution executive committee to decide funding. An internal review of this process found that without direct support from PE staff and technical advisors, fewer proposals were generated from lower income countries, with only one being generated in Africa, for instance. The same review found that those proposals from lower income countries were also generally of poorer quality. Moreover, in most cases, the proposals were based on likely insufficient information to support effective decision-making. Despite these issues a number of effective interventions were executed, relying on ad-hoc decision making in the field. Technical experts were often forced to make on-the-ground decisions reacting to new information and adjusting interventions accordingly.

To correct for these issues, and promote a more structured approach to this process, a somewhat more detailed proposal template was developed for pilot projects. PE staff and technical advisors were substantially involved in the process, including sample collection, project design, identification of key stakeholders, and proposal drafting. The work, conducted jointly with local partners in all cases, had the benefit of both building capacity through hands-on training and producing higher quality proposals.

Pure Earth staff were also involved in the evaluation of the proposals. All submitted proposals were reviewed by regional directors and support staff in New York. Reviewers utilized a standard format for evaluating the proposals. Each proposal was ranked across a series of parameters in a matrix to determine its relative feasibility and impact. Key criteria included the project's potential impact on human health, government support and co-financing, the quality of the project design, and the ability of the project to be replicated elsewhere. Of the 12 projects submitted eight were selected for execution, with

5 of those falling within the scope of this project. Those 5 projects are listed in Table 3 below. Four of the 5 projects were executed during the period covered by this report. The fifth is dependent on co-financing from a donor, Green Cross Switzerland, and has been delayed due delays within that organization. It is expected to be executed in the 3rd quarter of 2018.

All selected projects presented lead (Pb) contamination as the primary issue. This mirrors the results of TSIP efforts carried out under this award with most sites assessed having presented lead as the primary contaminant of concern. This outcome results from a number of factors that have influenced the selection of site assessments and risk mitigation projects. Foremost among them has been the preference of government agencies and partner organizations for working on lead pollution. Early discussion about the project's focus consistently revealed an interest in lead pollution. This was sometimes in concert with other pollution issues (e.g. with pesticides in Senegal and Bangladesh) and elsewhere reflected the explicitly preferred focus (e.g. Colombia). In addition advances in portable measurement equipment (i.e. the pXRF) facilitated an ease of metals assessment over organic pollutants, for instance. Finally, PE's own extensive experience dealing with lead contamination has resulted in the development of a number of cost effective and innovative strategies. Thus, in the context of limited resources, lead contaminated sites were prioritized given the relatively low cost of execution.

In addition to the projects for which proposals were developed and formally evaluated, a sixth project resulted from a joint USAID/ PE oversight visit to Colombia in the 3rd quarter of 2017. During the site visit to Cali, a Preliminary Site Assessment (PSA) was carried out in the residential area (La Dolores) surrounding a lead smelter near the city of Cali. The mission uncovered extensive contamination at the site. The preliminary results of that mission were presented to the relevant local government authorities (Corporación Autónoma Regional del Valle del Cauca-CVC; Secretaria de Salud Palmira) and later submitted formally in a report, which also included blood lead monitoring data (Attached as Annex G). The report unintentionally triggered a series of actions which lead to the temporary forced closure by CVC and subsequent reopening of the smelter. The intention of the report was to summarize the extent of lead contamination around the site for local authorities that they may incent the smelter to make necessary improvements. To facilitate these improvements PE organized for a training by the International Lead Association on their Benchmarking Assessment Tool (BAT). The BAT was developed specifically to assist smelters in LMICs to make incremental upgrades to their facilities over the medium term while providing regulatory agencies the tools to monitor those changes. Lamentably, in this case the smelter owners did not participate in the BAT training held in April 2018, owing largely to bad sentiment cultivated by the forced closure by the local auth orities of the facility. Nevertheless, the BAT training was executed successfully for regulatory authorities and built local capacity in a key area. A report on the BAT training is attached as Annex H.

Table 6. Table of Clean up Projects in 2017

Site	Country	Pollutant	Summary	Partners (with in-kind or cash support)	Exposed Population	Status
Kathgora	Bangladesh	Lead	The TSIP has identified 125 informal Used Lead Acid Battery (ULAB) smelters in the Dhaka region. This town previously had two smelters, both now shuttered. Lead in soil is well above recommended levels resulting in exposures to 3000 people.	University of Dhaka (local direction); Department of Environment (oversight); EC (funding)	300	Complete
La Dolores	Colombia	Lead	A formal active smelter shares exterior walls on one side with residential structures. While the facility is operating legally, lead and sulfur dioxide levels greatly exceed international standards. The project aimed to assist regulatory authorities to develop capacity to assess the smelter and to assist the smelter with upgrading.	International Lead Association	200	Complete
Malambo	Colombia	Lead	There are three former lead smelters in this village resulting in significantly elevated exposures in residential areas. Two of the sites are closed to public access, while a third is open. The project is remediating that third site.	Government of Malambo (labor); Ministry of Environment and Sustainable Development (guidance); Colombian Army (labor/ heavy equipment); Colombian Air Force (labor/ heavy equipment); EC (funding)	2,100	Major work complete. Ongoing household cleaning.
Karmalichak, Patna, Bihar	India	Lead	Used Lead Acid Batteries (ULABs) from Nepal and India are processed informally throughout the city, resulting in widespread lead poisoning. This project endeavors to relocate informal processors to an industrial zone and conduct cleanup	Institute of Environment and Eco-Development (local direction); EC (funding)	600	Underway

Site	Country	Pollutant	Summary	Partners (with in-kind or cash support)	Exposed Population	Status
			in residential areas.			
Pampanga	Philippines	Lead	This project installed a physical barrier (concrete wall) between a community and a lead smelter and carried out remediation work in the community including the construction of a road and soil capping.	Pampanga Government (Health workers and meeting spaces); Pampanga Regional Health Center (Assistance with BLL testing); GEF (funding); EC (funding)	1,000	Complete
Nghia Lo	Vietnam	Lead	A 2013-2015 remediation project in an adjacent Vietnamese village resulted in at least a 75% decrease in blood lead levels (BLLs) in children. Previously, BLLs were above the detection limit of field equipment but were estimated to be 20 times international standards. This second phase addresses similar contamination issues in Nghia Lo, an adjacent community.	Centre for Environment and Community Development (local direction); Vietnam Environment Administration (oversight/labor); EC (funding)	1,000	Anticipated start August 2018

Stakeholder groups were formed at each project site. Stakeholders consisted of community members and leaders, local and/ or national government agencies and relevant NGOs. In the context of often weaker institutions in LMICs, strong community involvement can help support the sustainability of these types of interventions. For PE, community involvement is primarily fostered through strong engagement of key stakeholders in working groups. Stakeholders are involved at every stage of the process including assessment, design and execution. In Kathgora, Bangladesh, a community awareness raising and education event was held for approximately 100 local residents. The participants were informed of the risks of lead exposure, the source of lead in their community, the remediation strategy and timeline, and steps they could take to protect their families. In Malambo, Colombia at least 47 women and 31 men participated in the community awareness activities. Women in particular played a key role in designing and organizing the activities here, including in organizing community meetings and conducting door-to-door outreach. In Karmalichak (India) a single stakeholder event in early December 2017 had over 400 participants and included a speech by the mayor of this city of 2 million people, indicating the strength of stakeholder engagement. A photograph of this event is featured on the cover of this report. This event was the culmination of months of stakeholder meeting and community outreach, which continued after the event.

Environmental health impacts were measurably mitigated at all sites, with the exception of La Dolores. Here while emissions were halted for a time being, and thus health benefits were accrues, industrial activity shortly resumed and resulted in significant offsite emissions. In the case of lead (Pb) contaminated sites, Pure Earth utilizes a target level of 100 mg/kg for bare soil where children play for all remediation projects. This is significantly below the US EPA standard 400 mg/kg, which is commonly used globally as most countries have not yet developed their own standards. As such, the USEPA levels for most contaminants serve as the de facto international guidance. In practice the results of project sites are often much lower. In Pampanga, Kathgora, and Patna the soil that was utilized for the caps contained <70 mg/kg lead.

Project work was executed at five locations during the period covered by this report: La Dolores (Colombia); Kathgora (Bangladesh), Karmalichak (India), Malambo (Colombia); Pampanga (the Philippines). Summaries of work conducted are given below, organized by country. Final reports are currently in preparation for all projects and are expected at the conclusion of the 2nd quarter of 2018.

Bangladesh

TSIP efforts in Bangladesh were focused almost exclusively on the identification and assessment of informal ULAB processors in the Dhaka region. One such site, Kathgora, was selected for intervention. The site was no longer active though contained a number of uncontrolled waste piles and extensive soil contamination. Two informal smelters had previously operated in the area resulting in a shallow layer of contamination across two distinct large areas. The first such area was spread across ~2.6 hectares while the second across ~0.8 hectares. An initial project plan called for disposal of uncontrolled piles of waste, capping contaminated soil and community education and blood monitoring. However after further investigation, the depth of contamination was determined to be exceptionally shallow (< 0.5 cm), indicating that the total amount of contaminated material was less than previously suspected. An alternative approach was proposed to the technical team and in-situ encapsulation was elected over the provision of a cap for the majority of areas. Workers manually excavated a thin layer of material and deposited it in an in-situ repository at a depth of 3.5 meters below the surface. Once deposited the waste was covered with a 2 meter cap of clean soil to bring the repository flush with the surface. At the suggestion of DoE, waste materials were initially intended to be deposited in a dedicated cell in a municipal landfill. DoE later suggested that this would not be an acceptable approach, and that moreover Bangladeshi regulations insufficiently addressed the proper disposal of such material. As an interim solution, an onsite secure concrete cell will be constructed for the storage of the material. Over the midterm, PE will work with DoE to develop an appropriate long-term solution.

The area is home to 300 residents, including 90 children. The project was executed from November 2017 to April 2018. Assessment, design and monitoring efforts were supported by USAID. Construction work was supported by UNIDO and the European Commission. Blood lead testing supported by this project was executed in January 2018. Blood samples of 75 children (<7 y/o) were taken and analyzed using a Leadcare 2 portable instrument. The testing was conducted by a well regarded local public health NGO (ICDDR,B). Summary results of the testing are given below. More robust statistical analysis will be included in the forthcoming project report. As context there is no known safe level of lead exposure, though the US CDC recommends a level of concern of 5 µg/dL. The average level of lead in blood for an American child is <1 µg/dL. Follow up blood leads will be taken in the 3rd quarter of 2018 under the expanded award. The summary results were as follows:

- 5 children - 7–10 µg/dL
- 30 children - 11–20 µg /dL
- 27 children - 21–30 µg /dL
- 8 children - 31–40 µg /dL
- 4 children - 41–47.5 µg /dL

Colombia

Two sites were identified in Colombia for intervention. The first, Malambo, is located near the coastal city of Barranquilla and is the former site of three lead smelters. The site is interspersed with residential areas. All three former smelters contained severely elevated lead levels in soil, however contamination does not seem to have migrated substantially to residential areas, with the exception of a small number of targeted hotspots. Two of the former smelters are fully enclosed with a secure fence and are currently being used by other, non-lead smelting, industries. The third is open on three sides and is inactive. All three are currently within city plans to be zoned for residential use in the future. The project's initial intervention strategy involved a number of administrative controls, including enclosing the open site with a chain link fence, working with the city to change future zoning and ensure industrial status, and carrying out a community education and blood monitoring campaign. Finally, a small number of hot spots were to be targeted for pilot remediation.

The open site to be fenced was privately owned. Colombia currently lacks legal justification to compel a private land owner to execute remedial activities. Blood lead testing near the site found exceptionally high levels (summarized below) attributable to unrestricted access to the site. However, the proposal to construct a fence at the site met resistance from the land-owner. As an alternative, an in-situ lined repository was constructed and medium and high level material from the area was excavated and deposited inside. To ensure long term sustainability of the repository, the location of the cell was made known to the site owner, the state government (including the Secretary of Environment), and the city government. In particular, The Department of Planning of the city of Malambo who is responsible for the issuing of construction permits was advised of the location. In addition, signs advising the location of the repository will be posted around the site. Finally PE teams will visit the site once a quarter for at least three years.

Low-level material around the site and in the nearby community was capped with a layer of clean soil. Heavy equipment was donated from the nearby army base, while the municipality contributed to site security. The design, community engagement, home cleaning and blood lead testing were supported by the USAID PE Cooperative agreement, while construction work was supported by the UNIDO/ EC project. Blood lead testing was carried out in October. Follow-up testing will be executed in August 2018 under the expanded award. In total, 181 blood lead measurements were taken by a local clinician with IRB approval. Of the 181 samples, 101 were taken of children and 80 of adults. The adults had an average Blood Lead Level (BLL) of 11.57 (SD 17.01) while the children had an average BLL of 18.95 (SD 15.24). Full results are attached in the Colombia annual report (Annex C).

The second Colombian site, La Dolores, is located near the city of Cali. Here, homes have been constructed informally around a legal but actively polluting smelter. A number of Colombian regulatory complications currently allow high levels of emissions to migrate to the areas surrounding the smelter, resulting in dangerous exposures. A brief summary is provided above in the preceding section.

India

Much of Nepal's ULAB waste is recycled across the Indian border in the state of Bihar. One city here, Patna contains a vast number of informal recycling operations of various sizes. Many of these have been assessed as part of TSIP work covered by the project. One site was selected for a cleanup project based on the feasibility of action and the high relative risk. The site, Karmalichak, is a small very poor residential neighborhood in the suburbs of Patna. A single battery manufacturer operated in the neighborhood for over a decade, but closed his shop in 2016. About 200 children attend an elementary school located 10 meters from battery processor. Many other children play all day on the dirt paths around the battery shop. Alleys and agricultural areas within a two-block radius in all directions from the closed battery shop were contaminated with lead. Activities at this site included blood analysis, education, waste removal, soil capping and structure cleaning.

The project engaged a local engineering firm for the purpose of designing a cap amenable to severe flooding during regular monsoon rains. This model will be expanded under the expanded award for the purposes of building local capacity. Blood lead testing was executed by researchers from King George's Medical University (Lucknow) and Era University (Lucknow). Mean BLL concentrations in children (age 4–10 years) were 19.28 (95% CI: 18.5–30.6).

A second project is also planned to initiate during the time period of the cooperative agreement though will have a longer horizon. The Kankarbagh neighborhood has about 12 small shops that disassemble, assemble and repair lead-acid batteries. Most shops also sell informally produced batteries that they have assembled or purchased from someone else. All battery processing is done on the sidewalk in front of the shops. Although each shop is conducting very small-scale activities (dumping acid, casting lead parts) and thus contaminating a limited area, the density of the operations (12 in a small neighborhood) has created fairly uniform contamination throughout a 5 block by 3 block residential area. The shops are typically in small commercial spaces below apartment buildings. The Bihar State Industrial Development Agency has a program to collectivize informal industrial groups and provide them with land within industrial estates and money for shared equipment. It is called the "Cluster Development Program." The program co-finances purchases at rates of 50% to 100%, depending on the relative poverty level of the cluster participants. PE will work with the small-scale processors to exploit this program and assist in relocation. No significant progress was made on this component during the period covered by the report.

The Philippines

As part of TSIP exercises carried out in early 2017 a site in the municipality of San Simon, Pampanga was identified as a candidate for a cleanup project. The site was an active lead smelter with residents living on the property. The homes of the residents were highly contaminated with lead resulting from manual deposition. Median values for lead in soil in the area were 4,396 mg/kg (IQR=791-48,166). Many of the residents work at the smelter and inadvertently carry material home on their clothes. Additionally a large amount (~30 m^3) of contaminated waste material was left on the residential section of the property. Finally, several homes had integrated battery parts into the structure, including the use of lead plates for flooring. The project was executed in the 2nd and 3rd quarter of 2017 with blood lead monitoring and community education being conducted. Construction included the erection of a wall between the community and facility, capping of contaminated residential areas, and redirection of drainage. The construction work at this site was supported by the United Nations Development Program with funding from the Global Environment Facility and was completed in December 2017.

Map of Project Site at Pampanga

Blood lead testing revealed exceptionally elevated BLL levels. BLLs were collected for 39 individuals of varying ages. Of these, 22 exceeded the detection limit of the equipment (65 µg/dL), thus the data are not normally distributed. The mean value for all BLLs was 51.6 µg/dL (95%CI:45.2–57.5), while the mean BLL for children under 6 was 63.6 µg/dL (n=5; 95%CI:59.6–67.6).

Vietnam

Much of Northern Vietnam's lead recycling is concentrated in Hung Yen province. A 2014 PE project in a village here (Dong Mai) successfully by mitigated significant environmental exposures to lead. The results are attached in a peer-reviewed publication supported this award. Nghia Lo is smaller village adjacent to Dong Mai. Preliminary assessment indicated similar levels of environmental contamination. A 2014 study of blood lead levels found universally elevated concentrations.[2] Pending confirmed co-financing from Green Cross Switzerland for the construction costs, a detailed assessment of the site will be carried out under the expanded award.

[2] Sanders, Alison P., et al. "Toxic metal levels in children residing in a smelting craft village in Vietnam: a pilot biomonitoring study." *BMC public health* 14.1 (2014): 114.

Mission Requested Work

Vietnam

In response to a solicitation from the Vietnam Environmental Administration (VEA) the USAID mission requested support identifying gaps and conducting a tailored workshop for VEA staff on environmental emergencies in the marine environment. In 2017 PE's partner (the Center for Environment and Community Development; CECoD) conducted surveys of government staff in 22 provinces to identify gaps and key pollution issues (submitted with previous reports). Key issues identified include the following: unplanned releases, monitoring and planning, and crisis management and communications (attached as Annex J).

From 4-9 March 2018, PE and CECoD convened a 5-day workshop for representatives from 26 provincial governments. The workshop engaged experts from 6 countries with academic, government, NGO, and industry experience. The workshop was structured around the results of the 2017 needs-assessment survey, and included case studies from other countries, including the Deep Water Horizon and Exxon Valdez. A survey following the workshop found a positive response from attendees (Annex L). Items requiring additional assistance were identified and are presented in Annex K. Under the expanded award, PE will work with the USAID mission to identify approaches to addressing certain gaps. Importantly, while the formal surveys revealed a high level of satisfaction with the workshop, informal feedback from a number of participants identified aspects of the workshop that could have been improved, including a clearer statement of objectives and increased opportunities for interaction between participants.

ANTICIPATED ACTIVITIES

Summary

Steady progress has been made against most key indicators. 300 sites have been assessed, versus 150 targeted. Five pilot projects have been completed. The publication of *the Lancet* Commission on Pollution and Health has been widely perceived as a seminal moment with regard to pollution in LMICs.

Importantly, there are also a number of areas in the project that could be improved. The number of sites assessed in each region has not been sufficiently balanced; with most site assessments (n=201) occurring in South Asia. With regard to sharing data with governments through final workshops, this activity has been subsequently delayed due to slow implementation of site assessments and efforts to link data sharing with action planning. Final workshops were expected to begin in the first quarter of 2018, but have been delayed to the 3rd quarter.

The current award is in the process of being expanded until 2021. Through this expansion several of the issues identified during project execution have been directly addressed in amendments to the project description. In particular, considerations of sustainability and local ownership of pilot projects will have a more central role. In addition, a revised communications program aim to document and share lessons from this project an others more effectively. Finally the TSIP program will be refined to address the more nuanced needs of governments, including the development of a Preliminary Site Assessment (PSA) protocol in the case of Vietnam.

In the remaining period of the current award, efforts will focus primarily on documentation of work executed to date. This will include final reports at pilot project sites and summary reports on TSIP data collection. Work will continue on HPAPs in Bangladesh, Colombia and the Philippines.

There are a number of indicators on which no progress has been made during the project. Significant effort will be placed into ameliorating this issue in the remaining time of the project. Two such indicators relate to collection of feedback about the project from different constituents. Two survey efforts will take place in the 2nd and 3rd quarter of 2018. One survey will be issued to donors to assess the results of donor meetings. A second will be given at project sites to assess community sentiment about the project. A separate indicator on which no progress has been made relates to the development of guidance documents. In the remaining time on the original timeline of the award a guidance document will be drafted on mitigating risks at hazardous waste sites.

Gender Considerations

Summary

PE has tracked gender at all trainings conducted during the project. With regard to TSIP trainings 46 attendees were female. This greatly exceeds the targeted number for the period of 15, but is less than the targeted 50% in PE's gender analysis. In addition to TSIP trainings, DSA trainings were conducted with 56 participants, 22 of whom were female. Both values again exceed the targeted 0 trainees for the period, but are significantly less than PE's target of 50% female at 27%.

In addition to the work described in the work plan, PE supported a training for Indian government officials in the assessment of lead smelters. The Battery Assessment Toolkit (BAT) training was attended by 22 participants, eight of whom was female.

In general PE is ahead of its targets for the number of females trained in each area, though significantly behind its internal percentage targets for gender inclusion. To correct this, the importance of gender inclusion will be emphasized during staff meetings and during planning.

During the period covered by this report, the TSIP database has been modified to track stakeholders by gender.

Progress Against Indicators

Objective	*Potential gender issues and relevance to the objective*	*Recommendations/Specific actions/General considerations*	
Objective 1. Improve developing country capacity to gather critical data about the scope of toxic pollution and its human health impacts	It is important to support capacity building of local female experts in the fields of environment and health, as well as equal opportunity employment. PE hires local people, typically from environmental or health sciences backgrounds, to gather critical data about polluted sites and exposed populations. Through the TSIP program, PE trained 98 female investigators in low- and middle-income countries, approximately 43% of the total number of investigators trained (2016 data).	PE supports gender inclusion by aiming for 50% female participation in all workshops, trainings and activities.	Fifty percent (n=120) of training attendees during the project have been female. This exceeds both the goal of 15 female attendees overall and meets the target percentage of 50% female.
(Outcome 1. Local capacity to gather critical data on the scope of toxic pollution and its associated impacts on human health, the environment and natural resources is improved.)	While each site analyzed does not include gender-aggregated data, more detailed information on community make-up, i.e. percent of women and girls exposed at a given site, and gender considerations are taken into account during remediation planning.	Care should be taken to ensure gender equality during the trainings. A target of 50% of the trained investigators should be female. PE projects should capitalize on relevant existing local female expertise where possible.	Forty-eight percent (n=46) of investigators trained during the project have been female. This exceeds the goal of 7.5 female investigators overall, but is lower than the targeted 50%.
Objective 2. Encourage national and international decision-makers to mainstream the issue of toxic pollution, chemicals and wastes and associated impacts on human health and the environment into development agendas through awareness raising and presentation of scientifically-based evidence	Depending on the country and agency, there may be an imbalance in the gender makeup of key decision-makers. This is outside of the scope of influence of PE. However, there is opportunity in this project to support gender equality at the local, municipal and national levels, especially in presentations, trainings and workshops, as well as seeking female authors of scientific papers/reports.	PE supports gender inclusion by aiming for 50% female participation in all workshops, trainings and activities, including panelists, trainers, trainees, participants, researchers, stakeholder groups, and other roles.	One action planning workshop was held during the period covered by the report, in Colombia. Of the 14 participants, 6 (43%) were female, below the target.

Objective	*Potential gender issues and relevance to the objective*	*Recommendations/Specific actions/General considerations*	
(Outcome 2. International and national awareness about toxic pollution and support for addressing its adverse impacts on the environment and human health is strengthened.)	PE looks at Global Burden of Disease of toxic pollution specifically on women. This includes papers in development assessing health risks posed by contaminated sites to women of child bearing age and other health-related impacts.	PE will capitalize on relevant existing in-country female expertise, and leadership, and encourage the participation of relevant women's organizations, where possible. PE will also support female scientists, including those in developing countries, by encouraging them to write, apply for PE author support, or participating in relevant research.	The three research publications produced during the period covered by this report included female co-authors from LMICs.
Objective 3. Assist decision-makers and communities to mitigate the impacts of toxic pollution on human health and the environment through training and capacity building, and provision of technical expertise and support for specific interventions that produce measurable reductions in exposure risk	Gender implications are highly relevant for this objective, for experts, trainers, trainees, participants and beneficiaries alike. Key considerations:	PE supports gender inclusion by aiming to have 50% female participation in all workshops, trainings and activities.	DSA trainings were conducted in Bangladesh, India, Colombia and the Philippines. In Colombia and the Philippines the majority of trainees were female, while in South Asia all but one were male. To correct for this, we will engage in a dialogue with our partners to encourage more female participation.
(Outcome 3. Local and national capacity to reduce health risks from toxic pollution, prevent future emissions and replicate pollution mitigation projects is enhanced.)	- Ensuring participation of all affected members of a community and representation of marginalized groups in decision-making	Past experience has shown that interventions that aim to reduce health exposures to toxic pollution (both active and legacy) have the most impact when they emphasize awareness, education and training for both genders, and especially for women. Once aware of the dangers of toxic pollution, women and men are both concerned about the health risks to the families and children. When presented with tools to minimize exposures, both men and women are likely to implement preventative measures and share knowledge with others.	At those sites where pilots were initiated, the majority of stakeholders were female.

Objective	*Potential gender issues and relevance to the objective*	*Recommendations/Specific actions/General considerations*	
	- Incorporation of gender considerations in data collection and strategy formulation, ensuring that different exposures or health impacts related to gender are clearly understood and accounted for in the project design	During remediation, advisors will examine roles and status of women and men in the community, household, political, industrial spheres and how that may impact project activities. Feasibility Studies will consider roles and responsibilities of men and women, particularly relating to how their roles impact their exposures and the exposures of their children. Both women and men will be encouraged to participate in project activities, especially the stakeholder groups. Adjustments to project activities will be made as necessary to promote women's involvement and minimize any possible unintended negative consequences. Where required, sex aggregated data/results will be collected and reported.	At those sites where pilots were initiated, the majority of stakeholders were female.
	- Appropriate and Accessible technical assistance, education, and communication initiatives		Education materials are attached as Annex O
	- Involvement of a representative staff both in management and in site investigators (inclusive of gender, language, and cultural background); and		Data was not collected on this indicator during the period covered by the report.
	- Consideration of gender norms in pilot project design, taking gender into account in the potential impact of the project.		Data was not collected on this indicator during the period covered by the report.

Environmental Mitigation and Monitoring Plans and Reports

Summary

Actions were taken throughout the reporting period to mitigate possible environmental risks. The large majority of these occurred during trainings when worker safety protocols are discussed. The table below summarizes progress against key indicators for objectives 1 and 2.

Progress Against Indicators

Output	Sub-activity or component	Description of Impact/ Baseline Issue	Mitigation Measures	Responsible Party	Monitoring Scheme			Estimated Cost	Monitoring Log		
					Indicators	Data Source/ Method	How Often		Date	Result	Follow-Up
Trainings	Site Visit	Accessing stores of hazardous waste contributing to spill.	Training to avoid stores and focus site assessment on public spaces	Regional Director; Country Director	Samples/ Photos taken at stores	TSIP Database	Ongoing	N/A	Sep 2016 - April 2018	No stores accessed	Ongoing through database
	Transport of Samples	Spills of contaminate d material	Training In sample handling and chain of custody	Regional Director; Country Director	Samples logs/ Chain of custody forms	TSIP Database	Ongoing	N/A	Sep 2016 - April 2018	No reported spills	None

Output	Sub-activity or	Description of Impact/	Mitigation Measures	Responsible Party	Monitoring Scheme			Estimated Cost	Monitoring Log		
Site Assessments	Site Visit	Accessing stores of hazardous waste contributing to spill.	Training to avoid stores and focus site assessment on public spaces	Regional Director; Country Director	Samples/ Photos taken at stores	TSIP Database	Ongoing	N/A	Sep 2016 - April 2018	No stores accessed	Ongoing through database
	Transport of Samples	Spills of contaminate d material	Training In sample handling and chain of custody	Regional Director; Country Director	Samples logs/ Chain of custody forms	TSIP Database	Ongoing	N/A	Sep 2016 - Dec 2016	No reported spills	None
Detailed Site Assessment	Field Sampling	Accessing stores of hazardous waste contributing to spill.	Training to avoid stores and focus site assessment on public spaces	Regional Director; Country Director	Samples/ Photos taken at stores	DSA Report	Ongoing	N/A	Feb-17	Minimal risk of spill given the nature of the material (lead).	Ongoing through database and DSAs
		Transport of contaminate d material to clean areas	Training is migration of material. Cleaning equipment and clothes when moving between areas	Regional Director; Country Director	Samples logs/ Chain of custody forms	DSA Report	Ongoing	N/A	Feb-17	Participant s trained in mitigation of "take home" risk (ie migration of material on clothing) at both DSAs and the BAT workshop.	None

Output	Sub-activity or	Description of Impact/	Mitigation Measures	Responsible Party	Monitoring Scheme			Estimated Cost	Monitoring Log		
	Transport of Samples	Spills of contaminated material	Training In sample handling and chain of custody	Regional Director; Country Director	Samples logs/ Chain of custody forms	DSA Report	Ongoing	N/A	Feb-17	No mitigation required. All analysis done onsite with pXRF	Ongoing

Budget

Summary

Since inception, PE expended USD $1,776,775. We anticipate spending an additional USD $223,225 from April 2018 until July 2018

Annex A – List of Assessed Sites

SiteID	Site_Name	Country	Latitude	Longitude	key_polluta	tot_pop_at_	sector1	sample_typ	sampling_m	pathway1	test_results	units1
IN-5391	New Pure E	India	28.820504	77.55038	Lead	515	0	targeted	Soil - Indust	Dust/soil/in	519	mg/kg or ppm
IN-5394	Sybli Indust	India	28.78547	77.520898	Lead	1200	0	targeted	Soil - Indust	Dust/soil/in	41	mg/kg or ppm
CO-2351	Abandoned	Colombia	10.305073	-75.50187	Mercury - e	9190	1	targeted	Hair	Food ingest	1.64	ppm
IN-5662	ALCO Batte	India	28.605609	77.018756	Lead	2000	0	0	Soil - Reside	Blank	41183	mg/kg or ppm
MN-5515	Altan us (Ba	Mongolia	46.182278	100.30272	Arsenic	130	1	targeted	Soil - Agricu	Dust/soil/in	0	mg/kg or ppm
BD-5255	Altu Khan Ju	Bangladesh	23.536372	89.652679	Lead	248	2	composite	Soil - Agricu	Dust/soil/in	3917.12	mg/kg or ppm
BD-5441	Aluminum E	Bangladesh	23.780471	90.71409	Lead	169	2	composite	Soil - Agricu	Dust/soil/in	659.22	mg/kg or ppm
IN-5663	AMBER Batt	India	29.270429	77.720622	Lead	2500	1	targeted	Soil - Agricu	Dust/soil/in	9703	mg/kg or ppm
IN-5066	Ambika Batt	India	21.5047	73.3389	Lead	6000	1	composite	Soil - Reside	Dust/soil/in	183	mg/kg or ppm
IN-5688	Amtex Batte	India	29.2262	78.934		200	0	targeted	Soil - Indust	Dust/soil/in	730	mg/kg or ppm
MN-5462	An ASGM si	Mongolia	46.287357	96.162895	Chromium (	70	1	targeted	Soil - Agricu	Dust/soil/in	98.27	mg/kg or ppm
MN-5854	An ASGM si	Mongolia	44.106987	105.27538	Arsenic	78	1	targeted	Soil - Agricu	Dust/soil/in	16.95	mg/kg or ppm
MN-5461	An ASGM si	Mongolia	45.199779	94.222031	Arsenic	50	1	targeted	Soil - Agricu	Dust/soil/in	19.78	mg/kg or ppm
SN-5213	Ancien site	Senegal	14.73214	-17.30574	Lead	584	1	composite	Soil - Indust	Dust/soil/in	156	mg/kg or ppm
SN-5683	Ancien site	Senegal	16.01211	-16.48854	Pesticides	300	1	composite	Soil - Reside	Dust/soil/in	17.059	mg/kg or ppm
CO-5240	Antigua Fun	Colombia	10.852773	-74.84546	Lead	137	1	targeted	Soil - Agricu	Dust/soil/in	1582	mg/kg or ppm
CO-5238	Antigua Fun	Colombia	10.859027	-74.79501	Lead	74	1	targeted	Soil - Agricu	Dust/soil/in	3975	mg/kg or ppm
CO-5163	Antigua plai	Colombia	4.54281	-74.2488	Lead	500	1	targeted	Soil - Indust	Dust/soil/in	27	mg/kg or ppm
CO-5171	Antig	Colombia	3.503552	-76.51643	Lead	650	1	targeted	Soil - Indust	Gases/vapo	121	mg/kg or ppm
BD-5453	Asia Battery	Bangladesh	24.008167	90.736981	Lead	550	2	composite	Soil - Agricu	Dust/soil/in	434.6	mg/kg or ppm
SN-5400	Atelier de m	Senegal	13.879371	-16376523	Lead	2900	1	composite	Soil - Indust	Dust/soil/in	143	mg/kg or ppm
SN-5324	Atelier de r	Senegal	14.74435	-17.41317	Lead	1100	1	targeted	Soil - Indust	Dust/soil/in	21	mg/kg or ppm
SN-5322	Atelier de te	Senegal	14.76627	-17.36257	Lead	780	1	targeted	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
SN-5202	Atelier Man	Senegal	14.67692	-17.44131	Lead	3950	1	targeted	Soil - Indust	Dermal cont	10293	mg/kg or ppm
SN-5682	Atelier meca	Senegal	16.02632	-16.49344	Lead	160	1	targeted	Soil - Indust	Dermal cont	0	mg/kg or ppm
IN-4877	Auto Marke	India	28.7041	77.2573	Lead	3750	1	targeted	Soil - Reside	Dust/soil/in	641	mg/kg or ppm
BD-4938	Badi Mia UL	Bangladesh	22.788771	89.534678	Lead	525	1	composite	Soil - Reside	Dust/soil/in	524.34	mg/kg or ppm
BD-4838	Bannex Batt	Bangladesh	22.74703	89.09847	Lead	2085	2	targeted	Soil - Reside	Dust/soil/in	7770.6	mg/kg or ppm
SN-2542	Base d'Aver	Senegal	15.56061	-13.29969	Pesticides	70	1	composite	Soil - Reside	Dust/soil/in	25.1	mg/kg or ppm
SN-5395	Base de stoc	Senegal	13.88665	-16.37198	Pesticides	950	1	composite	Soil - Indust	Dust/soil/in	0.7	mg/kg or ppm
BD-4839	Bashbari Lea	Bangladesh	22.77986	89.50608	Lead	240	3	composite	Soil - Reside	Gases/vapo	1472.63	mg/kg or ppm
CO-5623	Basurero de	Colombia	3.376335	-76.49777	Arsenic	1150	1	composite	Soil - Reside	Food ingest	10.483	mg/kg or ppm
MN-5514	Bayankhong	Mongolia	46.192333	100.71586	Chromium (	20500	1	targeted	Soil - Indust	Dust/soil/in	49.63	mg/kg or ppm
IN-4899	Bharat Batte	India	26.80176	84.51662	Lead	1200	1	targeted	Soil - Indust	Dust/soil/in	1807	mg/kg or ppm
IN-4917	Bheem Batt	India	24.80028	85.01109	Lead	4002	1	targeted	Soil - Indust	Dust/soil/in	28562	mg/kg or ppm
IN-5116	Bihar Batter	India	25.69521	85.21085	Lead	3210	1	targeted	Soil - Indust	Dust/soil/in	534	mg/kg or ppm
IN-5108	Bihar Batter	India	26.11853	85.35893	Lead	3210	1	targeted	Soil - Indust	Dust/soil/in	52614	mg/kg or ppm
IN-4915	Bisheshwar	India	24.79723	85.01163	Lead	4850	1	targeted	Soil - Indust	Dust/soil/in	2294	mg/kg or ppm
IN-5044	Brahamade	India	26.17609	85.87984	Lead	3500	1	targeted	Soil - Indust	Dust/soil/in	1063	mg/kg or ppm
BD-4840	Bronze cast	Bangladesh	23.968603	90.205441	Arsenic	1250	1	composite	Soil - Indust	Dust/soil/in	136.3	mg/kg or ppm
IN-4901	Calcutta bat	India	26.41553	85.04985	Lead	1070	1	targeted	Soil - Indust	Dust/soil/in	3417	mg/kg or ppm
CO-5087	Cantera aba	Colombia	4.567	-74.216	Lead	500	1	targeted	Soil - Indust	Dust/soil/in	21	mg/kg or ppm
CO-2353	Cartagena E	Colombia	10.38531	-75.51239	Lead	10000	1	targeted	Food	Food ingest	0.05	ppm
PH-2780	Celica Lead	Philippines	15.009873	120.7549	Lead	20	1	targeted	Soil - Indust	Dust/soil/in	82793.81	mg/kg or ppm
IN-5107	Chand Batte	India	26.11829	86.3583	Lead	1000	1	targeted	Soil - Indust	Dust/soil/in	2758	mg/kg or ppm
IN-5076	Chand Batte	India	25.77687	84.77773	Lead	1300	1	targeted	Soil - Indust	Dust/soil/in	390	mg/kg or ppm
JM-5898	Child Nurse	Jamaica	18.081543	-76.79636	Lead	45	1	targeted	Dust (inside	Dust/soil/in	150	ppm
IN-4898	Chotu Batte	India	26.15279	85.89863	Lead	1600	1	targeted	Soil - Indust	Dust/soil/in	289	mg/kg or ppm
SN-4291	Colobane W	Senegal	14.698865	-17.44151	Lead	3450	1	targeted	Soil - Reside	Dust/soil/in	98	mg/kg or ppm
CO-2345	Confinamie	Colombia	10.373917	-75.46831	Pesticides	4000	1	targeted	Soil - Reside	Dust/soil/in	2.33	mg/kg or ppm
BD-5308	Continental	Bangladesh	22.985297	88.979405	Lead	960	1	composite	Soil - Reside	Dust/soil/in	1056.63	mg/kg or ppm
IN-4893	Darbhanga	India	26.15292	85.89661	Lead	1330	1	targeted	Soil - Indust	Dust/soil/in	2900	mg/kg or ppm
SN-272	D	Senegal	14.80466	-17.31152	Lead	10000	1	composite	Soil - Indust	Dust/soil/in	31	mg/kg or ppm
IN-5071	Dhanu Batte	India	26.22553	84.34851	Lead	1495	1	targeted	Soil - Indust	Dust/soil/in	96	mg/kg or ppm
BD-4844	Dockyard, C	Bangladesh	23.699836	90.41177	Arsenic	6330	1	targeted	Soil - Indust	Dust/soil/in	104.52	mg/kg or ppm
BD-4895	ECO Batteri	Bangladesh	24.218261	90.453223	Lead	4300	2	composite	Soil - Agricu	Dust/soil/in	567.81	mg/kg or ppm
CO-5304	Ecotambore	Colombia	4.5642667	-74.22696	Lead	7240	1	targeted	Soil - Reside	Dust/soil/in	12	mg/kg or ppm
IN-5679	Elecon Batt	India	28.950906	77.675538	Cadmium		1	targeted	Soil - Reside	Dust/soil/in	1.389	mg/kg or ppm
SN-5694	Entreposag	Senegal	12.55844	-16.27749	Pesticides	7062	1	composite	Soil - Indust	Dust/soil/in	25.6	mg/kg or ppm
CO-5903	Finca Arena	Colombia	3.503552	-76.51643	Pesticides	200	1	composite	Soil - Agricu	Food ingest	18000	mg/kg or ppm
CO-5118	Flores canel	Colombia	4.8936	-74.0479	Pesticides	828	1	targeted	Soil - Agricu	Gases/vapo	0	mg/kg or ppm
SN-5317	Fonderie de	Senegal	14.745886	-17.43118	Lead	600	1	targeted	Soil - Indust	Dust/soil/in	0	mg/kg or ppm
PH-2984	Former Info	Philippines	14.25845	121.398	Lead	100	2	targeted	Soil - Reside	Dust/soil/in	150.4	mg/kg or ppm
PH-2945	Former ULA	Philippines	15.398317	120.94255	Lead	10	1	targeted	Soil - Reside	Dermal cont	822.79	mg/kg or ppm
PH-3068	Former Use	Philippines	14.3006	121.10195	Lead	40	1	targeted	Soil - Indust	Dust/soil/in	37032.58	mg/kg or ppm
PH-3095	Former Use	Philippines	14.3074	121.48288	Lead	30	1	targeted	Soil - Reside	Dust/soil/in	81.56	mg/kg or ppm
JM-5742	Frasers Con	Jamaica	18.011115	-76.9964	Lead	5500	0	targeted	Soil - Indust	Dust/soil/in	0	mg/kg or ppm
BD-5300	Fulahar Lea	Bangladesh	25.21997	89.31591	Lead	1570	1	composite	Soil - Agricu	Dust/soil/in	415.27	mg/kg or ppm
CO-5399	Fundici	Colombia	34.98.254	76.48.3137	Lead	650	1	targeted	Water - Irrig	Dust/soil/in	5.4	ug/l or ppb
SN-5396	Garage de r	Senegal	13.873961	-16.36869	Lead	3075	1	composite	Soil - Indust	Dust/soil/in	189	mg/kg or ppm
SN-5211	Garage de r	Senegal	14.74646	-17.38431	Lead	2555	1	targeted	Soil - Indust	Dermal cont	112	mg/kg or ppm
SN-5323	Garage de s	Senegal	14.72812	-17.30416	Lead	1610	1	targeted	Soil - Indust	Dust/soil/in	0	mg/kg or ppm
SN-5668	Garage m	Senegal	12.57276	-16.27035	Lead	2030	1	targeted	Soil - Indust	Dust/soil/in	34	mg/kg or ppm

SN-5205	Garage m	Senegal	14.68063	-17.44479	Lead	5600	1	targeted	Soil - Indust	Dermal cont	5867	mg/kg or ppm
SN-5356	Garage mec	Senegal	14.74896	-17.45762	Lead	2600	1	targeted	Soil - Indust	Dust/soil/in	45	mg/kg or ppm
CO-1516	Gold mines	Colombia	-0.53952	-69.61156	Mercury - e	948	1	targeted	Hair	Dermal cont	5	ppm
MN-5470	Gold ore mi	Mongolia	46.380852	96.27755	Lead	60	1	targeted	Soil - Indust	Dust/soil/in	43361.64	mg/kg or ppm
MN-5465	Gold ore mi	Mongolia	46.336063	96.330093	Lead	100	1	targeted	Soil - Reside	Dust/soil/in	97.49	mg/kg or ppm
MN-5471	Gold ore mi	Mongolia	46.438503	96.231102	Lead	30	1	targeted	Soil - Indust	Dust/soil/in	55	mg/kg or ppm
MN-5472	Gold ore mi	Mongolia	46.359734	96.264015	Arsenic	60	1	targeted	Soil - Reside	Dust/soil/in	25.26	mg/kg or ppm
IN-5685	Green Life I	India	28.640512	77.431543	Lead	3000	0	targeted	Soil - Indust	Dust/soil/in	60	mg/kg or ppm
BD-4929	Hamko Indu	Bangladesh	22.73834	89.63803	Lead	2065	1	targeted	Soil - Reside	Dust/soil/in	8421.2	mg/kg or ppm
MN-5402	HAMO LLC,	Mongolia	48.452305	106.31409	Arsenic	66	1	targeted	Soil - Indust	Dust/soil/in	1197.26	mg/kg or ppm
CO-5363	Hidrocarbur	Colombia	10.984078	-74.76549	Other	354	1	targeted	Soil - Reside	Dust/soil/in	29000	mg/kg or ppm
IN-5125	Informal Ba	India	25.57979	83.98811	Lead	2540	1	targeted	Soil - Indust	Dust/soil/in	35232	mg/kg or ppm
IN-5080	Informal Ba	India	25.78104	84.75328	Lead	3810	1	targeted	Soil - Indust	Dust/soil/in	869	mg/kg or ppm
IN-4888	Informal Ba	India	25.1545	86.09366	Lead	1080	1	targeted	Soil - Indust	Dust/soil/in	33597	mg/kg or ppm
IN-5389	Informal ba	India	13.0316	77.5266	Lead		1	targeted	Soil - Indust	Dust/soil/in	13.239167	mg/kg or ppm
IN-4889	Informal ba	India	25.37908	86.47468	Lead	1975	1	targeted	Soil - Indust	Dust/soil/in	484	mg/kg or ppm
IN-4905	Informal Ba	India	25.42159	86.11503	Lead	3000	1	targeted	Soil - Indust	Dust/soil/in	15103	mg/kg or ppm
IN-5067	Informal UL	India	25.57693	85.06834	Lead	4315	1	targeted	Soil - Indust	Dust/soil/in	1145	mg/kg or ppm
IN-4891	Informal UL	India	25.18827	85.51613	Lead	2800	1	targeted	Soil - Indust	Dust/soil/in	5199	mg/kg or ppm
IN-5074	Informal UL	India	25.78171	84.74445	Lead	3905	1	targeted	Soil - Indust	Dust/soil/in	3302	mg/kg or ppm
IN-5388	Informal UL	India	12.8144	77.6838	Lead	400	1	targeted	Soil - Indust	Dust/soil/in	127	mg/kg or ppm
IN-4887	Informal UL	India	25.15491	86.09408	Lead	1174	1	targeted	Soil - Indust	Dust/soil/in	15368	mg/kg or ppm
IN-5073	Informal UL	India	26.22247	84.36688	Lead	600	1	targeted	Soil - Indust	Dust/soil/in	27142	mg/kg or ppm
IN-4874	Informal UL	India	28.671	77.2567	Lead	8000	1	targeted	Soil - Reside	Dermal cont	221	mg/kg or ppm
IN-5377	Informal UL	India	13.0116	77.5072	Lead	360	1	targeted	Soil - Indust	Dust/soil/in	120	mg/kg or ppm
IN-4876	Informal UL	India	28.676955	77.337105	Lead	850	1	targeted	Soil - Indust	Dust/soil/in	219	mg/kg or ppm
IN-4878	Informal UL	India	28.7019	77.2878	Lead	2500	1	targeted	Soil - Reside	Dust/soil/in	5028	mg/kg or ppm
IN-4875	Informal UL	India	28.7148	77.2772	Lead	2550	1	composite	Soil - Reside	Dust/soil/in	106	mg/kg or ppm
IN-5053	Informal UL	India	28.66	77.22	Lead	800	1	composite	Soil - Indust	Dust/soil/in	742	mg/kg or ppm
IN-5022	Informal UL	India	28.689444	77.078056	Lead	1200	1	targeted	Soil - Reside	Dust/soil/in	65	mg/kg or ppm
IN-4914	Informal UL	India	28.610278	76.970556	Lead	1850	1	targeted	Soil - Reside	Dust/soil/in	27	mg/kg or ppm
PH-3025	Informal Us	Philippines	14.279933	121.41382	Lead	50	2	targeted	Soil - Reside	Dust/soil/in	4111.4	mg/kg or ppm
SN-5677	Installation	Senegal	16.05042	-16.45841	Pesticides	310	1	composite	Soil - Indust	Dust/soil/in	134.6	mg/kg or ppm
IN-5686	Inzen Powe	India	29.956375	78.065176	Lead	1000	1	targeted	Soil - Indust	Blank	17415	mg/kg or ppm
IN-5117	Jahid Batter	India	25.69975	85.2063	Lead	800	1	composite	Soil - Reside	Dust/soil/in	417	mg/kg or ppm
BD-5200	Jannat Batt	Bangladesh	23.176709	90.200946		875	2	composite	Soil - Reside	Dust/soil/in	19644.2	mg/kg or ppm
IN-5063	Janta Batter	India	25.60452	85.13519	Lead	1900	1	composite	Soil - Reside	Dust/soil/in	46	mg/kg or ppm
IN-4918	Jha Battery	India	26.10007	85.90287	Lead	600	1	targeted	Soil - Indust	Dust/soil/in	12900	mg/kg or ppm
IN-5070	Jyoti Batter	India	26.22665	84.34687	Lead	3500	1	targeted	Soil - Indust	Dust/soil/in	1364	mg/kg or ppm
IN-5072	Kali Battery,	India	26.22146	84.36785	Lead	2400	1	targeted	Soil - Indust	Dust/soil/in	703	mg/kg or ppm
IN-5665	Kanth Batte	India	28.7332	77.7687	Lead	3000	1	targeted	Soil - Reside	Dust/soil/in	37	mg/kg or ppm
MN-5412	Khargana w	Mongolia	48.555508	106.34857	Mercury - o	16	1	targeted	Soil - Agricu	Dust/soil/in	5	mg/kg or ppm
MN-5855	Khartolgoi-	Mongolia	43.718285	103.4624	Arsenic	10	1	targeted	Soil - Agricu	Dust/soil/in	10	mg/kg or ppm
MN-5518	Khatavchiin	Mongolia	46.280611	99.484778	Chromium (	12	1	targeted	Soil - Agricu	Dust/soil/in	118.43	mg/kg or ppm
MN-5451	Khukh sair	Mongolia	45.581154	98.312683	Arsenic	90	1	targeted	Soil - Agricu	Dust/soil/in	8	mg/kg or ppm
IN-5064	Krishna Batt	India	25.78556	84.71996	Lead	1600	1	composite	Soil - Reside	Dust/soil/in	52	mg/kg or ppm
CO-5236	La Bonga - N	Colombia	10.834803	-74.785298	Lead	225	1	targeted	Water - Drir	Water inges	0.1	ug/l or ppb
IN-5069	Lala Ji Batte	India	26.35899	84.33708	Lead	750	1	composite	Soil - Reside	Dust/soil/in	121	mg/kg or ppm
CO-5721	Las Pailas, V	Colombia	2.968	76.662	Mercury - e	187	1	targeted	Water - Drir	Water inges	0.005	ug/l or ppb
BD-4946	Lead Batter	Bangladesh	25.08629	89.51718	Lead	970	1	composite	Soil - Agricu	Dust/soil/in	421.8	mg/kg or ppm
BD-5131	Lead Batter	Bangladesh	23.52322	90.87834	Lead	125	1	composite	Soil - Agricu	Dust/soil/in	587.62	mg/kg or ppm
BD-4947	Lead Batter	Bangladesh	24.85332	89.46596	Lead	126	1	composite	Soil - Agricu	Dust/soil/in	1380.88	mg/kg or ppm
BD-5350	Lead Batter	Bangladesh	25.28145	89.23301	Lead	2220	1	composite	Soil - Reside	Dust/soil/in	980.18	mg/kg or ppm
BD-5352	Lead Batter	Bangladesh	25.21646	89.33201	Lead	545	1	composite	Soil - Agricu	Dust/soil/in	521.84	mg/kg or ppm
BD-5351	Lead Batter	Bangladesh	25.19262	89.3095	Lead	405	1	composite	Soil - Agricu	Dust/soil/in	8075.08	mg/kg or ppm
BD-5025	Lead Batter	Bangladesh	22.89276	91.53528	Lead	9630	1	composite	Soil - Reside	Dust/soil/in	129.99	mg/kg or ppm
BD-5123	Lead Batter	Bangladesh	24.55036	89.50626	Lead	1560	1	composite	Soil - Reside	Dust/soil/in	359.82	mg/kg or ppm
BD-5124	Lead Batter	Bangladesh	24.54945	89.50977	Lead	1277	1	composite	Soil - Reside	Dust/soil/in	1105.75	mg/kg or ppm
BD-5100	Lead Batter	Bangladesh	23.51409	90.86784	Lead	1075	1	composite	Soil - Reside	Dust/soil/in	73.92	mg/kg or ppm
BD-5121	Lead Batter	Bangladesh	23.46002	91.20116	Lead	565	1	composite	Soil - Reside	Dust/soil/in	66.31	mg/kg or ppm
BD-5086	Lead Batter	Bangladesh	23.43523	91.17198	Lead	690	1	composite	Soil - Reside	Dust/soil/in	95.43	mg/kg or ppm
BD-5023	Lead Batter	Bangladesh	22.31332	91.87534	Lead	830	1	composite	Soil - Agricu	Dust/soil/in	427.74	mg/kg or ppm
BD-5035	Lead Batter	Bangladesh	22.36	91.84201	Lead	4765	1	composite	Soil - Reside	Dust/soil/in	250.46	mg/kg or ppm
BD-5024	Lead Batter	Bangladesh	22.37683	91.7612	Lead	1805	1	composite	Soil - Reside	Dust/soil/in	286.68	mg/kg or ppm
BD-5101	Lead Batter	Bangladesh	23.41912	91.17362	Lead	2000	1	composite	Soil - Reside	Dust/soil/in	641.51	mg/kg or ppm
BD-5120	Lead Batter	Bangladesh	23.44638	91.17638	Lead	1080	1	composite	Soil - Reside	Blank	66.99	mg/kg or ppm
BD-5081	Lead Batter	Bangladesh	23.46056	91.16888	Lead	2710	1	composite		Blank	83.45	
BD-4961	Lead Batter	Bangladesh	24.80474	88.95596	Lead	3670	1	composite	Soil - Reside	Dust/soil/in	408.84	mg/kg or ppm
BD-5099	Lead Smelti	Bangladesh	24.54715	89.51225	Lead	1520	1	composite	Soil - Reside	Dust/soil/in	7833	mg/kg or ppm
BD-4834	Lead Smelti	Bangladesh	22.78241	89.55493	Lead	1030	2	targeted	Soil - Reside	Dust/soil/in	97073.27	mg/kg or ppm
BD-4948	Lead Smelti	Bangladesh	24.85666	89.38671	Lead	1380	1	composite	Soil - Agricu	Dust/soil/in	398.88	mg/kg or ppm
BD-4950	Lead Smelti	Bangladesh	22.99867	89.45871	Lead	589	1	targeted	Soil - Reside	Dust/soil/in	205778.64	mg/kg or ppm
BD-4849	Lead Smelti	Bangladesh	22.78111	89.58092	Lead	1600	2	composite	Soil - Reside	Dust/soil/in	28380.45	mg/kg or ppm
BD-4960	Lead Smelti	Bangladesh	24.7973	88.94565	Lead	2820	1	composite	Soil - Agricu	Dust/soil/in	285.64	mg/kg or ppm

BD-4859	Lead Smelti	Bangladesh	22.71685	89.65495	Lead	1448	1	targeted	Soil - Indust	Dust/soil/in	10342.94	mg/kg or ppm
BD-4835	Lead Smelti	Bangladesh	22.75134	89.53566	Lead	1189	2	composite	Soil - Agricu	Food ingest	168.27	mg/kg or ppm
BD-4954	Lead Smelti	Bangladesh	22.96601	89.47717	Lead	415	1	composite	Soil - Reside	Dust/soil/in	1915.46	mg/kg or ppm
BD-5298	Lead Smelti	Bangladesh	22.823575	89.518123	Lead	610	1	targeted	Soil - Reside	Dust/soil/in	13319.02	mg/kg or ppm
BD-4833	Liton Enterp	Bangladesh	23.676215	90.384493	Arsenic	760	1	targeted	Soil - Indust	Dust/soil/in	30.31	mg/kg or ppm
IN-5068	Magadh Bat	India	25.58422	85.09639	Lead	3300	1	targeted	Soil - Indust	Dust/soil/in	8076	mg/kg or ppm
SN-5709	Magasins de	Senegal	14.79534	-16.91784	Lead	7500	1	composite	Soil - Indust	Dust/soil/in	1222	mg/kg or ppm
BD-4943	Malek Batte	Bangladesh	22.81493	89.54145	Lead	1090	1	targeted	Soil - Reside	Dust/soil/in	478.07	mg/kg or ppm
BD-5130	Minto Batte	Bangladesh	23.44988	91.18266	Lead	3300	1	composite	Soil - Reside	Dust/soil/in	179.51	mg/kg or ppm
IN-5407	Mokumpur	India	28.954235	77.676691	Lead	1000	1	targeted	Soil - Indust	Dust/soil/in	287	mg/kg or ppm
CO-1675	Municipality	Colombia	7.079733	-74.70171	Mercury - e	53001	1	targeted	Air - Outside	Gases/vapo	0.42627	ug/m3
BD-5021	Navana Bat	Bangladesh	22.38281	91.76854	Lead	5370	1	composite	Soil - Reside	Dust/soil/in	133.66	mg/kg or ppm
BD-5301	Nayeb Ali Le	Bangladesh	25.20761	89.30825	Lead	540	1	composite	Soil - Agricu	Dust/soil/in	1556.95	mg/kg or ppm
MN-5406	Numt, Born	Mongolia	48.533852	106.18922	Mercury - o	40	1	targeted	Soil - Agricu	Dust/soil/in	19	mg/kg or ppm
MN-5450	Olon Bulgiin	Mongolia	45.95871	97.0519	Arsenic	520	1	targeted	Soil - Agricu	Dust/soil/in	6	mg/kg or ppm
IN-5047	Pailot Batte	India	26.15442	85.89867	Lead	3200	1	composite	Soil - Reside	Dust/soil/in	605	mg/kg or ppm
SN-5355	Parc Ferraill	Senegal	14.7374	-17.44347	Lead	90	1	targeted	Soil - Indust	Dust/soil/in	265	mg/kg or ppm
IN-5409	Partapur Ind	India	28.920245	77.655429	Lead	300	0	targeted	Soil - Indust	Dust/soil/in	3993	mg/kg or ppm
IN-5115	Patna Batte	India	25.69657	85.21269	Lead	4000	1	targeted	Soil - Indust	Dust/soil/in	6424	mg/kg or ppm
CO-5743	PCB Reman	Colombia	10.903745	-74.16847	PCBs (PolyC	269	1	targeted	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
CO-5309	Pesticidas e	Colombia	4.87133	-73.8884	Pesticides	5426	1	targeted	Water - Drir	Water inges	0.00018	ug/l or ppb
PH-2785	Philceramic	Philippines	13.476111	123.67139	Lead	100	1	0		Dust/soil/in	48995.93	
CO-5466	Plaguicidas	Colombia	10.746824	-74.15895	Pesticides	1666	1	targeted	Water - Drir	Water inges	0.22	ug/l or ppb
CO-5397	Plomo en Cc	Colombia	10.404225	-75.50671	Lead	1044	1	composite	Soil - Reside	Dust/soil/in	10	mg/kg or ppm
BD-5302	Polerhat Lea	Bangladesh	25.82707	88.77819	Lead	1460	1	composite	Soil - Agricu	Dust/soil/in	62580.94	mg/kg or ppm
BD-4924	Power Pack	Bangladesh	22.643119	89.798494	Lead	275	1	composite	Soil - Reside	Dust/soil/in	755.11	mg/kg or ppm
CO-5616	Presunta co	Colombia	3.45	-76.47561	Lead	16000	1	targeted	Soil - Indust	Dust/soil/in	34	mg/kg or ppm
IN-5689	Prime batte	India	28.64366	77.43615	Lead	500	1	targeted	Soil - Indust	Dust/soil/in	559	mg/kg or ppm
CO-5900	PRUEBA CAI	Colombia	123	1552	Lead	782	1	targeted	Water - Drir	Water inges	123	ug/l or ppb
IN-5408	Radix powe	India	29.036208	77.774617	Lead	5060	1	targeted	Soil - Reside	Dust/soil/in	74	mg/kg or ppm
IN-4906	Rajdhani Au	India	25.42385	86.12505	Lead	2300	1	targeted	Soil - Indust	Dust/soil/in	31354	mg/kg or ppm
IN-5048	Ram Battery	India	26.144457	85.91096	Lead	5500	1	composite	Soil - Reside	Dust/soil/in	16	mg/kg or ppm
IN-5077	Ramashank	India	25.78087	84.75493	Lead	5500	1	composite	Soil - Reside	Dust/soil/in	71	mg/kg or ppm
IN-5065	Ramco Batt	India	25.78504	84.72253	Lead	4100	1	composite	Soil - Reside	Dust/soil/in	59	mg/kg or ppm
IN-4916	Rashid Batt	India	24.79966	85.01141	Lead	3600	1	targeted	Soil - Indust	Dust/soil/in	5953	mg/kg or ppm
IN-5126	Russion Bat	India	25.57401	83.97481	Lead	3000	1	composite	Soil - Reside	Dust/soil/in	42	mg/kg or ppm
BD-4944	Sachibunia I	Bangladesh	22.78022	89.54577	Lead	745	1	composite	Soil - Reside	Dust/soil/in	465252.38	mg/kg or ppm
IN-5075	Sahu Batter	India	25.77631	84.78049	Lead	1805	1	targeted	Soil - Indust	Dust/soil/in	1694	mg/kg or ppm
BD-5339	Samad Batt	Bangladesh	22.844226	89.299127	Lead	700	1	targeted	Soil - Reside	Dust/soil/in	9118.9	mg/kg or ppm
CO-5168	Santa Lucia,	Colombia	10.324952	-74.96049	Arsenic	710	1	targeted	Soil - Agricu	Dust/soil/in	2.152	mg/kg or ppm
IN-5078	Sarswati Ba	India	25.78362	84.75554	Lead	2700	1	targeted	Soil - Indust	Dust/soil/in	4702	mg/kg or ppm
BD-4942	Sayed Batte	Bangladesh	23.16203	89.22247	Lead	2515	1	composite	Soil - Reside	Dust/soil/in	1467.67	mg/kg or ppm
BD-5254	SB Agro Ind	Bangladesh	23.539582	89.198356	Lead	455	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
JM-5897	Scrap Metal	Jamaica	18.003604	-76.82059	Lead	110	1	targeted	Soil - Reside	Dust/soil/in	2065	mg/kg or ppm
IN-5045	Shivnath Ba	India	26.08562	85.01552	Lead	800	1	composite	Soil - Reside	Dust/soil/in	33	mg/kg or ppm
BD-5299	Shokor Ali L	Bangladesh	25.28527	89.23199	Lead	6650	1	composite	Soil - Agricu	Dust/soil/in	37076.8	mg/kg or ppm
MN-5460	Shuvuutiin S	Mongolia	44.9882	94.7291	Arsenic	35	1	targeted	Soil - Agricu	Dust/soil/in	12	mg/kg or ppm
CO-5132	Sider	Colombia	3.542795	-76.28628	Lead	1510	1	targeted	Soil - Indust	Dust/soil/in	2875	mg/kg or ppm
SN-5387	Site d'extra	Senegal	14.09915	-12.05855	Mercury - o	1600	1	targeted	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
SN-5320	Site de d	Senegal	14.743142	-17.43729		250	1	targeted	Soil - Indust	Dust/soil/in	278	mg/kg or ppm
SN-5214	Site de stoc	Senegal	14.74513	-17.35477	&nbs	6450	1	targeted	Soil - Indust	Dust/soil/in	0	mg/kg or ppm
SN-5215	Site de stoc	Senegal	14.73128	-17.43138	&nbs	340	1	targeted	Soil - Reside	Dust/soil/in	0.01	mg/kg or ppm
SN-5680	Site de stoc	Senegal	16.46293	-15.69606	Pesticides	150	1	composite	Soil - Indust	Dust/soil/in	154.6	mg/kg or ppm
SN-5386	Sites d	Senegal	12.61227	-12.12538	Mercury - o	3000	1	targeted	Soil - Agricu	Dust/soil/in	0	mg/kg or ppm
SN-5684	Soci	Senegal	15.60822	-16.25007	&nbs	6000	1	targeted	Soil - Reside	Gases/vapo	0	mg/kg or ppm
SN-4203	Societe de p	Senegal	14.744873	-17.37509	Pesticides	2500	1	composite	Soil - Indust	Dust/soil/in	0	mg/kg or ppm
MN-5747	Soil pollutio	Mongolia	48.913389	106.0855	Arsenic	1560	1	targeted	Soil - Agricu	Dust/soil/in	70.15	mg/kg or ppm
SN-5667	Stockage de	Senegal	12.55904	-16.22442	&nbs	1602	1	targeted		Dust/soil/in	0	
MN-5411	Sujigt, Born	Mongolia	48.569153	106.51433	Arsenic	14	1	targeted	Soil - Indust	Dust/soil/in	85.45	mg/kg or ppm
IN-5106	Sunshine Ba	India	26.11666	85.35941	Lead	1205	1	targeted	Soil - Indust	Dust/soil/in	30355	mg/kg or ppm
BD-5458	Suntec Ener	Bangladesh	24.916043	91.942347	Lead	800	2	composite	Soil - Reside	Dust/soil/in	18248.26	mg/kg or ppm
IN-4890	Super batte	India	25.37971	86.47572	Lead	1740	1	targeted	Soil - Indust	Dust/soil/in	96	mg/kg or ppm
IN-5049	Suraj Batter	India	26.14457	85.90883	Lead	4500	1	composite	Soil - Reside	Dust/soil/in	267	mg/kg or ppm
JM-5611	T2 Mona Co	Jamaica	18.011529	-76.74184	Lead	6060	1	targeted	Soil - Reside	Dust/soil/in	83	mg/kg or ppm
BD-5292	Tamim Batt	Bangladesh	23.56525	89.19861	Lead	72	2	composite	Soil - Agricu	Dust/soil/in	504.35	mg/kg or ppm
MN-5357	Tannery ind	Mongolia	47.891372	106.89261	Chromium (	10000	1	targeted	Soil - Reside	Dust/soil/in	117.39722	mg/kg or ppm
MN-5856	Tavan tolgo	Mongolia	43.644917	105.59247	Arsenic	14280	1	targeted	Soil - Indust	Dust/soil/in	27.92	mg/kg or ppm
BD-5347	Tire Burning	Bangladesh	25.14999	89.26981	Arsenic	135	2	composite	Soil - Agricu	Dust/soil/in	12.23	mg/kg or ppm
IN-4892	Tulsi batter	India	26.15317	85.89518	Lead	2005	1	targeted	Soil - Indust	Dust/soil/in	10334	mg/kg or ppm
IN-5328	Ujjla Batter	India	24.49045	86.71465		1791	1	composite	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
BD-5457	ULAB break	Bangladesh	24.005514	90.730155	Lead	305	2	composite	Soil - Agricu	Dust/soil/in	9594.67	mg/kg or ppm
BD-5452	ULAB break	Bangladesh	23.911616	90.682846	Lead	174	2	composite	Soil - Agricu	Dust/soil/in	145904.06	mg/kg or ppm
BD-5448	ULAB break	Bangladesh	23.832978	90.679821	Lead	123	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5167	ULAB recyc	Bangladesh	24.436402	89.993366	Lead	160	1	targeted	Water - Drir	Water inges	0	ug/l or ppb

BD-5177	ULAB recyc	Bangladesh	24.327508	89.928452	Lead	47	2	composite	Soil - Agricu	Dust/soil/in	1200.79	mg/kg or ppm
BD-5463	ULAB break	Bangladesh	24.916821	91.942685	Lead	835	2	composite	Soil - Reside	Dust/soil/in	61318.54	mg/kg or ppm
BD-5027	ULAB break	Bangladesh	24.003833	89.648659	Lead	2320	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5129	ULAB break	Bangladesh	23.902291	89.145045	Lead	710	1	composite	Soil - Reside	Dust/soil/in	1739.68	mg/kg or ppm
BD-5165	ULAB break	Bangladesh	24.761363	90.437472		405	2	composite	Soil - Reside	Dust/soil/in	20368.93	mg/kg or ppm
BD-5062	ULAB break	Bangladesh	23.906863	89.121187	Lead	1500	1	composite	Soil - Reside	Dust/soil/in	2237.87	mg/kg or ppm
BD-5164	ULAB break	Bangladesh	24.75348	90.425094	Lead	1105	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5459	ULAB break	Bangladesh	22.719722	90.359883	Lead	950	1	composite	Soil - Reside	Dust/soil/in	41779.52	mg/kg or ppm
BD-5312	ULAB break	Bangladesh	25.10947	89.47346	Lead	575	2	composite	Soil - Agricu	Dust/soil/in	11942.4	mg/kg or ppm
BD-5294	ULAB break	Bangladesh	25.32678	89.5097	Lead	405	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5295	ULAB break	Bangladesh	25.32539	89.5084	Lead	120	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5346	ULAB break	Bangladesh	25.14984	89.28149	Lead	365	2	composite	Soil - Agricu	Dust/soil/in	1075.41	mg/kg or ppm
BD-5311	ULAB break	Bangladesh	25.14659	89.38719	Lead	330	2	targeted	Soil - Agricu	Dust/soil/in	1871.45	mg/kg or ppm
BD-5348	ULAB break	Bangladesh	25.63592	89.20424	Lead	231	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5345	ULAB break	Bangladesh	25.14492	89.25742	Lead	81	2	composite	Soil - Agricu	Dust/soil/in	610.02	mg/kg or ppm
BD-5368	ULAB break	Bangladesh	25.95411	88.97281	Lead	450	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5365	ULAB break	Bangladesh	25.54215	89.27483	Lead	110	2	composite	Soil - Agricu	Dust/soil/in	1084.14	mg/kg or ppm
BD-5293	ULAB break	Bangladesh	25.32502	89.51354	Lead	435	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5343	ULAB break	Bangladesh	25.112555	89.490567	Lead	395	2	composite	Soil - Agricu	Dust/soil/in	17320.21	mg/kg or ppm
BD-5440	ULAB break	Bangladesh	23.9943	90.682115	Lead	205	2	composite	Soil - Agricu	Dust/soil/in	26111.85	mg/kg or ppm
BD-5313	ULAB break	Bangladesh	25.10998	89.48923	Lead	200	2	composite	Soil - Reside	Dust/soil/in	77720.95	mg/kg or ppm
BD-5344	ULAB break	Bangladesh	25.34678	89.34063		100	2	composite	Soil - Agricu	Dust/soil/in	345.81	mg/kg or ppm
BD-5104	ULAB recycl	Bangladesh	24.15736	89.024677	Lead	940	2	composite	Soil - Reside	Dust/soil/in	7592.55	mg/kg or ppm
BD-5201	ULAB recycl	Bangladesh	23.177711	90.126209	Lead	210	2	composite	Soil - Agricu	Dust/soil/in	3890.26	mg/kg or ppm
BD-5102	ULAB recycl	Bangladesh	24.154889	89.023482	Lead	980	2	composite	Soil - Reside	Dust/soil/in	1096.97	mg/kg or ppm
BD-5013	ULAB recycl	Bangladesh	23.984687	89.640312	Lead	1020	2	composite	Soil - Reside	Dust/soil/in	1994.44	mg/kg or ppm
BD-5094	ULAB recycl	Bangladesh	23.988462	89.6485	Lead	1620	2	composite	Soil - Reside	Dust/soil/in	11972.18	mg/kg or ppm
BD-5026	ULAB recycl	Bangladesh	23.996241	89.642727	Lead	960	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5082	ULAB recycl	Bangladesh	24.006856	89.652425	Lead	1380	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5093	ULAB recycl	Bangladesh	23.990032	89.644257	Lead	1820	2	composite	Soil - Reside	Dust/soil/in	2113.56	mg/kg or ppm
BD-5083	ULAB recycl	Bangladesh	24.008821	89.650565	Lead	1750	2	composite	Soil - Reside	Dust/soil/in	502.68	mg/kg or ppm
BD-4860	ULAB recycl	Bangladesh	23.960711	90.320662	Lead	1550	1	composite	Soil - Indust	Dust/soil/in	262275.09	mg/kg or ppm
BD-4952	ULAB recycl	Bangladesh	24.271852	90.312197	Lead	610	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5012	ULAB recycl	Bangladesh	23.980496	89.644199	Lead	3181	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5159	ULAB recycl	Bangladesh	24.749344	90.426843	Lead	110	2	composite	Soil - Reside	Dust/soil/in	23426.44	mg/kg or ppm
BD-4842	ULAB recycl	Bangladesh	24.011274	90.150055	Lead	610	1	targeted	Soil - Indust	Dust/soil/in	204890.77	mg/kg or ppm
BD-5166	ULAB recycl	Bangladesh	24.539584	90.113357	Lead	125	2	targeted	Water - Irrig	Water inges	0	ug/l or ppb
BD-4845	ULAB recycl	Bangladesh	23.93814	90.323308	Lead	1050	1	composite	Soil - Indust	Dust/soil/in	243026.02	mg/kg or ppm
BD-4926	ULAB recycl	Bangladesh	24.165732	90.406673	Lead	1030	2	composite	Soil - Agricu	Dust/soil/in	4024.09	mg/kg or ppm
BD-4927	ULAB recycl	Bangladesh	24.188907	90.412267	Lead	1030	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4923	ULAB recycl	Bangladesh	24.141395	90.354643	Lead	2330	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5203	ULAB recycl	Bangladesh	23.244936	90.157571	Lead	102	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5176	ULAB recycl	Bangladesh	24.378242	90.001729	Lead	283	2	composite	Soil - Agricu	Dust/soil/in	200409.16	mg/kg or ppm
BD-4920	ULAB recycl	Bangladesh	24.143612	90.36124	Lead	920	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4957	ULAB recycl	Bangladesh	24.292448	90.345837	Lead	630	2	composite	Soil - Agricu	Dust/soil/in	1910.67	mg/kg or ppm
BD-4921	ULAB recycl	Bangladesh	23.919411	90.292314	Lead	4035	2	composite	Soil - Agricu	Dust/soil/in	74188.88	mg/kg or ppm
BD-5160	ULAB recycl	Bangladesh	24.747312	90.427619	Lead	395	2	composite	Soil - Agricu	Dust/soil/in	32101.13	mg/kg or ppm
BD-4841	ULAB recycl	Bangladesh	24.004577	90.167729	Lead	1085	1	targeted	Soil - Indust	Dust/soil/in	144276.11	mg/kg or ppm
BD-4896	ULAB recycl	Bangladesh	23.982933	90.294305	Lead	4090	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4955	ULAB recycl	Bangladesh	24.272975	90.367163	Lead	2690	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4909	ULAB recycl	Bangladesh	23.95565	90.302911	Lead	1150	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5246	ULAB recycl	Bangladesh	23.560338	89.800679	Lead	67	2	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4908	ULAB recycl	Bangladesh	23.962885	90.3155	Lead	1512	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4951	ULAB recycl	Bangladesh	24.26545	90.433588	Lead	2390	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-4928	ULAB recycl	Bangladesh	24.2651	90.452339	Lead	1250	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5019	ULAB recycl	Bangladesh	23.9915	89.6409	Lead	1445	1	composite	Soil - Indust	Dust/soil/in	9711.4	mg/kg or ppm
BD-5014	ULAB recycl	Bangladesh	23.988469	89.639395	Lead	1680	1	composite	Soil - Indust	Dust/soil/in	12999.12	mg/kg or ppm
PH-2869	ULAB Recyc	Philippines	15.410017	120.94848	Lead	20	1	targeted	Soil - Reside	Dust/soil/in	941.18	mg/kg or ppm
BD-4836	ULAB Recyc	Bangladesh	22.79895	89.52802	Lead	2750	2	composite	Soil - Reside	Dust/soil/in	92013.56	mg/kg or ppm
BD-5018	ULAB smelti	Bangladesh	23.977144	89.671345	Lead	109	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5310	ULAB smelti	Bangladesh	25.32489	89.50742	Lead	105	2	composite	Soil - Agricu	Dust/soil/in	1249.37	mg/kg or ppm
BD-5017	ULAB smelti	Bangladesh	23.984405	89.671195	Lead	337	2	composite	Soil - Agricu	Dust/soil/in	47271.64	mg/kg or ppm
BD-5016	ULAB smelti	Bangladesh	23.984328	89.670199	Lead	66	1	targeted	Water - Drir	Water inges	0	ug/l or ppb
BD-5015	ULAB smelti	Bangladesh	23.989669	89.669797	Lead	73	2	composite	Soil - Agricu	Dust/soil/in	1800.4	mg/kg or ppm
BD-5447	ULAB smelti	Bangladesh	23.850437	90.700364	Lead	220	2	composite	Soil - Agricu	Dust/soil/in	46961.6	mg/kg or ppm
BD-5245	ULAB smelti	Bangladesh	23.159185	90.019117	Lead	186	2	composite	Soil - Agricu	Dust/soil/in	2538.2	mg/kg or ppm
BD-5204	ULAB smelti	Bangladesh	23.269226	90.086052	Lead	65	2	composite	Soil - Agricu	Dust/soil/in	25722.87	mg/kg or ppm
BD-5152	ULABs Recy	Bangladesh	24.552586	89.504617	Lead	495	1	targeted	Soil - Reside	Dust/soil/in	523.17	mg/kg or ppm
SN-5678	Unit	Senegal	14.64918	-16.26662	&nbs	1522	1	targeted	Soil - Indust	Dust/soil/in	0	mg/kg or ppm
MN-5853	Used engine	Mongolia	46.006672	106.34197	Arsenic	10	1	targeted	Soil - Agricu	Dust/soil/in	6	mg/kg or ppm
SN-5169	Usine de rec	Senegal	14.726	-17.156	Lead	700	1	targeted	Soil - Indust	Dust/soil/in	9785	mg/kg or ppm
SN-5385	Utilisation d	Senegal	12.917504	-11.52503	Mercury - o	12000	1	composite	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
SN-5384	Utilisation d	Senegal	12.63961	-12.25309	Mercury - o	1500	1	targeted	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
SN-3911	Utilisation d	Senegal	12.6728	-12.27844	Mercury - o	11000	1	targeted	Soil - Reside	Dust/soil/in	0	mg/kg or ppm

SN-4061	Utilisation d	Senegal	12.79862	-12.2934	Mercury - o	500	1	targeted	Soil - Reside	Dust/soil/in	0	mg/kg or ppm
PH-3069	Various junl	Philippines	14.2605	121.10443	Lead	2060	1	targeted	Soil - Indust	Dust/soil/in	13095.83	mg/kg or ppm
IN-5079	Vikash Batt	India	25.78229	84.75441	Lead	3200	1	composite	Soil - Reside	Dust/soil/in	57	mg/kg or ppm
IN-5046	Vikash Batt	India	26.03574	85.14998	Lead	2200	1	targeted	Soil - Indust	Dust/soil/in	822	mg/kg or ppm
CO-5249	Willard -PIN	Colombia	10.83381	-74.76847	Lead	50	1	targeted	Soil - Indust	Dust/soil/in	9744	mg/kg or ppm

A Meta-Analysis of Blood Lead Levels in India and the Attributable Burden of Disease

Bret Ericson[1,2], Russell Dowling[1], Subhojit Dey[3], Jack Caravanos[1,4], Navya Mishra[5], Samantha Fisher[1], Myla Ramirez[1], Promila Sharma[1], Andrew McCartor[1], Pradeep Guin[6], Mark Patrick Taylor[2] and Richard Fuller[1]

Corresponding Author: Bret Ericson, Pure Earth, 475 Riverside Drive, Suite 860, New York, NY, USA; phone: +1 212 647 8330; email: bret@pureearth.org

[1] Pure Earth, 475 Riverside Drive, Suite 860, New York, NY, USA 10025

[2] Department of Environmental Sciences, Faculty of Science and Engineering, Macquarie University, North Ryde, Sydney, NSW 2109, Australia

[3] Indian Institute of Public Health (Delhi), Delhi NCR, Plot No. 47, Sector 44, Institutional Area Gurgaon – 122002

[4] College of Global Public Health, New York University, 41 East 11th Street, New York, NY, USA 10003

[5] Public Health Foundation of India, Delhi NCR, Plot No. 47, Sector 44, Institutional Area Gurgaon – 122002

[6] Jindal School of Government and Public Policy, O.P. Jindal Global University, Sonipat Narela Road, Sonipat, Haryana, India – 131001,

Abstract

Multiple studies in India have found elevated blood lead levels (BLLs) in target populations. However, the data have not yet been evaluated to understand population-wide exposure levels. Blood lead data published from 2010 to 2018 on Indian populations was used to calculate a mean blood lead level for multiple subgroups. The predicted attributable disease burden in IQ decrement and Disability Adjusted Life Years (DALYs) is calculated. Our Pubmed search yielded 1,066 articles. Of these, 32 studies representing the BLLs of 5,801 people in 9 states met our study criteria. Evaluating these, we found a mean BLL resulting from non-occupational exposures of 7.09 µg/dL (95% CI: 5.82–8.36) in adults and 8.41 µg/dL (95% CI: 5.93–10.9) in children. We calculated that these exposures resulted in 5.1 million DALYs (95% CI: 4.3–5.7) in the states we evaluated. Population-wide BLLs in India remain elevated despite regulatory action to deal with leaded petrol, the most significant historical source. The estimated attributable disease burden is larger than previously calculated, particularly with regard to associated

intellectual disability outcomes in children. Larger population-wide BLL studies are required to inform future calculations. Policy responses need to be developed to mitigate the worst exposures.

Keywords

blood; lead; India; meta-analysis; DALYs; contamination

Acknowledgements

Support for this research was provided in part by the United States Agency for International Development (Cooperative Agreement No. AID-OAA-A-16-00019). BE is a recipient of an International Macquarie University, Sydney, Australia, Research Excellence Scholarship.

Competing Interest

BE, RD, JC, SF, MR, PS, AS and RF were employed by Pure Earth while working on this manuscript. Pure Earth is a charity that works on pollution issues in low- and middle-income countries, including India.

Introduction

Lead is a naturally occurring metal with a range of industrial applications and well-documented adverse health effects when human exposure occurs (ATSDR, 2007). Its widespread use has resulted in significant contamination of natural and human environments (Needleman, 2004; Prüss-Üstün et al., 2010). Chronic lead exposure, even at very low levels, is associated with cognitive impairment, cardiovascular effects, anemia and low birth weight, among other adverse health outcomes (Budtz-Jørgensen et al., 2013; Lanphear, 2015; National Toxicology Program, 2012; United Nations Environment Programme, 2010). Lead exposure has been associated with decreased economic output, lower life expectancy and increased societal violence (Demayo et al., 1982; Landrigan and Goldman, 2011; Mielke and Zahran, 2012; Prüss-Üstün et al., 2010; Taylor et al., 2016).

The 2016 Global Burden of Disease, Injuries and Risk Factors Study by the Institute for Health Metrics and Evaluation (IHME) estimated that lead exposure resulted in 13.9 million Disability-Adjusted Life Years (DALYs) and 540,000 deaths in 2016 globally. In India alone, IHME found 4.6 million lead-attributable DALYs and nearly 165,000 deaths (IHME, 2017a).

The most significant historic global source of global lead exposure was the use of tetraethyl lead in petrol in the 20th century (Bollhöfer and Rosman, 2001, 2000; Flegal et al., 1984; McConnell et al., 2015; Schwikowski et al., 2004; Véron et al., 1999). In cities where it was used, leaded petrol accounted for 80 to 90% of airborne lead pollution (Lovei, 1999). High-income countries began banning the use of lead in most fuels, as well as in paints, in the 1970s, resulting in significant declines in societal blood lead levels (BLLs) (Needleman, 2004). Leaded petrol was phased out in India from 1996 to 2000 and was similarly followed by BLL declines (Singh and Singh, 2006). Nichani et al. (2006), for instance, documented a 60 % decrease in BLLs among residents of Mumbai from 1997 to 2002, following the full adoption of unleaded petrol. Similarly, (Singh and Singh, (2006) found a mean BLL decrease of 33 % following the leaded petrol phase out in the urban centers of Mumbai, Chennai, Bangalore, Amritsar and Lucknow.

Despite these substantial improvements in exposure reduction, studies conducted more than a decade after the Indian phase out of leaded petrol continue to report elevated BLLs, often associated with proximity to lead smelting sites (Bellinger et al., 2005; Ghose et al., 2005; Sharma et al., 2005). Other sources of lead exposure to the Indian public have included ayurvedic medicine, cosmetics (kohl/surma) and contaminated foodstuffs (Goswami, 2013; Raviraja et al., 2010; Singh et al., 2010; Singhal, 2016). In some cases these exposures have found severely elevated levels in both occupational and non occupational settings (Ghanwat et al., 2016; Goswami, 2013).

In this assessment we review existing studies on BLLs to infer broader conclusions about the population of a subset of India. We first conduct a literature review and meta-analysis of Indian BLLs in India published between 2010 and 2018. We then use the results to quantify the disease burden in terms of IQ decrement and attributable DALYs. The objective of this study is to quantify the potential public health impacts of lead exposure in India and to stimulate policies, education, and, where appropriate, remediation of contaminated sites.

Methods and Approach

Literature Review and Data Selection

We conducted a PubMed search in April 2018 using the terms blood (subheading, all fields, MeSH terms) lead (all fields, MeSH terms), and India (all fields, MeSH terms, abstract text) between 1 January 2010 and 1 January 2018 (National Library of Medicine (US), 1946). We then assessed each article by a the following 6 criteria: 1) The study published BLL data from human populations residing in India; 2) The study included at least 30 participants; 3) BLL data were derived from venous, capillary, or umbilical cord samples (bone, organ or tissue samples were excluded); 4) The utilized data were collected after 2005; 5) The study was published in English; 6) The study contained a statistical mean and standard deviation (SD) or standard error (SE) for the original data set. Articles that did not meet one or more of the above criteria were excluded from the meta-analysis.

Subgroup Rational

The BLL data for each for each study were analyzed by certain demographic categories following the literature review. Where possible samples were disaggregated by the following three subgroups: gender, age, urbanicity, and occupation.

Age categories were defined using UNICEF's parameters outlined in the Convention on the Rights of Children. An individual was considered a "child" if he or she was at or below the age of 17 at the time of the original study, and an "adult" if he or she was identified as at or above 18 (United Nations General Assembly, 1989). Gender was stratified into four different categories: female, male, both and unspecified. Urbanicity was determined by a review of studies for 'urban' or 'rural' keywords. If this was not indicated in the article, the study location was used to make this determination. The Census of India classification of 400 people per square kilometer was used as the threshold for an urban area (India, 2011). Finally samples were coded as occupational if the relevant occupation substantively involved lead and therefore a higher risk of elevated BLLs. Samples comprised of battery recyclers for instance were coded as occupational, while studies of teachers were coded as non-occupational.

Identification and Use of Sample Means

Where possible, the mean and SD/SE were derived for our specific subgroups. In cases where the subgroups used by study were incongruous with our own, the mean and SD/SE were taken for a larger subset, such as the study population.

If the same population was assessed multiple times, and treatment was not provided in between assessments, the mean for all analyses was used. In cases where the mean could not be taken, the most conservative value (ie lowest) value was used. If treatment was provided, pre-treatment values were used.

Three studies assessed the BLLs of the same large cohort of children at different points (Palaniappan et al., 2011; Roy et al., 2013, 2009). In this case, one study had a slightly larger sample size than the other two and all presented similar overall results with regard to BLLs. It was thus included and the other two were excluded.

In one case, BLLs were assessed at the same point using multiple methods having different results. (Reddy et al., 2014). In this case we selected the most conservative (ie lowest) value.

Some studies segregated the sample exclusively based on the results of the BLL test (e.g. high and low subgroups). In these cases the pooled BLL was taken. In one study (Ravibabu et al., 2015), the pooled mean was not available. We therefore use both subgroups as discrete samples. Other studies disaggregated the sample by health outcome. Tiwari et al. (2012), for instance analyzed BLLs for three groups of anemic women (mild, moderate, severe) and one control group. A pooled mean was not available for the study as a whole, so we used the means for each subgroup and presented them as discrete samples. Finally, Goswami, et al. (2012) look at children that apply surma (kohl) and a control group. A study mean was not available, so we report both samples as non-occupationally exposed children.

*Meta-Analysis of BLL*s

We pooled the results from each study using a Random Effects (RE) meta-analysis model. Meta-analyses are typically conducted using either and RE or Fixed Effects (FE) model. Fixed effects models are concerned with within-study variability only and do not account for variability between studies. An FE model is appropriate when the effect size for all studies is assumed to have one true value and any variance that occurs is due to sampling error (Borenstein et al., 2010). Random effects models, by contrast, assume that studies represent a random sampling of different populations within a larger 'super' population (DerSimonian and Kacker, 2007; Hedges, 1992). Thus in an RE model variance observed in the evaluated studies is assumed to be due in part to true variance between the sampled groups (Borenstein et al., 2010). Effectively this method weights each sample's effect size by its inverse variance in pooling effect sizes and confidence intervals.

In the present effort we evaluated studies drawn from discrete populations across India; each with different lifestyles and exposure scenarios. We therefore assumed that variance reflected in the samples was due, at least in part, to true difference in mean BLL concentrations. Accordingly we took the mean BLL and standard error from each sample and pooled them using a RE model. We used the metan tool in Stata 15.1 for the analysis (StataCorp. LP, 2017). The metan tool utilizes the DerSimonian & Laird method (1986) for RE and a method taken from Mantel-Haenszel (1959) to assess heterogeneity (Sterne, 2009). In addition to a pooled effect size and confidence intervals, the metan tool generates q, I^2, and tau^2 statistics. We present these in the relevant figures below. In all but one of our evaluated subgroups the p-value of the q-statistic is below 0.000, confirming heterogeneity and further indicating that an RE model is appropriate.

Calculating IQ Decrement

We calculated IQ decrement resulting from pediatric lead exposure using the log-linear model described in Budtz-Jørgensen *et al.* (2013). The authors used internationally pooled data from seven cohorts of children to calculate a benchmark dose of 0.1–1.0 μg/dL for the loss of a single IQ point. Budtz-Jørgensen *et al.* (2013) re-evaluate the data and approach of Lanphear *et al.'s* (2005) study of low level environmental lead exposure (defined as < 7.5 μg/dL) and its impact on the developing brain. The cohorts used in both studies are comprised of school-age children (age 5-10 years) with chronically elevated BLLs. Verbal and performance tests were conducted to determine the extent of intellectual impairment and those results are compared with BLL measurements from four different periods: early childhood (age 6-24 months); average lifetime; maximum lifetime; and concurrent (at the time of the IQ test). Lanphear *et al.* (2005) found that the concurrent BLL measurements had the strongest relationship with IQ decrement. Budtz-Jørgensen *et al.* (2013) accordingly applied concurrent geometric mean BLLs to both log-linear and two-piece linear models, and found log-linear to be the best fit. Here, we used the log-linear model presented and input the arithmetic mean BLL for the subgroup children in India to determine IQ points lost for children age 10 years and under.

Calculating DALYs

We use the meta-analysis results for non-occupationally exposed adults and children to calculate DALYs. DALYs are a metric intended to represent the disease burden in a given population and the relative contribution of disparate health outcomes to it. They are the sum of two other metrics, Years of Life Lost (YLD) and Years Lived with Disability (YLD). YLL represents early attributable mortality while YLD represents the severity and duration of a given health outcome (World Health Organization, 2016). DALYs are employed most notably by the World Health Organization (WHO) and IHME in their respective periodic global burden of disease reports (Forouzanfar et al., 2016; World Health Organization, 2016).

Lead exposure results in a number of quantifiable adverse health outcomes, however methods for integrating those outcomes into DALY calculations, as with other chemical exposures, are somewhat limited (Grandjean and Bellanger, 2017). We therefore calculated DALYs for two sequelae only: cardiovascular disease (CVD) and intellectual disability. We followed the approach outlined by Ericson *et al.* (2016; 2018a) and described below. DALY calculations for both sequelae utilize the total population of the all states where study were conducted.

To calculate DALYs resulting from cardiovascular disease in 2013 we used a prevalence rate calculator developed by the WHO for BLLs (Fewtrell et al., 2003). The calculator requires the geometric mean BLL and standard deviation for a given population to determine the lead-attributable fraction of CVD in that population. Values are returned for four classifications of CVD: ischemic, cerebrovascular, hypertensive, and other heart diseases. In the absence of a population wide geometric mean, we input the pooled arithmetic mean and standard deviation for non-occupational exposures for adults to determine the attributable fraction for each case. We then applied these attributable fractions to the most recent (2013) WHO CVD DALY estimates for India to determine the number of DALYs and deaths attributable to lead exposure (WHO, 2014). We further proportionately reduce the national number of DALYs for India to the population of those states from where studies were drawn.

To calculate DALYs resulting from lead induced intellectual disability in 2012 we used the WHO calculator described above to determine a prevalence of Mild Mental Retardation (MMR) in a given population of 0-4 year olds with a given geometric mean BLL. We again input the arithmetic mean and standard deviation for children in our study (all non-occupational). We again use the total population of the states from where studies were drawn rather the national population to develop our estimates.

The WHO calculator was developed in 2003 and uses the now antiquated classification of MMR and its associated disability weight. These values have since been revised to more accurately capture a gradient of intellectual disability. While MMR was previously quantified with a disability weight of 0.361, the revised disability weights for intellectual disability are as follows: borderline (0.0034), mild (0.1270), moderate (0.30), severe (0.3830) and profound (0.4440) intellectual disability (Colin et al., 2004; WHO, 2013). To determine the proportional composition of these subgroups, we assume MMR is analogous to mild intellectual disability and calculate the prevalence of the remaining subgroups by extrapolating from that value. To do so, we use relative proportions provided by the WHO (2013). We then determine the number of DALYs attributable to each sequalae using the following equation:

$$YLD = DW \times p$$

Where:

p = prevalence

DW = disability weight

Adapted from WHO (2013).

Results

Literature Review

Our PubMed search yielded 1,066 studies. Of these 979 did not contain BLL data on human populations within India and were excluded. A further 55 studies did not meet one or more of the remaining criteria and were excluded. The remaining 32 studies contained 69 samples for use in our study (marked with an asterisk in the references). The 69 samples represented a population of 5,801 people in 9 different Indian states (Andhra Pradesh, Karnataka, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Telangana, Uttar Pradesh, and West Bengal). These states had an approximate population of 717 million people representing 56% of India's national population (India, 2011). Mean blood lead levels and related statistics (confidence interval, p-value, q, I^2, tau^2) for subgroups are presented below in **Table 1.** A forest plot of all samples and studies used in the analysis are presented in **Figure 1**.

Blood Lead Levels

Nineteen of the 69 samples were comprised of children representing 2,338 individuals in 6 different states. These states had an estimated population of 560,190,596 at the time of the most recent census (India, 2011). All children in all studies were < 14 years of age. Most studies included a span of age ranges covering multiple years and provided limited detail on the composition of the those groups. Thus, a mean age for the study population could not be determined. Of those children included in the samples, at least 20% (n=486) were ≤2 years of age, at least 59% (n=1,387) were ≤7 years of age, at least 72% (n=2,341) were ≤10 years of age, and at least 92% (n=2,143) were ≤12 years of age. All childhood exposures were identified as non-occupational. The pooled arithmetic mean for all children in the study was 8.41 μg/dL (95% CI: 5.92–10.90). The related forest plot is presented as **Figure 2.**

Fifty of the samples were comprised of adults, representing 3,467 individuals. Of these 22 samples were comprised of 1,499 individuals with occupational exposures while the balance (n=28) were comprised of 1,964 individuals with non-occupational exposures. The pooled arithmetic mean for non-occupationally exposed adults in the study was 7.09 μg/dL (95% CI: 5.82–8.36). A forest plot with all samples from this subgroup used in the analysis is presented as **Figure 3.**

IQ Decrement

Within the study population, children had an arithmetic mean BLL of 8.41 μg/dL (95% CI: 5.92–10.90). Using the log-linear model described in Budtz-Jørgensen *et al* (2013) we find that this BLL would result in an average decrement of 4.42 IQ points (95% CI: 3.40–5.12) for children under age 10.

Disability Adjusted Life Years (DALYs)

We find that cardiovascular disease attributable to lead exposure resulted in 2.7 million DALYs (95% CI: 2.3–3) in 2012 the 9 states we reviewed. We further find that intellectual disability in children (age 0–4) attributable to lead exposure resulted in 2.4 million DALYs (95% CI: 1.9–2.7) in the same year in the 6 states we reviewed. Altogether we calculate 5.1 million DALYs (95% CI: 4.3–5.7) attributable to lead exposure in the 9 states in 2012. **Tables 2–4** summarize attributable DALYs and by sequelae and calculated BLLs.

Sensitivity Analysis

The RE model used here does not directly account for sample size as such. Rather the relative contribution of each study to the effect size is weighted by its standard error. Accordingly samples comprised of a relatively small number of observations can have outsized weight in the analysis if their standard error is also low. In the present study, the data are skewed right, with a small number of outliers representing highly elevated BLLs. These samples also have very low relative standard errors, indicating that the pooled mean may be artificially high.

In our sensitivity analysis we address the issue of outliers by removing values greater or less than one standard deviation from the mean of the samples. While no values were less than a single standard deviation from the mean, 5 were greater than one standard deviation above the mean in adults and 2 were greater than one standard deviation in children. Removing these outliers in the case of children resulted in a mean BLL of 6.86 µg/dL (95% CI: 4.38–9.33) and 2.1 million DALYs (95% CI: 1.6–2.5). In the case of adults removing outliers resulted in a mean BLL of 5.82 µg/dL (95% CI: 3.23–8.40) resulting in 2.3 million DALYs (95% CI: 1.6–2.8).

Discussion

Our analysis of studies of BLLs from 9 states found that 5.1 million DALYs (95% CI: 4.3–5.7) were attributable to lead exposure in 2012. This is significantly greater than the disease burden calculated by IHME of 4.6 million DALYs (95% CI: 2.9–6.5) (IHME, 2017b) for the country as a whole in 2016.

The discrepancy is most pronounced in children (0-4 years old) who accounted for 33,264 DALYs (95% CI: 12,428–33,264) in IHME's analysis. In the 9 states we reviewed we find this group incurred more than 2.7 million DALYs (95% CI: 2.3–3). This discrepancy is in part due to differences in how IHME weights sequelae related to intellectual disability and how we do so here. Following WHO we weight intellectual disability as follows: borderline (0.0034), mild (0.1270), moderate (0.30), severe (0.3830) and profound (0.4440) (WHO, 2013). By contrast, IHME provides the following weights: borderline (0.011), mild (0.043), moderate (N/A), severe (0.16) and profound (0.2) (Global Burden of Disease Collaborative Network, 2017). To quantify the impact of this difference, we calculated DALYs in our model with the IHME weights finding 772,438 DALYs (95% CI: 622,582–879,393) for children in our geographic subgroup in 2012. Thus differences in weighting alone are insufficient to account for the discrepancy.

Looking at ages 15 and above only, IHME calculates 4.3 million DALYs (95% CI: 2.6–6.3) attributable to lead exposure compared with the 2.7 million DALYs (95% CI: 2.3–3) found by this study. The 9 states covered by this study represent approximately 56% of the national population. Scaling IHME's values to a population of comparable size results in 2.4 million DALYs (95% CI: 1.4–3.5). Thus the values are similar for adults.

It is possible that the 2016 IHME GBD report underestimates the pediatric disease burden from lead exposure in India. In this study, we calculate a mean BLL of 8.41 μg/dL (95% CI: 5.92–10.90) for all children in our geographic subgroup. We further calculate that a national geometric mean BLL of $<$ 1 μg/dL would be required to arrive at the 33,264 DALYs (95% CI: 12,428–61,466) calculated by IHME for 2016 using our method. While this value has been achieved in the United States, it would seem inconsistent with the recent blood lead exposure data examined here (Center for Health Statistics, 2017).

In the WHO 2004 global burden of disease estimate, an average BLL for both children and adults of 7.4 μg/dL was used (Prüss-Üstün et al., 2010). Based on this, the researchers calculated a prevalence of 5.5 cases of MMR per 1000 population attributable to lead exposure. This is somewhat less than we find in the present effort (~14 cases of MMR per 1000) however significantly more than the ~0.27 per 1000 prevalence that would be required to reach the 33,264 DALYs calculated by IHME (using our method). Few other studies have calculated the disease burden of chemicals either globally or on a national level for India (Chatham-Stephens et al., 2013; Prüss-Ustün et al., 2011). Therefore, there is a limited basis for assessing the relative accuracy of the estimates provided here and by WHO and IHME. Given the robust literature on the adverse effects of lead on neurological development and the likely elevated BLLs in children in India, the topic could clearly benefit from further study.

A 2015 study by Iyer, et al. reports on the blood lead analysis of 222,668 individuals from multiple states in India. The study provides limited statistical information and was therefore not included in the present analysis. Specifically, neither SD nor SE were included with the sample mean. However given the exceptionally large size of the sample, the study provides useful context for our results. For children under 2 years of age (n=119), the authors find a mean BLL of 4.91 µg/dL and for children 2–10 years of age (n=688) the authors find a mean BLL of 4.2 µg/dL. In adults (n=219,303), the authors find mean BLLs of different age groups ranging from 4.24–4.95 µg/dL. In all cases, the values reported by Iyer, et al. (2015) are somewhat lower than our results. Of particular interest are the geographic difference in BLLs identified by Iyer, et al. (2005). For instance, the authors define a 'high' BLL as 15 µg/dL and provide the percentage of blood samples from each state that exceed this threshold. In two states, Maharashtra and Bihar, this percentage exceeds 10, while in Gujarat it is 2.5. This indicates that significant differences in BLLs exist between states. Further review of the vast dataset utilized by Iyer, et al. (2015) to better understand these differences could greatly benefit other researchers.

Sources of Contemporary Lead Contamination

Eighty-five percent of global lead production is used in the manufacture of storage, lighting and ignition (SLI), or lead-acid, batteries (International Lead Association, 2016). The product life cycle of lead-acid batteries is regulated under India's *Batteries*

Management and Handling Rules of 2001, amended in 2010 (Ministry of Environment and Forests (India) 2001, 2010). The Rules create a deposit refund system in which retailers collect used lead-acid batteries (ULABs) from consumers when they purchase new batteries and offer a rebate for the new purchase. ULABs must be sold only to registered recyclers, who are required to transport, handle and recycle the used batteries responsibly. Despite this existing legislation, informal (unregulated) ULAB recycling is widespread. One study found that among major battery manufacturers, few were able to collect more than 40% of the used batteries they had produced (Prajapati, 2016). This is likely due in part to the relatively large informal sector (approximately 21 % of GDP) and increased auto ownership, and is consistent with findings in other countries (Bret Ericson et al., 2016; Schneider et al., 2010; Shukla et al., 2015). From 2001 to 2012, the number of motor vehicles in India increased from 55 million to 159.5 million (Shukla et al., 2015). Ericson et al. (2016) estimate that more than 700,000 metric tons of lead are generated from secondary sources each year in India, with less than half being recycled formally. The India Lead Zinc Development Association has developed a similar estimate of 750,000 metric tons per annum (Pugazhenthy, 2017). Recycling ULABs offers an economic opportunity for unskilled or semi-skilled workers, as lead from the batteries is easily melted down for resale to manufacturers. Exposures to lead resulting from this practice are prominent in low- and middle-income countries (LMICs) where primitive operations of unregulated backyard smelters cause widespread lead contamination (Daniell et al., 2015; Bret Ericson et al., 2016; Haefliger et al., 2009; Prajapati, 2016). As backyard smelters are illegal, recycling activities are often operated intermittently and can move from neighborhood to neighborhood to avoid regulatory intervention, creating lead hotspots throughout a community (e.g. Shen et al., 2016). Due to lead's low mobility in the environment, contamination hotspots are likely to remain contaminated indefinitely without remediation (Kabala and Singh, 2001). One well documented example of an extreme case of poisoning resulting from informal ULAB recycling was the deaths of 18 children in Senegal linked to informal battery smelting (Haefliger et al., 2009). Besides contamination by lead alone, smelting operations can generate elevated concentrations of other toxic trace metals including arsenic, cadmium and mercury (Roussel et al., 2010; Stafilov et al., 2010). There are limited published studies detailing effective approaches to mitigating the health risks posed at informal ULAB sites. One recent example from Vietnam describes the construction of an industrial zone for informal workers located 1 km from residential areas. The relocation, coupled with community education and soil lead abatement work, resulted in median BLL declines of 67 % in children (<6 years of age) within one year of the intervention (Ericson et al., 2018b).

A number of other sources of lead exposure are also present in India and require further investigation. Among them, ayurvedic medicines and surma (kohl) use pose unique risks. It is worth noting that the highest BLL for a subgroup in our study was among 69 surma using boys with a mean BLL of 29.6 µg/dL (Goswami, 2013).

Study Limitations

The study is most significantly limited by its reliance on a relatively small number of studies (n=32). As a result, values are inferred for a population of 717 million from the BLL results of only 5,801 non-occupationally exposed people. Future studies might endeavor to collect more comprehensive biological data from a more representative cross-section of the country. It should be noted that the US National Health and Nutrition Examination Survey (NHANES) is comparable larger in size, with data collected from approximately 5,000 individuals annually, though collected with the specific intention of inferring results for the population as a whole (Center for Health Statistics, 2017).

A second limitation is our reliance on an older method for calculating the attributable disease burden. The prevalence rate calculator we use was developed by WHO in 2003 and has been validated, though to the best of the authors' knowledge has not been modified in the intervening years. Significantly, the WHO calculator estimates the prevalence of MMR using an older linear IQ decrement model developed by Schwartz (Schwartz, 1994). Replacing those values with the more recent Budtz-Jørgensen *et al.* (2013) log-linear model would likely result in a higher estimate of the prevalence of intellectual disability, and thus a higher disease burden (Ericson et al., 2018a). We do not endeavor to do so hear.

Conclusion

Population-wide BLLs in India remain elevated despite regulatory action to deal with the most significant sources. The attributable disease burden may be larger than previously calculated, particularly with regard to intellectual disability in children. Larger population-wide BLL studies are required to inform future calculations. Major traditional sources of lead exposure based on leaded petrol emissions and depositions are insufficient to account for the results here. Therefore, the attributable portion of disease associated with lead exposure must involve other sources, with the most likely suspect being ULAB processing. Lead exposure can result in a number of lifelong outcomes with adverse implications for individuals as well broader society. Consequently, there are clear societal benefits that could be accrued from more targeted investment in remediation, mitigation and policy development to mitigate the worst the exposures.

Papers included in Meta Analysis (Included for formatting purposes only – To be deleted before publication)

(Ahamed et al., 2011; Bansal et al., 2017; Chambial et al., 2015; Chaudhary et al., 2017; Chinde et al., 2014; Choudhari et al., 2010; Dongre et al., 2013, 2011, Ghanwat et al., 2016, 2015; Goswami, 2013; Jangid et al., 2012; Kalahasthi et al., 2014; Kalra et al., 2013; Khan et al., 2010; Lokesh, 2016; Mazumdar and Goswami, 2014; Mishra et al., 2010; Mohan et al., 2014; Palaneeswari M, 2012; Patel et al., 2011; Pratinidhi et al., 2014; Ravibabu et al., 2015; Reddy et al., 2011, 2014; Roy et al., 2013; Sharma et al., 2014; Singh et al., 2013; Singh and Chadha, 2016; Subrahmanyam et al., 2016; Tiwari et al., 2012; Vani et al., 2012; Wani et al., 2017)

References

*Ahamed, M., Akhtar, M.J., Verma, S., Kumar, A., Siddiqui, M.K.J., 2011. Environmental lead exposure as a risk for childhood aplastic anemia. Biosci. Trends 5, 38–43. doi:10.5582/bst.2011.v5.1.38

ATSDR, 2007. ATSDR - Toxicological Profile: Lead [WWW Document]. URL https://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=96&tid=22 (accessed 11.10.16).

*Bansal, N., Aggarwal, A., Faridi, M.M.A., Sharma, T., Baneerjee, B.D., 2017. Association of Lead Levels and Cerebral Palsy. Glob. Pediatr. Heal. 4, 2333794X17696681. doi:10.1177/2333794X17696681

Bellinger, D.C., Hu, H., Kalaniti, K., Thomas, N., Rajan, P., Sambandam, S., Ramaswamy, P., Balakrishnan, K., 2005. A Pilot Study of Blood Lead Levels and Neurobehavioral Function in Children Living in Chennai, India. Int. J. Occup. Environ. Health 11, 138–143. doi:10.1179/oeh.2005.11.2.138

Bollhöfer, A., Rosman, K.J.., 2001. Isotopic source signatures for atmospheric lead: the

Northern Hemisphere. Geochim. Cosmochim. Acta 65, 1727–1740. doi:10.1016/S0016-7037(00)00630-X

Bollhöfer, A., Rosman, K.J.., 2000. Isotopic source signatures for atmospheric lead: the Southern Hemisphere. Geochim. Cosmochim. Acta 64, 3251–3262. doi:10.1016/S0016-7037(00)00436-1

Borenstein, M., Hedges, L. V., Higgins, J.P.T., Rothstein, H.R., 2010. A basic introduction to fixed-effect and random-effects models for meta-analysis. Res. Synth. Methods 1, 97–111. doi:10.1002/jrsm.12

Budtz-Jørgensen, E., Bellinger, D., Lanphear, B., Grandjean, P., Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T., Rothenberg, S.J., Needleman, H.L., Schnaas, L., Wasserman, G., Graziano, J., Roberts, R., 2013. An international pooled analysis for obtaining a benchmark dose for environmental lead exposure in children. Risk Anal. 33, 450–461. doi:10.1111/j.1539-6924.2012.01882.x

Center for Health Statistics, N., 2017. National Health and Nutrition Examination Survey Overview.

*Chambial, S., Shukla, K.K., Dwivedi, S., Bhardwaj, P., Sharma, P., 2015. Blood Lead Level (BLL) in the Adult Population of Jodhpur: A Pilot Study. Indian J. Clin. Biochem. 30, 357–359. doi:10.1007/s12291-015-0496-y

Chatham-Stephens, K., Caravanos, J., Ericson, B., Sunga-Amparo, J., Susilorini, B., Sharma, P., Landrigan, P.J., Fuller, R., 2013. Burden of disease from toxic waste sites in India, Indonesia, and the Philippines in 2010. Environ. Health Perspect. 121, 791–796.

*Chaudhary, S., Firdaus, U., Manazir Ali, S., Mahdi, A.A., 2017. Factors Associated With Elevated Blood Lead Levels in Children. Indian Pediatr. 55, 38–40.

*Chinde, S., Kumari, M., Devi, K.R., Murty, U.S., Rahman, M.F., Kumari, S.I., Mahboob, M., Grover, P., 2014. Assessment of genotoxic effects of lead in occupationally exposed workers. Environ. Sci. Pollut. Res. 21, 11469–11480. doi:10.1007/s11356-014-3128-9

Choudhari, R., Sathwara, N.G., Shivgotra, V.K., Patel, S., Rathod, R.A., Shaikh, S., Shaikh, M.I., Dodia, S., Parikh, D.J., Saiyed, H.N., 2010. Study of lead exposure to children residing near a lead-zinc mine. Indian J. Occup. Environ. Med. 14, 58–62. doi:10.4103/0019-5278.72243

Colin, M., Ties, B., Fat, D.M., 2004. Global burden of disease, 2004 update 15–17.

Daniell, W.E., Van Tung, L., Wallace, R.M., Havens, D.J., Karr, C.J., Bich Diep, N., Croteau, G.A., Beaudet, N.J., Duy Bao, N., Daniell, W.E., Van Tung, L., Wallace, R.M., Havens, D.J., Karr, C.J., Bich Diep, N., Croteau, G.A., Beaudet, N.J., Duy Bao, N., 2015. Childhood Lead Exposure from Battery Recycling in Vietnam. Biomed Res. Int. 2015, 1–10. doi:10.1155/2015/193715

Demayo, A., Taylor, M.C., Taylor, K.W., Hodson, P. V., Hammond, P.B., 1982. Toxic effects of lead and lead compounds on human health, aquatic life, wildlife plants, and livestock. C R C Crit. Rev. Environ. Control 12, 257–305. doi:10.1080/10643388209381698

DerSimonian, R., Kacker, R., 2007. Random-effects model for meta-analysis of clinical trials: An update. Contemp. Clin. Trials 28, 105–114. doi:10.1016/J.CCT.2006.04.004

DerSimonian, R., Laird, N., 1986. Meta-analysis in clinical trials. Control. Clin. Trials 7, 177–88.
*Dongre, N.N., Suryakar, A.N., Patil, A.J., Ambekar, J.G., Rathi, D.B., 2011. Biochemical effects of lead exposure on systolic & diastolic blood pressure, heme biosynthesis and hematological parameters in automobile workers of North Karnataka (India). Indian J. Clin. Biochem. 26, 400–6. doi:10.1007/s12291-011-0159-6
*Dongre, N.N., Suryakar, A.N., Patil, A.J., Hundekari, I.A., Devarnavadagi, B.B., 2013. Biochemical effects of lead exposure on battery manufacture workers with reference to blood pressure, calcium metabolism and bone mineral density. Indian J. Clin. Biochem. 28, 65–70. doi:10.1007/s12291-012-0241-8
Ericson, B., Caravanos, J., Depratt, C., Santos, C., Cabral, M.G., Fuller, R., Taylor, M.P., 2018a. Cost Effectiveness of Environmental Lead Risk Mitigation in Low-and Middle-Income Countries. GeoHealth 2, 87–101. doi:10.1002/2017GH000109
Ericson, B., Duong, T., Keith, J., Nguyen, T.C., Havens, D., Daniell, W., Karr, C.J., Ngoc Hai, D., Van Tung, L., Thi Nhi Ha, T., Wilson, B., Hanrahan, D., Croteau, G., Patrick Taylor, M., 2018b. Improving human health outcomes with a low-cost intervention to reduce exposures from lead acid battery recycling: Dong Mai, Vietnam. Environ. Res. 161. doi:10.1016/j.envres.2017.10.042
Ericson, B., Landrigan, P., Taylor, M.., Frostad, J., Caravanos, J., Keith, J., Fuller, R., 2016. The Global Burden of Lead Toxicity Attributable to Informal Used Lead-Acid Battery Sites. Ann. Glob. Heal. 82. doi:10.1016/j.aogh.2016.10.015
Ericson, B., Landrigan, P., Taylor, M.P., Frostad, J., Caravanos, J., Keith, J., Fuller, R., 2016. The Global Burden of Lead Toxicity Attributable to Informal Used Lead-Acid Battery (ULAB) Sites. Ann. Glob. Heal. In Print. doi:10.1016/J.AOGH.2016.10.009
Fewtrell, L., Kaufmann, R., Prüss-Üstün, A., 2003. Lead: Assessing the environmental burden of disease at national and local levels, WHO Environmental Burden of Disease Series, No. 2. World Health Organization.
Flegal, A.R., Schaule, B.K., Patterson, C.C., 1984. Stable isotopic ratios of lead in surface waters of the Central Pacific. Mar. Chem. 14, 281–287. doi:10.1016/0304-4203(84)90048-3
Forouzanfar, M., Murray, C.J., Afshin, A., 2016. GBD 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioral, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease S. Lancet 388, 1659–1724.
*Ghanwat, G., Patil, A., Patil, J.A., Kshirsagar, M.S., Sontakke, A., Ayachit, R.K., 2015. Biochemical effects of lead exposure on oxidative stress and antioxidant status of battery manufacturing workers of Western Maharashtra, India. J. Basic Clin. Physiol. Pharmacol. 27, 141–146. doi:10.1515/jbcpp-2015-0030
*Ghanwat, G., Patil, A., Patil, J., Kshirsagar, M., Sontakke, A., Ayachit, R.K., 2016. Effect of Vitamin C Supplementation on Blood Lead Level, Oxidative Stress and Antioxidant Status of Battery Manufacturing Workers of Western Maharashtra, India. J. Clin. Diagnostic Res. 10. doi:10.7860/JCDR/2016/15968.7528
Ghose, M.K., Paul, R., Banerjee, R.K., 2005. Assessment of the Status of Urban Air pollution And Its Impact on Human Health in the City of Kolkata. Environ. Monit. Assess. 108, 151–167. doi:10.1007/s10661-005-3965-6

Global Burden of Disease Collaborative Network, 2017. Global Burden of Disease Study 2016 (GBD 2016) Disability Weights. Seattle, United States.

*Goswami, K., 2013. Eye cosmetic “Surma”: Hidden threats of lead poisoning. Indian J. Clin. Biochem. 28, 71–73. doi:10.1007/s12291-012-0235-6

Grandjean, P., Bellanger, M., 2017. Calculation of the disease burden associated with environmental chemical exposures: application of toxicological information in health economic estimation. Environ. Heal. 16, 123. doi:10.1186/s12940-017-0340-3

Haefliger, P., Mathieu-Nolf, M., Lociciro, S., Ndiaye, C., Coly, M., Diouf, A., Faye, A.L., Sow, A., Tempowski, J., Pronczuk, J., Filipe Junior, A.P., Bertollini, R., Neira, M., 2009. Mass lead intoxication from informal used lead-acid battery recycling in dakar, senegal. Environ. Health Perspect. 117, 1535–40. doi:10.1289/ehp.0900696

Hedges, L. V, 1992. Meta-Analysis. J. Educ. Stat. Winter 17, 279–296.

IHME, 2017a. Global, regional, and national disability-adjusted life years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet 390, 1260–344.

IHME, 2017b. Global Burden of Disease Study 2016 (GBD 2016) Results [WWW Document]. URL http://ghdx.healthdata.org/gbd-results-tool (accessed 12.8.17).

India, C. of, 2011. Census of India 2011 Provisional Population Totals Urban Agglomerations and Cities.

International Lead Association, 2016. Lead Recycling [WWW Document]. ila-lead.org. URL http://www.ila-lead.org/lead-facts/lead-recycling (accessed 10.14.16).

Iyer, S., Sengupta, C., Velumani, A., 2015. Lead toxicity: An overview of prevalence in Indians. Clin. Chim. Acta 451, 161–164. doi:10.1016/j.cca.2015.09.023

*Jangid, A.P., John, P.J., Yadav, D., Mishra, S., Sharma, P., 2012. Impact of chronic lead exposure on selected biological markers. Indian J. Clin. Biochem. 27, 83–89. doi:10.1007/s12291-011-0163-x

Kabala, C., Singh, B.R., 2001. Fractionation and Mobility of Copper, Lead, and Zinc in Soil Profiles in the Vicinity of a Copper Smelter. J. Environ. Qual. 30, 485. doi:10.2134/jeq2001.302485x

*Kalahasthi, R.B., Barman, T., Rajmohan, H.R., 2014. The relationship between blood lead levels and morbidities among workers employed in a factory manufacturing lead-acid storage battery. Int. J. Environ. Health Res. 24, 246–55. doi:10.1080/09603123.2013.809702

*Kalra, V., Sahu, J.K., Bedi, P., Pandey, R.M., 2013. Blood lead levels among school children after phasing-out of leaded petrol in delhi, India. Indian J. Pediatr. 80, 636–640. doi:10.1007/s12098-013-0999-6

*Khan, M.I., Ahmad, I., Mahdi, A.A., Akhtar, M.J., Islam, N., Ashquin, M., Venkatesh, T., 2010. Elevated blood lead levels and cytogenetic markers in buccal epithelial cells of painters in India. Environ. Sci. Pollut. Res. 17, 1347–1354. doi:10.1007/s11356-010-0319-x

Landrigan, P.J., Goldman, L.R., 2011. Children’s Vulnerability To Toxic Chemicals: A Challenge And Opportunity To Strengthen Health And Environmental Policy. Health Aff. 30, 842–850. doi:10.1377/hlthaff.2011.0151

Lanphear, B.P., 2015. The Impact of Toxins on the Developing Brain. Annu. Rev. Public

Health 36, 211–230. doi:10.1146/annurev-publhealth-031912-114413
Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T., Rothenberg, S.J., Needleman, H.L., Schnaas, L., Wasserman, G., Graziano, J., Roberts, R., 2005. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. Environ. Health Perspect. 113, 894–9.
*Lokesh, S., 2016. Trace Elements in Chronic Haemodialysis Patients and Healthy Individuals-A Comparative Study. J. Clin. Diagnostic Res. 10, 10–13. doi:10.7860/JCDR/2016/22031.8618
Lovei, M., 1999. Eliminating a silent threat - World Bank support for the global phase-out of lead from gasoline.
Mantel, N., Haenszel, W., 1959. Statistical aspects of the analysis of data from retrospective studies of disease. J. Natl. Cancer Inst. 22, 719–48.
*Mazumdar, I., Goswami, K., 2014. Chronic exposure to lead: A cause of oxidative stress and altered liver function in plastic industry workers in Kolkata, India. Indian J. Clin. Biochem. 29, 89–92. doi:10.1007/s12291-013-0337-9
McConnell, J.R., Maselli, O.J., Sigl, M., Vallelonga, P., Neumann, T., Anschütz, H., Bales, R.C., Curran, M.A.J., Das, S.B., Edwards, R., Kipfstuhl, S., Layman, L., Thomas, E.R., 2015. Antarctic-wide array of high-resolution ice core records reveals pervasive lead pollution began in 1889 and persists today. Sci. Rep. 4, 5848. doi:10.1038/srep05848
Mielke, H.W., Zahran, S., 2012. The urban rise and fall of air lead (Pb) and the latent surge and retreat of societal violence. Environ. Int. 43, 48–55. doi:10.1016/j.envint.2012.03.005
Ministry of Environment and Forests (India), 2001. Batteries (Management and Handling) Rules, 2001.
*Mishra, K.P., Rani, R., Yadav, V.S., Naik, S., 2010. Effect of lead exposure on lymphocyte subsets and activation markers. Immunopharmacol. Immunotoxicol. 32, 446–449. doi:10.3109/08923970903503668
Mohan, V.R., Sharma, S., Ramanujam, K., Babji, S., Kang, G., Koshy, B., Bondu, J.D., John, S.M., 2014. Effects of elevated blood lead levels in preschool children in urban Vellore. Indian Pediatr. 51, 621–625.
National Library of Medicine (US), 1946. PubMed. Bethesda (MD).
National Toxicology Program, 2012. NTP Monograph Health Effects of Low-Level Lead. US Dep. Hum. Serv.
Needleman, H., 2004. Lead Poisoning. Annu. Rev. Med. 55, 209–222. doi:10.1146/annurev.med.55.091902.103653
Nichani, V., Li, W.-I., Smith, M.A., Noonan, G., Kulkarni, M., Kodavor, M., Naeher, L.P., 2006. Blood lead levels in children after phase-out of leaded gasoline in Bombay, India. Sci. Total Environ. 363, 95–106. doi:10.1016/j.scitotenv.2005.06.033
*Palaneeswari M, S., 2012. Blood Lead in End-Stage Renal Disease (ESRD) Patients who were on Maintainence Haemodialysis. J. Clin. Diagnostic Res. 1633–1635. doi:10.7860/JCDR/2012/4865.2627
Palaniappan, K., Roy, A., Balakrishnan, K., Krishnan, L., Mukherjee, B., Hu, H., Bellinger, D.C., 2011. Lead Exposure and Visual-Motor Abilities in Children from

Chennai, India. Neurotoxicology 76, 211–220. doi:10.1007/s11103-011-9767-z.Plastid

*Patel, A.B., Belsare, H., Banerjee, A., 2011. Feeding practices and blood lead levels in infants in Nagpur, India. Int. J. Occup. Environ. Health 17, 24–30. doi:10.1179/107735211799031040

Prajapati, S., 2016. Lead Acid Battery Recycling In India. IOSR J. Electr. Electron. Eng. Ver. I 11, 2278–1676. doi:10.9790/1676-111199101

*Pratinidhi, S.A., Patil, A.J., Behera, M., Patil, M., Ghadage, D.P., Pratinidhi, A.K., 2014. Effects of blood lead level on biochemical and hematological parameters in children with neurological diseases of Western Maharashtra, India. J. Basic Clin. Physiol. Pharmacol. 25, 229–233. doi:10.1515/jbcpp-2013-0062

Prüss-Üstün, A., Fewtrell, L., Landrigan, P.J., Ayuso-Mateos, J.L., 2010. Lead Exposure, in: Comparative Quantification of Health Risks. World Health Organization, Geneva.

Prüss-Ustün, A., Vickers, C., Haefliger, P., Bertollini, R., 2011. Knowns and unknowns on burden of disease due to chemicals: a systematic review. Environ. Heal. 10, 9. doi:10.1186/1476-069X-10-9

Pugazhenthy, L., 2017. Lead Battery & Recycling in India - Future Indicators. Banglaore.

*Ravibabu, K., Barman, T., Rajmohan, H., 2015. Serum Neuron-Specific Enolase, Biogenic Amino-Acids and Neurobehavioral Function in Lead-Exposed Workers from Lead-Acid Battery Manufacturing Process. Int. J. Occup. Environ. Med. 6, 436-50–7.

Raviraja, A., Vishal Babu, G.N., Sehgal, A., Saper, R.B., Jayawardene, I., Amarasiriwardena, C.J., Venkatesh, T., 2010. Three cases of lead toxicity associated with consumption of ayurvedic medicines. Indian J. Clin. Biochem. 25, 326–9. doi:10.1007/s12291-010-0051-9

*Reddy, S.Y., Pullakhandam, R., Radha Krishna, K. V., Uday Kumar, P., Dinesh Kumar, B., 2011. Lead and essential trace element levels in school children: A cross-sectional study. Ann. Hum. Biol. 38, 372–377. doi:10.3109/03014460.2010.536166

*Reddy, Y.S., Aparna, Y., Ramalaksmi, B.A., Dinesh Kumar, B., 2014. Lead and trace element levels in placenta, maternal and cord blood: A cross-sectional pilot study. J. Obstet. Gynaecol. Res. 40, 2184–2190. doi:10.1111/jog.12469

Roussel, H., Waterlot, C., Pelfrêne, A., Pruvot, C., Mazzuca, M., Douay, F., 2010. Cd, Pb and Zn Oral Bioaccessibility of Urban Soils Contaminated in the Past by Atmospheric Emissions from Two Lead and Zinc Smelters. Arch. Environ. Contam. Toxicol. 58, 945–954. doi:10.1007/s00244-009-9425-5

Roy, A., Bellinger, D., Hu, H., Schwartz, J., Ettinger, A.S., Wright, R.O., Bouchard, M., Palaniappan, K., Balakrishnan, K., 2009. Lead Exposure and Behavior among Young Children in Chennai, India. Environ. Health Perspect. 117, 1607–1611. doi:10.1289/ehp.0900625

*Roy, A., Ettinger, A.S., Hu, H., Bellinger, D., Schwartz, J., Modali, R., Wright, R.O., Palaniappan, K., Balakrishnan, K., 2013. Effect modification by transferrin C2 polymorphism on lead exposure, hemoglobin levels, and IQ. Neurotoxicology 38, 17–22. doi:10.1016/j.neuro.2013.05.005

Schneider, F., Buehn, A., Montenegro, C.E., 2010. New Estimates for the Shadow

Economies all over the World. Int. Econ. J. 24, 443–461. doi:10.1080/10168737.2010.525974

Schwartz, J., 1994. Low-Level Lead Exposure and Children′s IQ: A Metaanalysis and Search for a Threshold. Environ. Res. 65, 42–55. doi:10.1006/enrs.1994.1020

Schwikowski, M., Barbante, C., Doering, T., Gaeggeler, H.W., Boutron, C., Schotterer, U., Tobler, L., van de Velde, K., Ferrari, C., Cozzi, G., Rosman, K., Cescon, P., 2004. Post-17th-century changes of European lead emissions recorded in high-altitude alpine snow and ice. Environ. Sci. Technol. 38, 957–64.

Sharma, M., Maheshwari, M., Morisawa, S., 2005. Dietary and Inhalation Intake of Lead and Estimation of Blood Lead Levels in Adults and Children in Kanpur, India. Risk Anal. 25, 1573–1588. doi:10.1111/j.1539-6924.2005.00683.x

*Sharma, T., Banerjee, B.D., Yadav, C.S., Gupta, P., Sharma, S., 2014. Heavy metal levels in adolescent and maternal blood: association with risk of hypospadias. ISRN Pediatr. 2014, 714234. doi:10.1155/2014/714234

Shen, H., Peters, T.M., Casuccio, G.S., Lersch, T.L., West, R.R., Kumar, A., Kumar, N., Ault, A.P., 2016. Elevated Concentrations of Lead in Particulate Matter on the Neighborhood-Scale in Delhi, India As Determined by Single Particle Analysis. Environ. Sci. Technol. 50, 4961–4970. doi:10.1021/acs.est.5b06202

Shukla, P.R., Garg, A., Dholakia, H.H., 2015. Energy-emissions trends and policy landscape for India.

Singh, A., Sharma, R.K., Agrawal, M., Marshall, F.M., 2010. Risk assessment of heavy metal toxicity through contaminated vegetables from waste water irrigated area of Varanasi, India. Trop. Ecol. 51, 375–387. doi:10.1016/j.fct.2009.11.041

Singh, A.K., Singh, M., 2006. Lead decline in the Indian environment resulting from the petrol-lead phase-out programme. Sci. Total Environ. 368, 686–694. doi:10.1016/J.SCITOTENV.2006.04.013

*Singh, Z., Chadha, P., 2016. Assessment of DNA damage as an index of genetic toxicity in welding microenvironments among iron-based industries. Toxicol. Ind. Health 32, 1817–1824. doi:10.1177/0748233715590518

*Singh, Z., Chadha, P., Sharma, S., 2013. Evaluation of oxidative stress and genotoxicity in battery manufacturing workers occupationally exposed to lead. Toxicol. Int. 20, 95–100. doi:10.4103/0971-6580.111550

Singhal, K., 2016. Food Safety and Standards: The Maggi Episode. SSRN Electron. J. doi:10.2139/ssrn.2759772

Stafilov, T., Šajn, R., Pančevski, Z., Boev, B., Frontasyeva, M. V., Strelkova, L.P., 2010. Heavy metal contamination of topsoils around a lead and zinc smelter in the Republic of Macedonia. J. Hazard. Mater. 175, 896–914. doi:10.1016/j.jhazmat.2009.10.094

StataCorp. LP, 2017. Stata Statistical Software: Release 15.

Sterne, J.A.C., 2009. Meta-analysis in Stata : an updated collection from the Stata journal. Strata Press.

*Subrahmanyam, G., Pathapati, R.M., Ramalingam, K., India, S.A., Kantha, K., Soren, B., 2016. Arterial Stiffness and Trace Elements in Apparently Healthy PopulationA Cross-sectional Study. J. Clin. Diagnostic Res. 10, 10–13. doi:10.7860/JCDR/2016/21648.8548

Taylor, M.P., Forbes, M.K., Opeskin, B., Parr, N., Lanphear, B.P., 2016. The relationship

between atmospheric lead emissions and aggressive crime: an ecological study. Environ. Heal. 15, 23. doi:10.1186/s12940-016-0122-3
*Tiwari, A.K.M., Mahdi, A.A., Zahra, F., Sharma, S., Negi, M.P.S., 2012. Evaluation of low blood lead levels and its association with oxidative stress in pregnant anemic women: A comparative prospective study. Indian J. Clin. Biochem. 27, 246–252. doi:10.1007/s12291-012-0202-2
United Nations Environment Programme, C.B., 2010. Final review of scientific information on lead.
United Nations General Assembly, 1989. OHCHR | Convention on the Rights of the Child.
*Vani, K., Kurakula, M., Syed, R., Alharbi, K., 2012. Clinical relevance of vitamin C among lead-exposed infertile men. Genet. Test. Mol. Biomarkers 16, 1001–6. doi:10.1089/gtmb.2012.0027
Véron, A., Flament, P., Bertho, M.L., Alleman, L., Flegal, R., Hamelin, B., 1999. Isotopic evidence of pollutant lead sources in Northwestern France. Atmos. Environ. 33, 3377–3388. doi:10.1016/S1352-2310(98)00376-8
*Wani, A.L., Ahmad, A., Shadab, G.G.H.A., Usmani, J.A., 2017. Possible role of zinc in diminishing lead-related occupational stress—a zinc nutrition concern. Environ. Sci. Pollut. Res. 24, 8682–8691. doi:10.1007/s11356-017-8569-5
WHO, 2014. Global health estimates 2014 summary tables. Health Statistics and Information Systems Web site. Updated 2014. [WWW Document]. URL http://www.who.int/entity/healthinfo/global_burden_disease/GHE_DALY_2012_country.xls?ua=1 (accessed 10.10.16).
WHO, 2013. WHO methods and data sources for global burden of disease estimates 2000-2011. Glob. Heal. Estim. Tech. Pap. WHO/HIS/HSI/GHE/2013.4 81.
World Health Organization, 2016. WHO Metrics: Disability-Adjusted Life Year (DALY) [WWW Document]. URL http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/ (accessed 10.16.16).

Table 1. Mean values and relevant statistics of Indian blood lead levels by subgroup

Subgroup	Mean BLL (µg/dL)	LCI	UCI	CHI^2	p	I^2	TAU^2

Sex							
Female	4.31	3.41	5.22	413.71	0.000	98.1%	1.62
Male	26.85	23.66	30.04	27,432.60	0.000	99.9%	57.18
Both	11.35	9.27	13.43	3,081.37	0.000	99.4%	18.33
Unspecified	25.77	15.99	35.56	5,261.11	0.000	99.8%	295.75
Age							
Adult	21.44	19.65	23.23	50,073.40	0.000	99.9%	37.56
Child	8.41	5.92	10.9	7,645.60	0.000	99.8%	28.68
Urbanicity							
Urban	13.53	11.91	15.14	36,189.36	0.000	99.9%	29.78
Rural	8.367	3.46	13.26	26.64	0.000	96.2%	12.03
Both	13.69	9.77	17.61	6.67	0.010	85.0%	6.83
Unspecified	36.82	26.94	46.70	6,591.65	0.000	99.8%	351.17
Occupational							
Occupational	45.72	37.82	53.62	19,511.54	0.000	99.9%	341.93
Non-occupational	7.96	5.88	10.05	1.7e+05	0.000	100.0%	50.99

Table 2. DALYs from to cardiovascular disease attributable to lead exposure in Indian states in 2012

	Hyper Tension	Ischemic	Cerebrovascular	Other CVD	Total DALYs (CVD)
Pooled Mean (7.52 µg/dL)	93,082	1,146,922	1,199,438	286,028	2,725,470
LCI (5.28 µg/dL)	79,573	983,168	1,033,822	244,882	2,341,444
UCI (9.75 µg/dL)	103,241	1,269,450	1,322,146	316,886	3,011,723

Table 3. DALYs from to intellectual disability attributable to pediatric lead exposure in 9 Indian states in 2012

	Borderline	Mild	Moderate	Severe	Profound	Total DALYS (Intellectual Disability)
Pooled mean (8.41 µg/dL)	28,347	1,298,563	1,106,177	481,986	209,532	3,124,605
LCI (5.92 µg/dL)	22,847	1,046,636	891,574	388,479	168,882	2,518,419
UCI (10.9 µg/dL)	32,272	1,478,367	1,259,343	548,724	238,545	3,557,251

Table 4. Calculated DALYs (all sequalae) attributable to lead exposures in India in 2012

	Total DALYs (CVD)	Total DALYS (Intellectual Disability)	Total DALYs (all sequalae)
Pooled mean	2,725,470	3,124,605	5,850,075

LCI	2,341,444	2,518,419	4,859,863
UCI	3,011,723	3,557,251	6,568,974

Figure 1. Forest plot of all samples and studies used in the analysis.

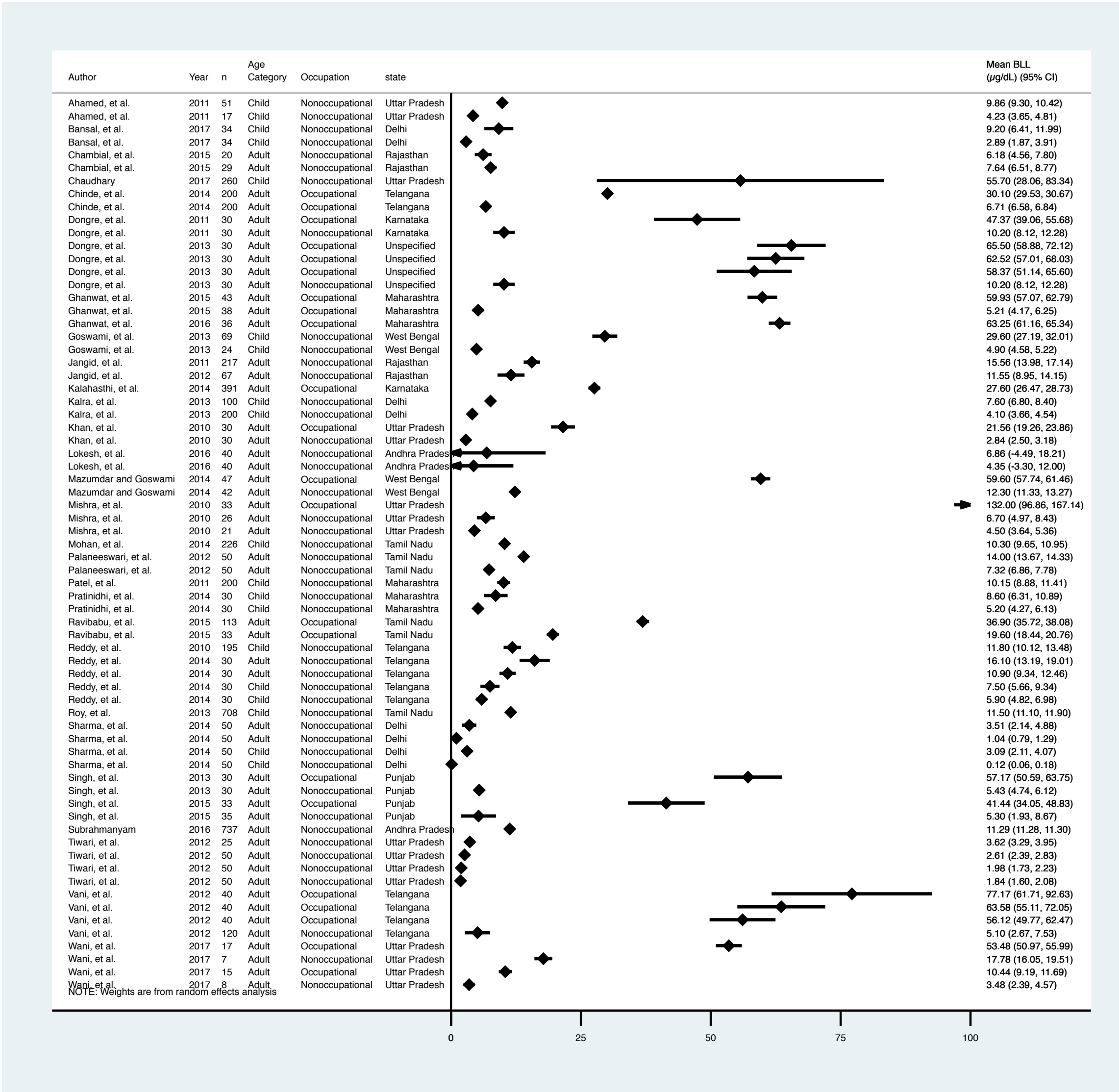


Figure 2. Forest plot of all samples of children used to calculate BLLs and attributable DALYs.

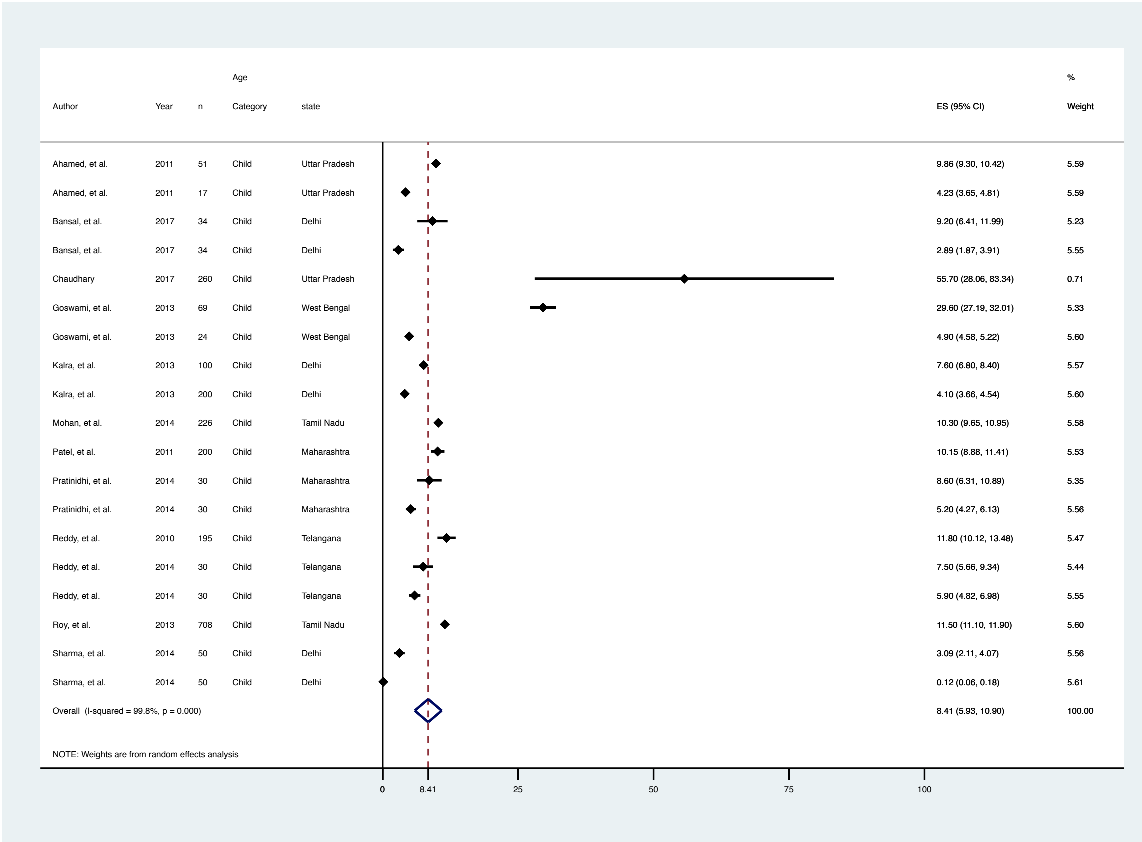
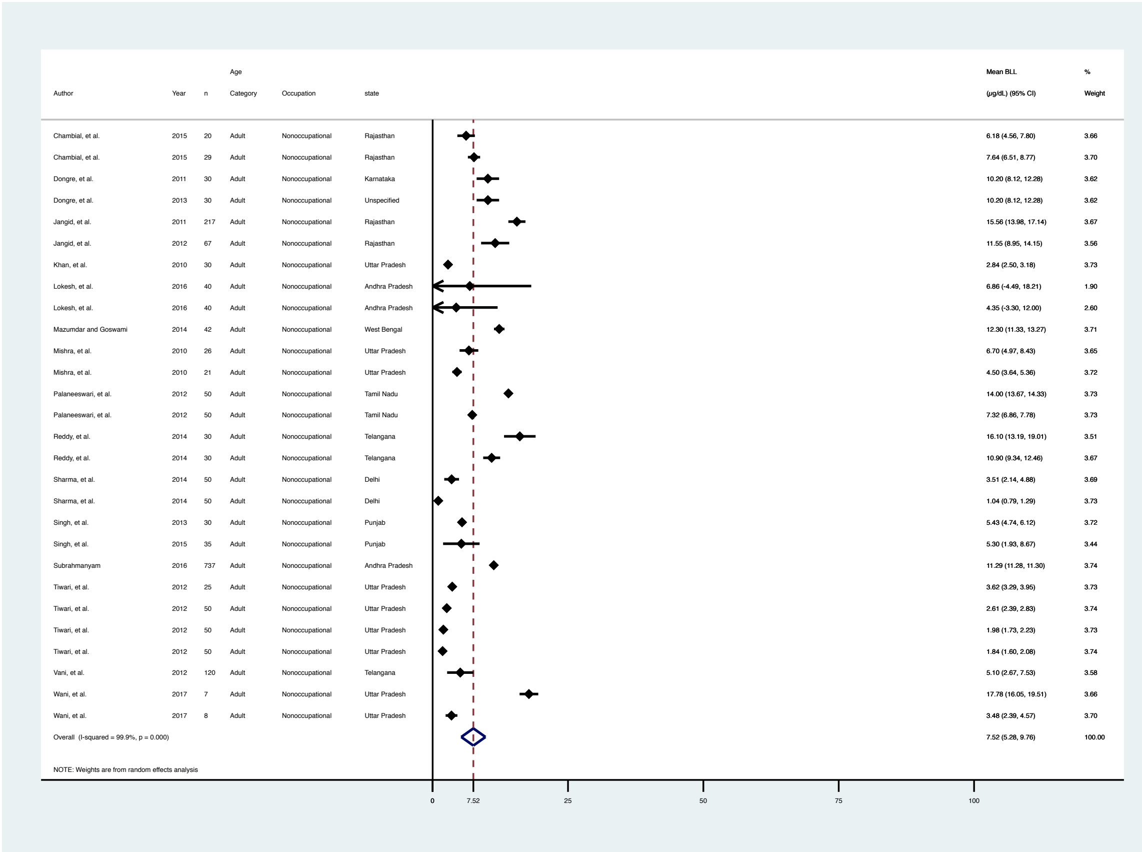


Figure 2. Forest plot of all samples non-occupationally exposed adults used to calculate BLLs and attributable DALYs.


Author Year n Age Category Occupation state Mean BLL (µg/dL) (95% CI) % Weight
Chambial, et al. 2015 20 Adult Nonoccupational Rajasthan 6.18 (4.56, 7.80) 3.66
Chambial, et al. 2015 29 Adult Nonoccupational Rajasthan 7.64 (6.51, 8.77) 3.70
Dongre, et al. 2011 30 Adult Nonoccupational Karnataka 10.20 (8.12, 12.28) 3.62
Dongre, et al. 2013 30 Adult Nonoccupational Unspecified 10.20 (8.12, 12.28) 3.62
Jangid, et al. 2011 217 Adult Nonoccupational Rajasthan 15.56 (13.98, 17.14) 3.67
Jangid, et al. 2012 67 Adult Nonoccupational Rajasthan 11.55 (8.95, 14.15) 3.56
Khan, et al. 2010 30 Adult Nonoccupational Uttar Pradesh 2.84 (2.50, 3.18) 3.73
Lokesh, et al. 2016 40 Adult Nonoccupational Andhra Pradesh 6.86 (-4.49, 18.21) 1.90
Lokesh, et al. 2016 40 Adult Nonoccupational Andhra Pradesh 4.35 (-3.30, 12.00) 2.60
Mazumdar and Goswami 2014 42 Adult Nonoccupational West Bengal 12.30 (11.33, 13.27) 3.71
Mishra, et al. 2010 26 Adult Nonoccupational Uttar Pradesh 6.70 (4.97, 8.43) 3.65
Mishra, et al. 2010 21 Adult Nonoccupational Uttar Pradesh 4.50 (3.64, 5.36) 3.72
Palaneeswari, et al. 2012 50 Adult Nonoccupational Tamil Nadu 14.00 (13.67, 14.33) 3.73
Palaneeswari, et al. 2012 50 Adult Nonoccupational Tamil Nadu 7.32 (6.86, 7.78) 3.73
Reddy, et al. 2014 30 Adult Nonoccupational Telangana 16.10 (13.19, 19.01) 3.51
Reddy, et al. 2014 30 Adult Nonoccupational Telangana 10.90 (9.34, 12.46) 3.67
Sharma, et al. 2014 50 Adult Nonoccupational Delhi 3.51 (2.14, 4.88) 3.69
Sharma, et al. 2014 50 Adult Nonoccupational Delhi 1.04 (0.79, 1.29) 3.73
Singh, et al. 2013 30 Adult Nonoccupational Punjab 5.43 (4.74, 6.12) 3.72
Singh, et al. 2015 35 Adult Nonoccupational Punjab 5.30 (1.93, 8.67) 3.44
Subrahmanyam 2016 737 Adult Nonoccupational Andhra Pradesh 11.29 (11.28, 11.30) 3.74
Tiwari, et al. 2012 25 Adult Nonoccupational Uttar Pradesh 3.62 (3.29, 3.95) 3.73
Tiwari, et al. 2012 50 Adult Nonoccupational Uttar Pradesh 2.61 (2.39, 2.83) 3.74
Tiwari, et al. 2012 50 Adult Nonoccupational Uttar Pradesh 1.98 (1.73, 2.23) 3.73
Tiwari, et al. 2012 50 Adult Nonoccupational Uttar Pradesh 1.84 (1.60, 2.08) 3.74
Vani, et al. 2012 120 Adult Nonoccupational Telangana 5.10 (2.67, 7.53) 3.58
Wani, et al. 2017 7 Adult Nonoccupational Uttar Pradesh 17.78 (16.05, 19.51) 3.66
Wani, et al. 2017 8 Adult Nonoccupational Uttar Pradesh 3.48 (2.39, 4.57) 3.70
Overall (I-squared = 99.9%, p = 0.000) 7.52 (5.28, 9.76) 100.00
NOTE: Weights are from random effects analysis
0
7.52
25
50
75
100

AGU PUBLICATIONS

GeoHealth

RESEARCH ARTICLE
10.1002/2017GH000109

Key Points:
- Pollution remediation in low- and middle-income countries has yet to be evaluated for its cost effectiveness
- We calculate DALYs averted by the lead remediation in Paraiso de Dios, Haina, the Dominican Republic completed in 2010
- Pollution remediation is cost effective according to WHO thresholds

Supporting Information:
- Supporting Information S1

Correspondence to:
B. Ericson,
bret.ericson@students.mq.edu.au

Citation:
Ericson, B., Caravanos, J., Depratt, C., Santos, C., Cabral, M. G., Fuller, R. & Taylor, M. P. (2018). Cost effectiveness of environmental lead risk mitigation in low- and middle-income countries. *GeoHealth*, *2*, 87–101. https://doi.org/10.1002/2017GH000109

Received 10 SEP 2017
Accepted 31 JAN 2018
Accepted article online 8 FEB 2018
Published online 22 FEB 2018
Corrected 19 JUN 2018

This article was corrected on 19 JUN 2018. See the end of the full text for details.

Cost Effectiveness of Environmental Lead Risk Mitigation in Low- and Middle-Income Countries

Bret Ericson[1,2,3], Jack Caravanos[3], Conrado Depratt[4], Cynthia Santos[5], Mishelle Gomez Cabral[6], Richard Fuller[1], and Mark Patrick Taylor[2,7]

[1]Pure Earth, New York, NY, USA, [2]Department of Environmental Sciences, Faculty of Science and Engineering, Macquarie University, Sydney, New South Wales, Australia, [3]College of Global Public Health, New York University, New York, NY, USA, [4]The Autonomous University of Santo Domingo, Santo Domingo, Dominican Republic, [5]Department of Emergency Medicine, Toxicology, Rutgers University Hospital, Newark, NJ, USA, [6]York College, City University of New York, Jamaica, NY, USA, [7]Energy and Environmental Contaminants Research Centre, Macquarie University, Sydney, New South Wales, Australia

Abstract Environmental remediation efforts in low- and middle-income countries have yet to be evaluated for their cost effectiveness. To address this gap we calculate a cost per Disability Adjusted Life Year (DALY) averted following the environmental remediation of the former lead smelter and adjoining residential areas in Paraiso de Dios, Haina, the Dominican Republic, executed from 2009 to 2010. The remediation had the effect of lowering surface soil lead concentrations to below 100 mg/kg and measured geometric mean blood lead levels (BLLs) from 20.6 μg/dL to 5.34 ug/dL. Because BLLs for the entire impacted population were not available, we use environmental data to calculate the resulting disease burden. We find that before the intervention 176 people were exposed to elevated environmental lead levels at Paraiso de Dios resulting in mean BLLs of 24.97 (95% CI: 24.45–25.5) in children (0–7 years old) and 13.98 μg/dL (95% CI: 13.03–15) in adults. We calculate that without the intervention these exposures would have resulted in 133 to 1,096 DALYs and that all of these were averted at a cost of USD 392 to 3,238, depending on assumptions made. We use a societal perspective, meaning that we include all costs regardless of by whom they were incurred and estimate costs in 2009 USD. Lead remediation in low- and middle-income countries is cost effective according to World Health Organization thresholds. Further research is required to compare the approach detailed here with other public health interventions.

Plain Language Summary We review the cost effectiveness of the remediation of a lead contaminated site in the Dominican Republic that posed a health risk to the surrounding community. We find that the project reduced a significant health burden for an acceptable cost according to thresholds established by the World Health Organization. Pollution poses a credible health risk to a large number of people; thus, it is important to identify cost effective methods of dealing with the worst sites.

1. Introduction

Cost effectiveness analysis is a potentially informative tool in the debate on resource allocation (Murray et al., 2000). In the case of public health interventions the Disability Adjusted Life Year (DALY) enables comparison between different health outcomes in terms of morbidity and mortality (Murray & Lopez, 2013). The DALY approach is a robust and globally accepted method used by the World Health Organization (WHO) and the Institute for Health Metrics Evaluation (IHME) for estimating the Global Burden of Disease (GBD) from an extensive list of health outcomes (Forouzanfar et al., 2016; World Health Organization (WHO), 2013). A DALY is the sum of two metrics: a year of life lost (YLL) and a year lost to disability (YLD). The former captures years lost due to premature death, while the latter captures the relative severity and duration of various adverse health outcomes (World Health Organization, 2016).

GBD estimates consider a multitude of risk factors and health outcomes. Several researchers, for example, have reviewed the DALY contribution of health risks such as smoking or urban air quality (Cohen et al., 2005; Zaher et al., 2004). Others, notably Prüss-Ustün et al. (2016, 2011) have calculated DALYs resulting from chemical exposures, including pesticides and naturally occurring arsenic in groundwater. An important gap in the literature, however, is the contribution of hazardous waste sites to the burden of disease, due in part to a lack of global information on their occurrence and related health risks.

Chatham-Stephens et al. (2013) examined this knowledge gap by utilizing data collected as part of Pure Earth's Toxic Sites Identification Program (TSIP). Pure Earth maintains a database of contaminated sites with estimates of exposed populations and the results of environmental sampling and analysis, among other parameters (Ericson et al., 2013). In reviewing TSIP data on hazardous waste sites in India, Indonesia, and the Philippines, the authors found that the burden of disease from toxic contaminant exposures in these countries was comparable to other significant environmental health risks, such as malaria (Chatham-Stephens et al., 2013).

In high-income countries, a number of studies have employed cost effectiveness analysis in evaluating pollution remediation projects. For example, Hamilton and Viscusi (1997) reviewed data from 150 Superfund sites in the USA to determine the cost per cancer averted. In the United Kingdom, a comparable effort evaluated the cost per life year gained from radon remediation efforts (Kennedy et al., 1999). In low- and middle-income countries (LMICs), a limited set of papers have reviewed health benefits of pollution remediation (Ericson et al., 2018; Jones et al., 2013; Ludlow & Roux, 2012; Tirima et al., 2016). However, evaluations of the cost effectiveness of these sorts of interventions in LMICs are, to the best of our knowledge, nonexistent.

This paper endeavors to begin to fill this gap by calculating the generalized cost effectiveness of remediating lead contaminated soil in the Dominican Republic community of Paraiso de Dios, Haina. The attributable disease burden from the site is modeled, and the cost effectiveness of the intervention is evaluated from a societal perspective. The purpose of this effort is to inform the discussion on resource allocation.

The source of contamination was a poorly managed secondary lead smelter that operated until the late 1990s, when high blood lead levels (BLLs) were documented in the surrounding community and the smelter was forced to close (Kaul et al., 1999; Kaul & Mukerjee, 1999; Wilson, 2002). Studies conducted before and after the closure found considerable decreases in the BLLs of area children. Mean BLLs declined from 72 μg/dL ($n = 116$) before the closure to 32 μg/dL ($n = 146$) 6 months after, indicating that the most significant exposures were associated with the smelter's operation (Kaul et al., 1999). The closure included a rudimentary repository for high-level material that failed shortly thereafter. Following the closure, the site was characterized by uncontrolled piles of battery waste and heavily lead-laden material.

The Haina soil lead intervention project, which was designed and overseen by TerraGraphics, Inc., was carried out in two distinct phases: the removal or capping of onsite contaminated soil in December 2009 and the mitigation of offsite exposures through soil removal and construction in August 2010 (Blacksmith Institute, 2010). Soil abatement has been shown to effectively mitigate exposures at lead contaminated sites (Ericson et al., 2018; Lanphear et al., 2003). Community education efforts were carried out in parallel. The site now serves as a city park.

A number of environmental assessments were carried out before and after the intervention. Hunter College and Pure Earth assessed concentrations of lead in surface soils and house dust in 2007. Samples were collected onsite and analyzed in New York, USA, using atomic absorption spectrometry (Caravanos, Fuller, & Nieves, 2007). This study reported median lead in soil concentrations of 55,420 mg/kg (IQR: 17,960–305,045) onsite and 11,225 mg/kg (IQR: 3,185–27,335) in residential yards based on 12 samples from each area (Caravanos et al., 2007). Median values were reported due to the log normal distribution of the data. Mean values for industrial and residential areas were 65,735 mg/kg (95%CI: 25,986–166,285) and 17,648 mg/kg (95%CI: 5436–29,859), respectively (Caravanos et al., 2007).

Caravanos et al. (2007) also collected dust samples in both Paraiso de Dios and, for the purpose of a control, the city center of Haina. The mean dust loadings inside of 13 sampled homes in Haina was 64.4 μg/ft^2 (95%CI: 32–97) and 9.7 μg/ft^2 (95%CI: 3.4–16.1) inside of 12 sampled homes in the city center. For context, the relevant U.S. Environmental Protection Agency (USEPA) reference levels for residential and industrial soils are 400 and 1,200 mg/kg, respectively (U.S. Environmental Protection Agency (USEPA), 1998). The relevant USEPA reference level for household dust is 40 μg/ft^2 (USEPA, 1998) (USEPA guidance is provided in US customary units. A square foot can be converted to a square meter by multiplying by 0.092903.). The Dominican Republic has not yet developed its own reference levels.

Pure Earth and TerraGraphics, Inc. collected 152 additional in situ surface soil lead measurements in 2010 between the onsite and offsite interventions. Analysis was conducted with a portable InnovX Delta series X-Ray fluorescence instrument (pXRF) with a lower detection limit for lead of 5 mg/kg (InnovX, 2016).

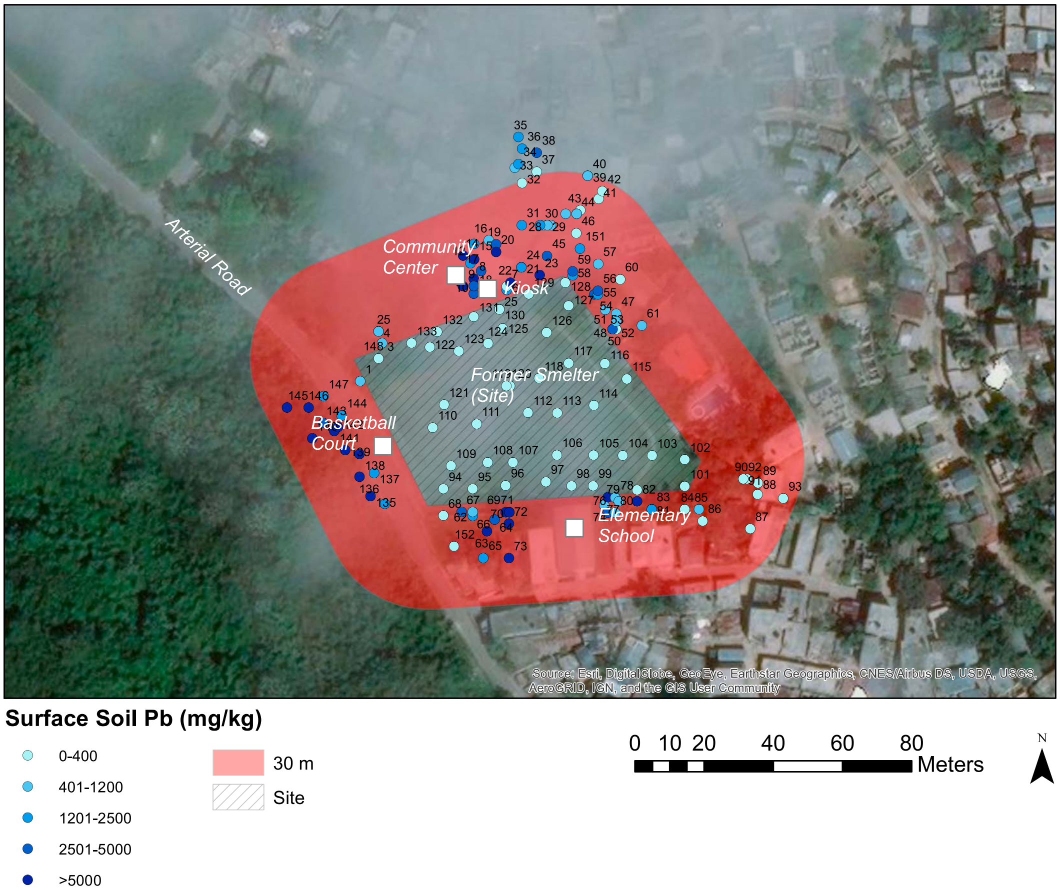


Figure 1. Overhead map of the former site of the MetaloXsa Smelter (Paraiso de Dios, Haina, Dominican Republic) and exposure scenarios used in this analysis. Soil lead concentrations displayed here were analyzed after the onsite remediation and before the offsite work.

Thirty-eight of the 152 measurements were taken from the former site having a mean lead concentration of 17 mg/kg (95%CI: 4–30), reflecting the effectiveness of the first phase of the intervention. One hundred and three measurements were taken within 30 m the site having a mean lead concentration of 4,410 mg/kg (95% CI: 3,175–5,645). These results are projected in Figure 1 and attached in the supporting information. Analysis of the comparability of in situ versus ex situ pXRF measurements using an Olympus InnovX Delta was carried out by Rouillon et al. (2017), who showed that in-field sampling was suitably robust (Rouillon et al., 2017).

2. Materials and Methods

2.1. Summary of Approach

To determine the cost per DALY averted as a result of the Haina intervention, we construct a number of models of the attributable disease burden. Key parameters of each model include: total exposed population; behavior of the population; soil lead content; soil ingestion rate; and lifetime of the project. The totals of all groups are summed to determine the total DALYs-averted.

2.2. Sources of Data for DALY Calculations

We utilize environmental data collected by TerraGraphics Inc., Pure Earth and Hunter College (Blacksmith Institute, 2010; Caravanos et al., 2007). Blood lead data are used to assess the effectiveness of the intervention and to guide the estimation of DALYs. Blood lead assessment in the population was undertaken by Pure Earth, the Autonomous University of Santo Domingo, and the Mount Sinai School of Medicine. Financial data are used to assess the overall cost effectiveness of the intervention and were acquired from a range of sources including government and multilateral websites, as detailed below. Where financial data could not be acquired, estimates are presented.

Table 1
Blood Lead Tests Stratified by Year and Age Group

Age range blood lead tested in years	9 May	10 May	10 Dec	14 Feb
0–6	20	9	6	8
7–10	25	14	14	21
11–15	16	17	14	22
>15	17	11	10	31
Not recorded	1	1	1	
Total	79	52	45	82

2.3. Blood Lead Assessment

Blood lead levels (BLLs) were assessed on three instances between 2009 and 2010 by Pure Earth and the Autonomous University of Santo Domingo (UASD). Community BLLs were again assessed by Pure Earth in 2014 with the Mount Sinai School of Medicine (New York, USA). Samples were extracted and analyzed by physicians in a manner consistent with Institutional Review Board ethical guidelines using Magellan Diagnostics LeadCare I (May 2009) and Leadcare II (May 2010, December 2010, and February 2014) analyzers. The LeadCare II instrument, which is used widely for lead screening, has lower and upper detection limits of 3.3 μg/dL and 65 μg/dL (Magellan Diagnostics, 2015). Its predecessor, the Leadcare I had a lower detection limit of 1.4 μg/dL and the same upper detection limit of 65 μg/dL (ESA Biosciences, 1997).

Blood samples were collected and analyzed for 79 residents in May 2009, 52 in May 2010, 45 in December 2010, and 82 in February 2014. Participant residential addresses were not collected. Age information was collected in 2009 and 2014 only and was derived from this information for 2010 sampling events. Ages could be deduced for all but one sampled resident in 2009 and both 2010 sampling events. Age distributions of sampled residents are given in Table 1.

Twenty-five residents had their blood analyzed in both 2009 and 2014. In 2009, 4 were aged 0–6 years, 11 were aged 7–10 years, 5 were aged 11–14 years, and 5 were aged 15 years and above. The median age in 2009 was 10, while the median age in 2014 was 15.

2.4. Blood Lead Modeling

Blood lead data for the impacted population were required to calculate the attributable disease burden. However, because BLLs were only available for a subset of the population, we calculate BLLs using the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) and Adult Lead Methodology (ALM) (US EPA, OSWER, 2016). We model exposure scenarios for eight different groups of people. For all groups we determined the age and sex of the exposed population by applying unpublished national level age and sex distribution information from the latest IHME GBD study (Forouzanfar et al., 2016). The IHME GBD tables provide estimates of the relative percentage of the population across 20 different age groups and two sex categories, with more granularity at younger ages than could be identified elsewhere. The tables present estimates for five age groups under 10 years in comparison with two presented by the Dominican national census or the U.S. Census for foreign populations, for instance (National Statistics Office, 2012; US Census Bureau, 2016). All reviewed data included only one age group for ages 5–9 years. Because ages 5–7 years are of particular importance to this study, we estimated the number of 5–7 year olds by multiplying the 5–9 year old population by 0.6. We assume that the demographic composition of the site is identical to the national composition.

The relative severity and duration of each group's exposure is determined by their use of three distinct distal areas: the site, the site perimeter (defined as within 30 m from the border of the site), and offsite (defined as any area beyond the 30 m perimeter). For each distal area we assign uniform soil and dust lead concentrations. With regard to soil contamination in the onsite area, we use the median surface soil concentration from Caravanos et al. (2007) of 55,240 mg/kg. The small sample size and high variability of concentrations indicate that the mean (65,735 mg/kg) would not likely be an appropriate metric. For the perimeter we use the mean soil concentration of 4,410 mg/kg from the 103 measurements taken during 2010 Pure Earth/ TerraGraphics, Inc. assessment.

There is a dearth of available data on soil lead concentrations in Haina or the Dominican Republic more broadly beyond the site. Thus, to estimate a soil concentration offsite, we use house dust loadings from Caravanos et al. (2007) and convert these values to likely soil lead concentrations using the default IEUBK soil-to-dust coefficient of 0.7 finding a mean concentration of 323 mg/kg (OSWER, 1994). This value is similar to average soil lead concentrations in a number of cities globally (Ajmone-Marsan & Biasioli, 2010).

To calculate dust concentrations onsite we use the default IEUBK soil-to-dust coefficient of 0.7 finding a median concentration of 38,794 μg/g (OSWER, 1994). To determine the dust lead concentrations in homes in the perimeter, we adjust default IEUBK values downward to more accurately represent likely exposures.

Table 2
Number of Receptors, Relevant Soil Concentrations (Pb) and Durations of Exposure at Paraiso de Dios Before the Intervention

Group	Composition	Pop.	Hours onsite/week (work or play)	Hours in perimeter/week (home or school)	Hours offsite/week (work or other)	Time-weighted dust (μg/g)	Time-weighted soil (mg/kg)
			(soil = 55,420 mg/kg; dust = 38,794 μg/g)	(soil = 4,410 mg/kg; dust = 780 μg/g)	(soil = 323 mg/kg; dust = 226 μg/g)		
1	Children age 5–7 years living in perimeter	13	10	102	0	4,174	8,964
2	Children age 0–4 years living in perimeter	8	0	84	0	780	4,410
3	Children age 5–7 living offsite, attending school in perimeter	52	10	30	72	3,818	6,337
4	Children 0–7 living and attending school offsite (control)	74	0	0	112	226	323
5	Adults age > 14 years living in perimeter, working onsite	10	10	72	30	4,026	7,869
6	Adults age > 14 years living in perimeter and working offsite	83	0	72	40	582	2,950
7	Adults age > 14 years living offsite, working onsite	10	10	0	102	3,670	5,242
8	Adults age > 14 years living and working offsite (control)	103	0	0	112	226	323

Caravanos et al. (2007) analyzed 36 dust wipes collected from 13 homes within 30 m of the site and 12 collected from a control area. Wipes from within 30 m had mean lead loadings of 64.3 μg/ft^2 compared with 9.7 μg/ft^2 in the control area. The IEUBK utilizes dust lead concentrations rather than loadings. While noting that conversions between the two are prone to significant error, we nevertheless utilize the equation set out by the USEPA Office of Pollution Prevention and Toxics (2010) and provided below (OSWER, 2003):

$$\text{dust lead concentration}, \mu g/g = 50.96 \times \left(\text{dust lead loading}, \mu g/ft^2\right)^{0.6553}$$

Using this method we calculate a mean dust concentration of 780 μg/g for structures in the perimeter and 226 μg/g for structures offsite. Leaving the IEUBK dust conversions intact, we calculate 3,087 μg/g for the perimeter. Thus, our use of the Caravanos et al. (2007) values is conservative.

To determine the use of each distal area (site, perimeter, and offsite), we make a number of assumptions based on observations before and during the intervention. Where possible we complement these observations with information derived from census data and satellite imagery. Based on the use of each distal area, we time-weight soil concentrations as set out in the relevant IEUBK guidance material (OSWER, 2003). The usage patterns of our eight different exposed groups are given in Table 2. Two of the eight groups are used as controls, as they do not have regular contact with the site. Major assumptions underpinning the other usage patterns are as follows:

1. An elementary school in the perimeter has 150 pupils aged 5–13 years. We assume 60 of these pupils are aged 5–7 years, with all children in this age group living in the perimeter attending school here and the balance living offsite;
2. All children aged 5–7 years living in the perimeter or attending the school play 2 h/d onsite;
3. Twenty scavengers (adults >14 years old) access the site for 10 h each week. Ten live in the perimeter and 10 live offsite;
4. The perimeter has 133 residents. We use satellite imagery to count the households in this area and assume 2.5 to 4 residents per household based on census data, resulting in 102 to 164 residents. We take the average (133) as the population. (National Statistics Office, 2012).

2.5. Calculating Blood Lead Levels

To calculate BLLs for the exposure groups, the USEPA IEUBK and ALM were used. Both models were developed by the USEPA for the American context, and thus rely on default parameters that may not accurately reflect exposure scenarios in informal settlements in the Dominican Republic. One such parameter, ingestion rates, was evaluated here. Some studies, notably Sun and Meinhold (1997) and Harris and Harper (2004), have found higher rates of soil ingestion in LMICs and traditional societies resulting from comparatively dustier conditions than those in high-income countries. The IEUBK default intake values for soil ingestion are 85–135 mg/d, depending on age. By contrast Sun and Meinhold (1997) suggest a value of 500 mg/d, while Harris and Harper (2004) use 400 mg/d. Two recent studies also find large variances in daily soil intake rates. In the American state of Idaho, von Lindern et al. (2016) evaluated the relationship between historical BLL data and bioavailable lead in household and yard dust near a former lead mining and smelting complex, finding intake rates below 100 mg/d for children (<8 years old). Conversely, Kwong et al. (2017) observed the soil ingestion habits of a cohort of Bangladeshi children (<4 years old), finding intake rates from nearly 300 mg/d to 550 mg/d.

To determine which ingestion rate best reflect the study site conditions, we conduct three different batch runs in the IEUBK adjusting the soil ingestion inputs to low, medium, and high values. We then compare the results with the 2009 preintervention BLLs. We use the IEUBK default values of 85–135 mg/d as the low value and 400 mg/d as the high. We then proportionately scale back from this value to a range of 250–400 mg/d. Our medium value is the average of these two, 168–267 mg/d. We leave all other default IEUBK parameters intact. We then conduct three paired *t* tests of actual and predicted BLLs for groups 1 and 2 using Stata 15 and find that the default ingestion rates are the best fit (StataCorp. LP, 2017). We therefore use only these values (85–135) for our DALY calculations.

For adults, we adjust the ALM default soil ingestion values to reflect low, medium, and high rates and adjust exposure frequency to 365 days from 219 to account for residential, rather than occupational exposure. We use the default 50 mg/d as the low intake value, 72.5 mg/d as the medium, and 200 mg/d as the high. The latter two values are set out in the guidance material for reasonable medium and maximum exposure scenarios for occupational settings (OSWER, 2003). The ALM provides a single-point estimate for the geometric mean BLL of an adult worker. We take the low, medium, and high estimates for groups 5 and 6 and compare them to the actual geometric BLLs for adults >14 years old, finding the medium ingestion rate (72.5 mg/d) to be the best fit. We therefore use this value in our DALY calculations. The ALM is not intended for use in residential settings as IEUBK results are meant to determine remediation goals. The ALM is used here as no other comparable method for estimating adult BLLs is known.

2.6. Calculating DALYs

We calculate attributable DALYs from cardiovascular disease and intellectual disability resulting from lead exposure based on values for the year 2013. We do so in a manner consistent with current WHO and IHME approaches and described in WHO (2013).

2.6.1. Cardiovascular Disease

To calculate DALYs from cardiovascular disease (CVD) we utilize a prevalence rate calculator developed by WHO for determining the attributable fraction of CVD due to lead exposure (Fewtrell, Kaufmann, & Prüss-Üstün, 2003). The geometric mean BLL for adults in each group is used to determine the attributable fraction for ischemic, cerebrovascular, hypertensive, and other heart diseases. We then scale the most recent WHO DALY (2013) values for cardiovascular disease in the Dominican Republic to the population in each exposure scenario and apply the attributable fraction to the scaled value (WHO, 2014). The national prevalence of CVD is assumed to be representative of the site and is not calibrated upward to account for possible increases due to lead exposure. We use the most recent WHO DALY values (WHO, 2013) for the Dominican Republic because contemporaneous DALY calculations were done in a method that is no longer utilized. Thus, we assume that the 2013 values are representative of 2009 DALYs.

2.6.2. Intellectual Disability

We use the WHO prevalence rate calculator referred to above and input the geometric mean BLL for exposed children to calculate the prevalence of mild mental retardation (MMR) in children 7 years of age and younger. We assume that mild intellectual disability is analogous to MMR and extrapolate from this value to determine prevalence of borderline, severe and profound intellectual disability. To guide this extrapolation we use values provided by the WHO for the relative prevalence of each sequelae (WHO, 2013). YLD is then calculated with the straightforward multiplicative method below.

$$\mathbf{YLD_i} = \mathbf{DW_i} \times \boldsymbol{P_i},$$

where p = prevalence and DW = disability weight, adapted from WHO (2013).

We use the following WHO disability weights for each gradient of intellectual disability: borderline (0.0034), mild (0.1270), moderate (0.2930), severe (0.3830), and profound (0.4440) (WHO, 2013). We do not attempt to calculate YLL for children.

The WHO prevalence rate calculator utilizes values from Schwartz's (1994) meta-analysis of IQ decrement, which found a 2.6 reduction in IQ for a BLL increase from 10 to 20 μg/dL (Fewtrell et al., 2004). More recent meta-analyses have found higher levels of IQ decrement with a reduction of more than seven IQ points in this range (Budtz-Jørgensen et al., 2013; Lanphear et al., 2005). Thus, in addition to using the default Schwartz (1994) values, we also calculate DALYs from Intellectual Disability using values derived from the log-linear model presented in Budtz-Jørgensen et al. (2013).

2.6.3. Uncertainty

In addition to our best estimate, we calculate DALYs using the lower and upper confidence intervals for each groups BLLs in an approach outlined by WHO (Fewtrell et al., 2003). We also provide estimates of undiscounted DALYs, following Edejer et al. (2003). A more robust statistical analysis might model uncertainty using Monte Carlo analysis. As we do not attempt such an analysis, our results should be considered indications rather than uncertainty values, as such (Fewtrell et al., 2003).

2.7. Lifespan of Project Location

The project involved two major engineering controls to mitigate exposures. The first was the excavation and removal of ~3,000 m^3 of high-level waste and the in situ encapsulation of ~2,500 m^3 of contaminated soil under a cap with a minimum depth of 0.6–1.0 m. The second was the encapsulation of contaminated soil with the construction of a graded and reinforced concrete road. The failure of engineered repositories such as the one at this site is rare. Similar, albeit much larger, repositories around the city of Kellogg, Idaho (USA), for instance, are expected to last at least hundreds of years (EPA Region 10, 2016). Lead is highly immobile in the environment, requiring significant time (~700 years) to meaningfully migrate between horizons (Kabala & Singh, 2001; Semlali et al., 2004). Therefore, we assume that the risk of remobilization of the material is low and place a likely lifespan on the project of 35 years. In addition we model a conservative estimate of 20 years and an optimistic lifespan of 50 years.

2.8. Costs

We use a societal perspective, meaning that we incorporate all costs regardless of by whom they were incurred (Sanders et al., 2016). We reference all costs to 2009, the year the project was initiated. We estimate that the mitigation measures implemented at the site incurred a total cost of USD 430,684. The Ministry of Environment's (MoE's) financial statements and relevant detailed expense reports for FY 2009 are not accessible on the Internet and were not shared with coimplementers. However, an end of financial year report of MoE 2009 budget by program states that 8.9 million Dominican Pesos were allocated to the Remediation of Lead Contaminated Areas in Paraiso de Dios, Haina (Proyecto Presupuesto de Ingresos y Ley de Gastos Publicos 2009, 2009). We convert this amount to USD 247,222 using an exchange rate of 36.0000083198 from 1 December 2009 USD, the approximate date the project began (XE Currency Table: DOP—Dominican Peso, 2017). We assume that this amount covered all costs associated with the onsite phase of the project, including disposal. The Inter American Development Bank project allocated USD 85,000 to this component and Pure Earth reported USD 71,612 in cofinancing expenses, mostly related to project coordination among executing agencies.

TerraGraphics contributed significant in-kind costs to the design and management of the onsite intervention. We do not have access to their final accounting, but a budget in the original project proposal for both onsite and offsite work estimated USD 41,447 for all project design and oversight. We deduct the amount for offsite work paid by the Inter American Development Bank and estimate an in-kind expenditure of USD 26,850. Finally, we account for an outlay of USD 1,000 per year for operation and maintenance (O&M) and discount costs in future years by 3% (Department of Environmental Protection, 2014). Table 3 presents the costs incurred by each party.

Table 3
Costing for Environmental Intervention at Paraiso de Dios by Funding Agency (USD)

Funding source	Amount (USD)	Source of data
Ministry of Environment and Natural Resources	247,222	Relevant line item Ministry of Environment FY 2009 Budget
Inter-American Development Bank	85,000	Inter-American Development Bank project document
Pure Earth	71,612	Cofinancing letter submitted to IADB
TerraGraphics, Inc. (in kind)	26,850	Proposal budget
Operation and maintenance	1,000/year (Discounted 3%/yr)	
Total	430,684 (not including O&M)	

2.9. Calculating Cost Effectiveness Ratio

To calculate the cost effectiveness ratio (cost per DALY averted) we divide the total cost of the intervention plus the discounted O&M costs by the total DALYs averted.

We assume zero morbidity attributable to the site following the intervention. We further assume that this lack of attributable morbidity remains zero during the entire lifespan of all three scenarios (20, 35, and 50 years). The exposures at the site were the result of legacy contamination rather than ongoing emissions. The engineering controls implemented removed these exposures entirely. Thus, while lifelong disability and socioeconomic effects are likely, they would be the result of exposures from before the intervention and would thus be attributable to that time period (Reuben et al., 2017). Therefore, any attributable morbidity after the intervention would be due to a curtailed lifespan of the repository.

To determine the number of DALYs averted, we calculate the number of DALYs attributable to site and subtract those attributable to lead exposures not related to the site. To calculate the latter value we use background levels identified by Caravanos et al. (2007).

In our counterfactual scenario, the total number of DALYs is the annual amount existing preintervention (2009) multiplied by the total years in each modeled lifespan. We discount future attributable DALYs by 3% to account for societal preference for benefits in the present time (Edejer et al., 2003). That is, we assume a value of 1 for each DALY averted in the first year after the project (2010), while we assume a discounted value for subsequent DALYs averted as a result of the project. Therefore, one DALY in 2010 receives a value of 1, while a DALY in 2030 receives a value of 0.553 and a value of 0.228 in 2060.

We do not discount remediation costs, as all expenses were incurred in the first year. As noted above, we discount operation and maintenance costs at a rate of 3% year. Finally, we follow Edejer et al. (2003) and calculate undiscounted DALYs as well.

3. Results

Using our model, we find that before the intervention 176 people were exposed to elevated environmental lead levels at Paraiso de Dios resulting in mean BLLs of 24.97 (95% CI: 24.45–25.5) in children (0–7 years old) and 13.98 μg/dL (95%CI: 13.03–15) in adults. Measurements taken in the field in 2009 found geometric mean BLLs of 21.3 μg/dL (95% CI: 16.2–28) for children and 21.44 (95% CI: 14.59–31.49) for adults. Using the default values, from Schwartz (1994), for IQ decrement we calculate that without the intervention these exposures would have resulted in 133 to 444 DALYs, depending on the lifespan of the project. Using the revised values for IQ decrement, from Budtz-Jørgensen et al. (2013), we calculate 327 to 1096 DALYs attributable to the site. In all cases children accounted for the vast majority of DALYs (>95%).

With regard to cost effectiveness, using default IQ decrement values we find that one DALY was averted for USD 968 to 3,328, depending on lifespan of the project and discount rate. Using the revised values for IQ decrement, we find a cost per DALY averted of USD 392 to 1,317. Table 4 presents the main results using the default IQ decrement values, while Table 5 presents the main results using the revised values.

Using WHO cost effectiveness criteria, the Haina intervention was very cost effective (Edejer et al., 2003). Notably, this means only that the cost per DALY averted is less than the national annual gross domestic product (GDP) per capita of the Dominican Republic. In 2009, the Dominican GDP per capita was USD 5,099 (in 2010 USD), thus this threshold was easily met (World Bank, 2017).

10.1002/2017GH000109

Table 4
Estimation of DALYs at Paraiso de Dios Organized by Exposure Scenario With Default Values for IQ Decrement (95% CI)

					DALYs averted, discounted 3%			DALYs averted, not discounted		
Population		Soil Pb (mg/kg)	Dust Pb (μg/g)	BLL μg/dL	20 years	35 years	50 years	20 years	35 years	50 years
Attributable to exposures from the site										
Group 1	13	8,964	4,174	28.94 (28.25–29.64)	24.23 (24.08–24.37)	34.98 (34.76–35.17)	41.87 (41.62–42.11)	32.51 (32.31–32.69)	56.89 (56.55–57.22)	81.28 (80.78–81.74)
Group 2	8	4,409	780	20.59 (19.93–21.25)	11.26 (11.09–11.42)	16.25 (16–16.49)	19.45 (19.16–19.74)	15.1 (14.87–15.32)	26.43 (26.03–26.82)	37.76 (37.19–38.31)
Group 3	52	6,337	3,818	24.79 (24.16–25.42)	92.56 (91.76–93.29)	133.6 (132.45–134.65)	159.94 (158.56–161.2)	124.18 (123.11–125.16)	217.32 (215.45–219.03)	310.46 (307.79–312.9)
Group 5	10	7,869	4,026	28.88 (27.58–30.19)	0.66 (0.65–0.66)	0.95 (0.93–0.96)	1.13 (1.12–1.15)	0.88 (0.87–0.89)	1.54 (1.52–1.56)	2.2 (2.17–2.23)
Group 6	83	2,950	582	11.77 (11.24–12.29)	3.36 (3.22–3.48)	4.84 (4.65–5.03)	5.8 (5.57–6.02)	4.5 (4.32–4.67)	7.88 (7.57–8.18)	11.25 (10.81–11.69)
Group 7	10	5,242	3,670	19.74 (18.44–21.04)	0.57 (0.55–0.59)	0.83 (0.8–0.86)	0.99 (0.96–1.02)	0.77 (0.74–0.79)	1.35 (1.3–1.39)	1.93 (1.86–1.99)
			Subtotal (site)		132.63 (131.35–133.82)	191.44 (189.6–193.15)	229.19 (226.98–231.24)	177.95 (176.24–179.54)	311.42 (308.41–314.19)	444.88 (440.59–448.85)
Attributable to background exposures										
Group 4	74	323	226	3.48 (3.3–3.65)	0 (0–0.01)	0 (0–0.02)	0 (0–0.02)	0 (0–0.01)	0 (0–0.03)	0.01 (0–0.04)
Group 8	103	323	226	2.62 (2.17–3.08)	0.4 (0.26–0.58)	0.58 (0.37–0.83)	0.7 (0.44–1)	0.54 (0.34–0.77)	0.95 (0.6–1.36)	1.36 (0.86–1.94)
			Subtotal (offsite)		0.41 (0.26–0.59)	0.59 (0.37–0.85)	0.7 (0.44–1.02)	0.55 (0.34–0.79)	0.95 (0.6–1.38)	1.36 (0.86–1.97)
			Total DALYs averted		132.23 (131.1–133.23)	190.86 (189.23–192.3)	228.49 (226.54–230.22)	177.41 (175.89–178.75)	310.46 (307.81–312.81)	443.52 (439.73–446.87)

Table 5
Estimation of DALYs at Paraiso de Dios Organized by Exposure Scenario With Revised Values for IQ Decrement (95% CI)

					DALYs averted, discounted 3%			DALYs averted, not discounted		
Population		Soil Pb (mg/kg)	Dust Pb (μg/g)	BLL μg/dL	20 years	35 years	50 years	20 years	35 years	50 years
Attributable to exposures from the site										
Group 1	13	8,964	4174	28.94 (28.25–29.64)	60.94 (60.61–61.24)	87.96 (87.48–88.4)	105.3 (104.73–105.83)	81.76 (81.32–82.17)	143.08 (142.3–143.8)	204.4 (203.29–205.43)
Group 2	8	4,409	780	20.59 (19.93–21.25)	29.51 (29.13–29.88)	42.6 (42.05–43.12)	51 (50.34–51.63)	39.6 (39.09–40.08)	69.3 (68.4–70.15)	99 (97.72–100.21)
Group 3	52	6,337	3818	24.79 (24.16–25.42)	232.19 (230.4–233.83)	335.14 (332.56–337.51)	401.22 (398.13–404.06)	311.52 (309.12–313.73)	545.16 (540.96–549.02)	778.8 (772.8–784.32)
Group 5	10	7,869	4026	28.88 (27.58–30.19)	0.66 (0.65–0.66)	0.95 (0.93–0.96)	1.13 (1.12–1.15)	0.88 (0.87–0.89)	1.54 (1.52–1.56)	2.2 (2.17–2.23)
Group 6	83	2,950	582	11.77 (11.24–12.29)	3.36 (3.22–3.48)	4.84 (4.65–5.03)	5.8 (5.57–6.02)	4.5 (4.32–4.67)	7.88 (7.57–8.18)	11.25 (10.81–11.69)
Group 7	10	5,242	3670	19.74 (18.44–21.04)	0.57 (0.55–0.59)	0.83 (0.8–0.86)	0.99 (0.96–1.02)	0.77 (0.74–0.79)	1.35 (1.3–1.39)	1.93 (1.86–1.99)
		Subtotal (site)			327.22 (324.56–329.69)	472.31 (468.47–475.88)	565.44 (560.85–569.71)	439.03 (435.46–442.34)	768.3 (762.05–774.1)	1097.57 (1088.65–1105.86)
Attributable to background exposures										
Group 4	74	323	226	3.48 (3.3–3.65)	0.01 (0–0.06)	0.01 (0–0.08)	0.01 (0–0.1)	0.01 (0–0.08)	0.02 (0–0.13)	0.03 (0–0.19)
Group 8	103	323	226	2.62 (2.17–3.08)	0.4 (0.26–0.58)	0.58 (0.37–0.83)	0.7 (0.44–1)	0.54 (0.34–0.77)	0.95 (0.6–1.36)	1.36 (0.86–1.94)
		Subtotal (offsite)			0.41 (0.26–0.63)	0.6 (0.37–0.92)	0.71 (0.44–1.1)	0.55 (0.34–0.85)	0.97 (0.6–1.49)	1.38 (0.86–2.13)
		Total DALYs averted			326.81 (324.3–329.06)	471.72 (468.11–474.96)	564.73 (560.4–568.62)	438.48 (435.12–441.49)	767.33 (761.45–772.61)	1096.19 (1087.79–1103.73)

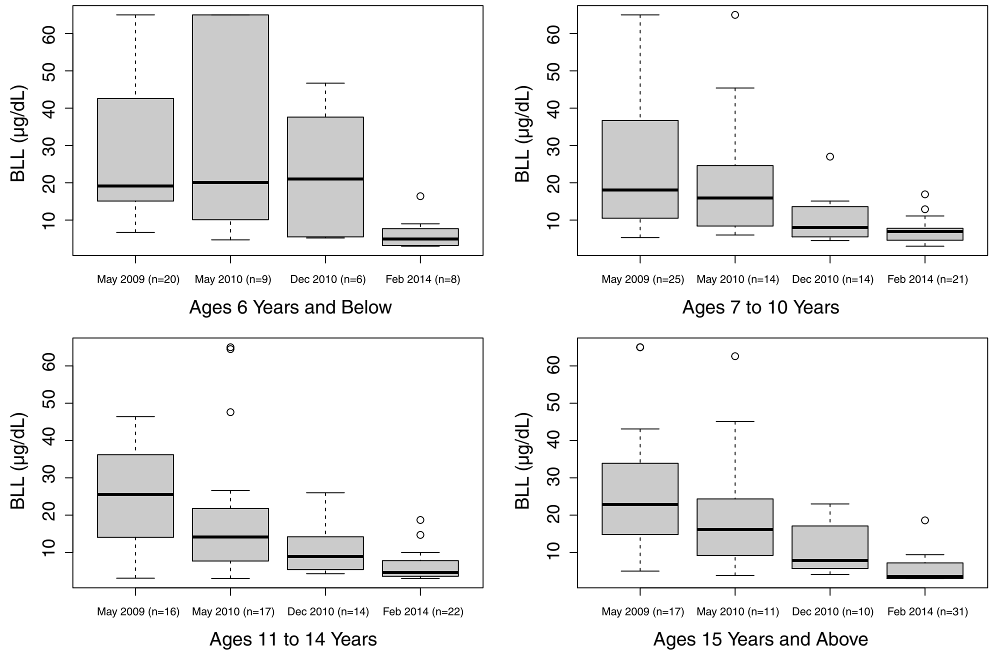


Figure 2. Blood lead level analysis results (median, IQR, and outliers) from 2009 to 2014 stratified according to age group.

Analyzed BLLs for all sampled residents decreased from a geometric mean of 20.6 µg/dL (95% CI: 17.5–24.3; GSD = 2.08) in May 2009 to 5.34 µg/dL (95% CI: 4.8–6; GSD = 1.67) in February 2014. In an unpaired *t* test the decrease was statistically significant ($p < 0.05$). Median and IQR values for BLLs are presented in Figure 2 stratified by age group. Twenty-five residents were tested in both 2009 and 2014. Over this period, the BLLs of these residents declined from a geometric mean of 22 µg/dL (95% CI: 15.8–30.7; GSD = 2.23) to 5.7 (95% CI: 4.4–7.3; GSD = 1.84). In a paired *t* test the decrease was statistically significant ($p < 0.05$) Figure 3.

Arithmetic mean BLLs for all residents decreased from 26.2 µg/dL (95% CI: 22.3–30; SD = 17.3) to 6.2 µg/dL (95% CI: 5.3–7; SD = 3.7). The BLLs of 20 individuals in the 2014 study were at or below the lower detection limit of the equipment (3.3 µg/dL), indicating that actual BLLs following the intervention are lower than we report here.

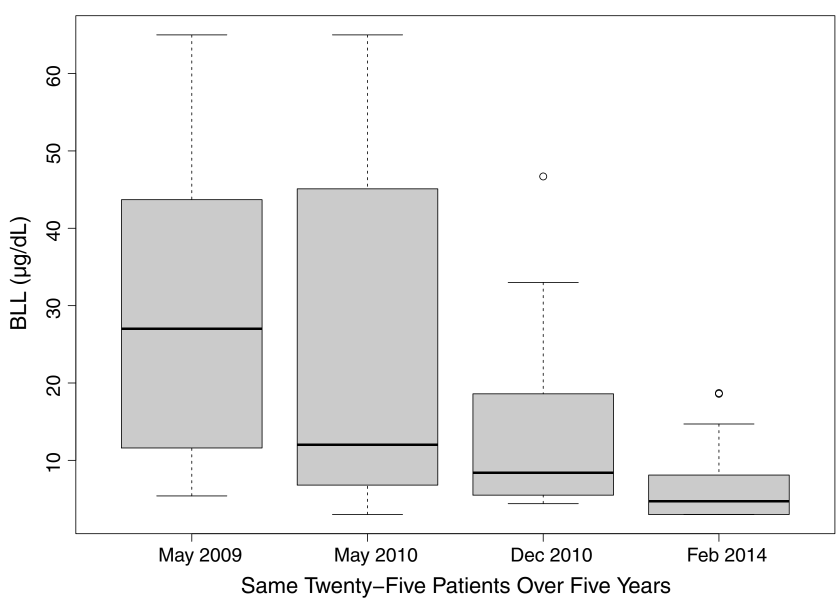


Figure 3. Blood lead levels (median, IQR, and outliers) for the same 25 residents over the 5 year period evaluated in this study (Median age in 2009 = 10 years).

4. Discussion

4.1. Cost per DALY Comparison

There is a dearth of studies on the topic of environmental remediation in the LMIC context, and we are aware of no such study that reviews an intervention through cost effectiveness analysis. As such, our results are of limited utility in assessing the project's cost effectiveness through the narrow lens of environmental remediation. A number of studies utilize cost effectiveness analysis to compare interventions targeting the same set of risk factors or a specific disease; however, those conducting a cross-sectorial analysis are limited (Murray et al., 2000). Additionally, the utilization of DALYs alone to calculate the lead attributable disease burden has been criticized for failing to capture a range of adverse societal and health impacts (Grandjean & Bellanger, 2017).

A related but separate approach, cost-benefit analysis, has been applied elsewhere to quantify the social and economic benefits of public health interventions. Gould (2009), for instance, found that each USD invested in lead paint hazard control in the USA yields USD 17–221 in returns, exceeding the cost-benefit of vaccinations, calculated at between USD 5.30 and 16.50. Future efforts might endeavor to calibrate these findings for the LMIC context.

The Institute for Health Metric Evaluation (IHME) recently estimated that between 4.2 and 15.6 million DALYs resulted from lead exposure in 2015 (Forouzanfar et al., 2016). Their analysis relies largely on the impact of exposures resulting from aerial deposition from leaded gasoline. Due in part to a lack of information, exposure at hazardous waste sites like Paraiso de Dios are not included. A number of recent publications provide evidence that the disease burden from these sites may be significantly larger than previously thought. These include case studies of lead poisoning epidemics recently reported in Nigeria, Senegal, Vietnam, and Zambia (Ajumobi et al., 2014; Caravanos et al., 2014; Haefliger et al., 2009; Noguchi et al., 2014) as well as estimations of the prevalence and nature of contaminated sites. Ericson et al. (2016), for instance, estimate the existence of between 10,599 to 29,241 lead contaminated sites result from the informal recycling of car batteries in LMICs adversely affecting the health of up to 16 million people. Separately, Dowling et al. (2016) conducted an extrapolation exercise in one country (Ghana) estimating the presence of between 812 and 3,075 contaminated sites with an apparent human exposure pathway. Of these, more than one third were contaminated with lead.

Studies from both LMICs and high-income countries have demonstrated the effectiveness of environmental remediation in mitigating exposures to toxic substances. Significant declines in elevated BLLs, for example, following soil abatement have been observed in a number of sites (Ericson et al., 2018; Lanphear et al., 2003). In the resource-poor environment of LMICs, there is a pressing need to include cost in the analysis of effectiveness; this paper offers one possible method.

A separate, possibly significant, finding of this paper is the likely underestimate of previous WHO estimates of the pediatric disease burden from lead exposure. The WHO prevalence rate calculator utilizes default values from an older study (Schwartz, 1994). More recent and robust analyses (Budtz-Jørgensen et al., 2013; Lanphear et al., 2005) find larger neurological deficits.

4.2. Limitations

Our analysis offers a potentially useful first assessment of environmental intervention; that of cost effectiveness analysis as regard contaminated site remediation in LMICs. The analysis has inherent limitations. The most significant of these is the reliance on limited environmental and biological data. The environmental and biological data initially collected at Paraiso de Dios were not necessarily intended for this sort of analysis, and consequently, the blood lead data lack extensive age or household information, limiting our ability to determine its spatial distribution in the community. While the existing environmental data are fairly comprehensive within 30 m of the site, data density tapers off significantly beyond this area. The result is that the disease burden has been underestimated in this study and the calculations should be viewed as a conservative evaluation.

A related limitation is the relatively small number of analyzed BLLs. While additional data on each age group would improve the statistical power of the analysis, the existing data show that BLLs in the final sample (February 2014) are significantly lower ($p < 0.05$) than the first sample prior to remediation in May 2009.

Regarding the future disease burden, we argue that the intervention resulted in zero prevalence of disease attributable to the site in subsequent years. We then calculate DALYs averted over three different time frames (20, 35, and 50 years) deducting background exposures. We are unaware of this approach being used elsewhere.

We use national population profiles and CVD rates for the study population. Studies in LMICs have found that both the relative proportion of children and CVD rates are higher in low-income areas like Haina (Gaziano et al., 2010). Our analysis calculates DALYs from IQ decrement in children and CVD rates in adults only, thus these demographic assumptions likely result in an underestimate of the disease burden.

Regarding the cost of the intervention, much of the historical data were inaccessible or commercial in confidence. We take submitted estimates at their face value, absent a reasonable alternative. It is likely that the most significant assumption with regard to cost is that the USD 247,222 MoE budget line item is inclusive of all disposal costs. In reality the value of the excavated material hauled to the new smelter likely vastly exceeds that of the overall project. It is possible, though has not been established, that this material was reprocessed and that the excavation costs were reimbursed to MoE. If this were the case, the societal cost of the intervention would be greatly reduced. However, due to the confidential nature of these arrangements, we conservatively include the full USD 247,222 in our costs. Additionally, we have not endeavored to calculate benefits accrued through related increased taxable income of the smelter or local project executors.

Finally, we depart from WHO guidance for the prevalence rate calculator in two significant ways. First, we calculate prevalence of MMR for ages 5–7 years, while it was intended for ages 0–4 years only. We argue there is sufficient justification in the literature to support the assumption that neurological decrement continues beyond age 4. Budtz-Jørgensen et al. (2013) and Lanphear et al. (2005), for instance, both found the strongest association of IQ decrement with BLLs in concurrent measurements of school age children aged 5–10 years. Reuben et al. (2017) evaluated the relationship between cognitive function at age 38 with BLLs taken at age 11 in 1,037 New Zealanders. In addition to identifying a strong association between lower socioeconomic status and childhood BLLs, Reuben et al. (2017) found that each 5 μg/dL increase in BLL at age 11 was associated with a decrease in 1.61 IQ points by age 38, indicating a continued loss of IQ attributable to childhood BLL. Second, we augment the estimated prevalence of MMR in the population with the use of the log-linear model from Budtz-Jørgensen et al. (2013). We argue that these results are much more robust than those presented by Schwartz (1994) and present both values in Tables 4 and 5.

5. Conclusions

On its face, the intervention at Haina would appear to have significant utility at similarly impacted environments. However, further research of equivalent type projects is required to determine its true cost effectiveness relative to other public health interventions and also to ensure scarce resources are allocated efficiently within and between projects.

Acknowledgments
Support for this research was provided in part by the European Commission. Support for the intervention described was provided by the Inter American Development Bank. B. E. is a recipient of an International Macquarie University Research Excellence Scholarship. Pure Earth executes environmental remediation projects in low- and middle-income countries. Support for this research was provided in part by the United States Agency for International Development (Cooperative Agreement No. AID-OAA-A-16-00019). Environmental data used in the calculations of DALYs is available in the supporting information.

References

Ajmone-Marsan, F., & Biasioli, M. (2010). Trace elements in soils of urban areas. *Water, Air, & Soil Pollution*, *213*(1-4), 121–143. https://doi.org/10.1007/s11270-010-0372-6

Ajumobi, O. O., Tsofo, A., Yango, M., Aworh, M. K., Anagbogu, I. N., Mohammed, A., et al. (2014). High concentration of blood lead levels among young children in Bagega community, Zamfara - Nigeria and the potential risk factor. *The Pan African Medical Journal*, *18*(Suppl 1), 14. https://doi.org/10.11694/pamj.supp.2014.18.1.4264

Blacksmith Institute (2010). *Haina project completion report*. New York. Retrieved from http://www.pureearth.org/project/haina/

Budtz-Jørgensen, E., Bellinger, D., Lanphear, B., Grandjean, P., Lanphear, B. P., Hornung, R., et al. (2013). An international pooled analysis for obtaining a benchmark dose for environmental lead exposure in children. *Risk Analysis*, *33*(3), 450–461. https://doi.org/10.1111/j.1539-6924.2012.01882.x

Caravanos, J., Fuller, R., & Nieves, R. (2007). Lead contamination at an abandoned lead-acid battery recycling facility in the Dominican Republic (a preliminary report). New York. Retrieved from http://www.pureearth.org/wp-content/uploads/2014/03/Haina_Dust_report_March16_2007_V1.pdf

Caravanos, J., Fuller, R., & Robinson, S. (2014). Notes from the field: Severe environmental contamination and elevated blood lead levels among children — Zambia, 2014. Retrieved September 25, 2016, from http://www.cdc.gov/MMWr/preview/mmwrhtml/mm6344a7.htm

Chatham-Stephens, K., Caravanos, J., Ericson, B., Sunga-Amparo, J., Susilorini, B., Sharma, P., et al. (2013). Burden of disease from toxic waste sites in India, Indonesia, and the Philippines in 2010. *Environmental Health Perspectives*, *121*(7), 791–796. https://doi.org/10.1289/ehp.1206127

Cohen, A. J., Ross Anderson, H., Ostro, B., Pandey, K. D., Krzyzanowski, M., Künzli, N., et al. (2005). The global burden of disease due to outdoor air pollution. *Journal of Toxicology and Environmental Health. Part A*, *68*(13-14), 1301–1307. https://doi.org/10.1080/15287390590936166

Department of Environmental Protection, N. J (2014). Technical guidance on the capping of sites undergoing remediation, 1–106. Retrieved from http://www.state.nj.us/dep/srp/guidance/srra/capping_remediation_sites.pdf

Dowling, R., Caravanos, J., Grigsby, P., Rivera, A., Ericson, B., Amoyaw-Osei, Y., et al. (2016). Estimating the prevalence of toxic waste sites in low- and middle-income countries. *Annals of Global Health*, *82*(5), 700–710. https://doi.org/10.1016/J.AOGH.2016.07.008

Edejer, T. T.-T., Baltussen, T., Adam, T., Hutubessy, R., Acharya, A., Evans, D. B., & Murray, C. J. L. (2003). Making choices in health: WHO guide to cost-effectiveness analysis. Retrieved from http://www.who.int/choice/publications/p_2003_generalised_cea.pdf?ua=1

EPA Region 10 (2016). Optimization review report long-term monitoring optimization study: Bunker Hill Mining and Metallurgical Complex, operable unit 03 east mission flats and big creek repositories Kootenai County and Shoshone County, Idaho. Retrieved from https://semspub.epa.gov/work/10/100040227.pdf

Ericson, B., Caravanos, J., Chatham-Stephens, K., Landrigan, P., & Fuller, R. (2013). Approaches to systematic assessment of environmental exposures posed at hazardous waste sites in the developing world: The toxic sites identification program. *Environmental Monitoring and Assessment*, *185*(2), 1755–1766. https://doi.org/10.1007/s10661-012-2665-2

Ericson, B., Duong, T. T., Keith, J., Nguyen, T. C., Havens, D., Daniell, W., et al. (2018). Improving human health outcomes with a low-cost intervention to reduce exposures from lead acid battery recycling: Dong Mai, Vietnam. *Environmental Research*, *161*, 181–187. https://doi.org/10.1016/j.envres.2017.10.042

Ericson, B., Landrigan, P., Taylor, M. P., Frostad, J., Caravanos, J., Keith, J., & Fuller, R. (2016). The global burden of lead toxicity attributable to informal used lead-acid battery (ULAB) sites. *Annals of Global Health*. https://doi.org/10.1016/J.AOGH.2016.10.009

ESA Biosciences (1997). *User's guide LeadCare ® I blood testing system*. MA, USA: Chelmsford.

Fewtrell, L., Kaufmann, R., & Prüss-Üstün, A. (2003). Lead: Assessing the environmental burden of disease at national and local levels. WHO environmental burden of disease series, no. 2. World Health Organization. Retrieved from http://www.who.int/quantifying_ehimpacts/publications/en/leadebd2.pdf?ua=1

Fewtrell, L., Prüss-Üstün, A., Landrigan, P., & Ayuso-Mateos, J. (2004). Estimating the global burden of disease of mild mental retardation and cardiovascular diseases from environmental lead exposure. *Environmental Research*, *94*(2), 120–133. https://doi.org/10.1016/S0013-9351(03)00132-4

Forouzanfar, M., Murray, C. J., & Afshin, A. (2016). GBD 2015 risk factors collaborators. Global, regional, and national comparative risk assessment of 79 behavioral, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: A systematic analysis for the global burden of disease S. *The Lancet*, *388*(10053), 1659–1724. https://doi.org/10.1016/S0140-6736(16)31679-8

Gaziano, T. A., Bitton, A., Anand, S., Abrahams-Gessel, S., & Murphy, A. (2010). Growing epidemic of coronary heart disease in low- and middle-income countries. *Current Problems in Cardiology*, *35*(2), 72–115. https://doi.org/10.1016/j.cpcardiol.2009.10.002

Gould, E. (2009). Childhood lead poisoning: Conservative estimates of the social and economic benefits of lead hazard control. *Environmental Health Perspectives*, *117*(7), 1162–1167. https://doi.org/10.1289/ehp.0800408

Grandjean, P., & Bellanger, M. (2017). Calculation of the disease burden associated with environmental chemical exposures: Application of toxicological information in health economic estimation. *Environmental Health*, *16*(1), 123. https://doi.org/10.1186/s12940-017-0340-3

Haefliger, P., Mathieu-Nolf, M., Lociciro, S., Ndiaye, C., Coly, M., Diouf, A., et al. (2009). Mass lead intoxication from informal used lead-acid battery recycling in Dakar, Senegal. *Environmental Health Perspectives*, *117*(10), 1535–1540. https://doi.org/10.1289/ehp.0900696

Hamilton, J. T., & Viscusi, W. K. (1997). Benefits and costs of regulatory reforms for superfund. *The Stanford Environmental Law Journal*, *16*. Retrieved from http%3A%2F%2Fheinonline.org%2FHOL%2FPage%3Fhandle%3Dhein.journals%2Fstaev16%26amp%3Bid%3D185%26amp%3Bdiv%3D%26amp%3Bcollection

Harris, S. G., & Harper, B. L. (2004). Exposure scenario for CTUIR traditional subsistence lifeways. Department of Science & engineering, confederated tribes of the Umatilla Indian reservation, P.O. Box 638, Pendleton, OR 97801. Retrieved from http://health.oregonstate.edu/sites/health.oregonstate.edu/files/research/pdf/tribal-grant/CTUIR-SCENARIO.pdf

InnovX (2016). Delta environmental handheld XRF analyzer. Retrieved December 1, 2016, from http://www.olympus-ims.com/en/xrf-xrd/delta-handheld/delta-env/#!cms%5Btab%5D=%2Fxrf-xrd%2Fdelta-handheld%2Fdelta-env%2Fresources

Jones, D. E., Pérez, M. C., Ericson, B., Sánchez, D. E., Gualtero, S., Smith-Jones, A., & Caravanos, J. (2013). Childhood blood lead reductions following removal of leaded ceramic glazes in artisanal pottery production: A success story. *Journal of Health and Pollution*, *3*(4), 23–29. https://doi.org/10.5696/2156-9614-3.4.23

Kabala, C., & Singh, B. R. (2001). Fractionation and mobility of copper, lead, and zinc in soil profiles in the vicinity of a copper smelter. *Journal of Environmental Quality*, *30*(2), 485. https://doi.org/10.2134/jeq2001.302485x

Kaul, B., & Mukerjee, H. (1999). Elevated blood lead and erythrocyte protoporphyrin levels of children near a battery-recycling Plant in Haina, Dominican Republic. *International Journal of Occupational and Environmental Health*, *5*(4), 307–312. https://doi.org/10.1179/oeh.1999.5.4.307

Kaul, B., Sandhu, R. S., Depratt, C., & Reyes, F. (1999). Follow-up screening of lead-poisoned children near an auto battery recycling plant, Haina, Dominican Republic. *Environmental Health Perspectives*, *107*(11), 917–920. https://doi.org/10.2307/3454481

Kennedy, C. A., Gray, A. M., Denman, A. R., & Phillips, P. S. (1999). A cost-effectiveness analysis of a residential radon remediation programme in the United Kingdom. *British Journal of Cancer*, *81*(7), 1243. https://doi.org/10.1038/sj.bjc.6690836

Kwong, L., Ercumen, A., Pickering, A., Unicomb, L., Davis, J., Leckie, J., & Luby, S. (2017). Soil ingestion among children 0–3 years old in rural Bangladesh. Symposium conducted at the International Society of Exposure Science (p. 48). Research Triangle Park, NC, USA. Retrieved from https://intlexposurescience.org/ISES2017/Schedule/Online_Program/ISES2017/Schedule/Online_Program.aspx?hkey=1881d027-36ce-4173-bd75-b230a6284853

Lanphear, B. P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D. C., et al. (2005). Low-level environmental lead exposure and Children's intellectual function: An international pooled analysis. *Environmental Health Perspectives*, *113*(7), 894–899. https://doi.org/10.1289/ehp.7688

Lanphear, B. P., Succop, P., Roda, S., & Henningsen, G. (2003). The effect of soil abatement on blood lead levels in children living near a former smelting and milling operation. *Public Health Reports*, *118*(2), 83–91. https://doi.org/10.1093/phr/118.2.83

Ludlow, A., & Roux, P. (2012). Innovative technologies for sustainable environmental remediation in poor and middle income countries. *Journal of Health and Pollution*, *2*(3), 1–4. https://doi.org/10.5696/2156-9614-2.3.1

Magellan Diagnostics (2015). *LeadCare ® II blood lead analyzer user's guide*. Massachusetts, USA: N. Billerica. Retrieved from http://www.leadcare2.com/getmedia/73ac501b-35e3-4d74-b6a9-9e7fc51adef0/70-6551_Rev_07_User-s_Guide,_LeadCare_II_(PRINT)-1.pdf.aspx

Murray, C. J. L., Evans, D. B., Acharya, A., & Baltussen, R. M. P. M. (2000). Development of WHO guidelines on generalized cost-effectiveness analysis. *Health Economics*, *9*(3), 235–251. https://doi.org/10.1002/(SICI)1099-1050(200004)9:3%3C235::AID-HEC502%3E3.0.CO;2-O

Murray, C. J. L., & Lopez, A. D. (2013). Measuring the global burden of disease. *New England Journal of Medicine*, *369*(5), 448–457. https://doi.org/10.1056/NEJMra1201534
National Statistics Office, D. R. (2012). Dominican Republic population and housing census *2010*. Retrieved from http%3A%2F%2Fcenso2010.one.gob.do%2Findex.php%3Fmodule%3Darticles%26amp%3Bfunc%3Dview%26amp%3Bptid%3D2%26amp%3Bp%3D6
Noguchi, T., Itai, T., Tue, N. M., Agusa, T., Ha, N. N., Horai, S., et al. (2014). Exposure assessment of lead to workers and children in the battery recycling craft village, dong Mai, Vietnam. *Journal of Material Cycles and Waste Management*, *16*(1), 46–51. https://doi.org/10.1007/s10163-013-0159-0
OSWER (1994). *Guidance manual for the IEUBK model for lead in children*. Washington, DC: Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency. Retrieved from https://semspub.epa.gov/work/HQ/176284.pdf
OSWER (2003). Assessing intermittent or variable exposures at lead sites. Retrieved from https://semspub.epa.gov/work/11/176288.pdf
Proyecto Presupuesto de Ingresos y Ley de Gastos Publicos 2009 (2009). Retrieved from http://www.digepres.gob.do/wp-content/uploads/2013/07/Presupuesto-Formulado-2009.pdf
Prüss-Ustün, A., Vickers, C., Haefliger, P., & Bertollini, R. (2011). Knowns and unknowns on burden of disease due to chemicals: A systematic review. *Environmental Health*, *10*(1), 9. https://doi.org/10.1186/1476-069X-10-9
Prüss-Ustün, A., Wolf, J., Corvalán, C., Neville, T., Bos, R., & Neira, M. (2016). Diseases due to unhealthy environments: An updated estimate of the global burden of disease attributable to environmental determinants of health. *Journal of Public Health*. https://doi.org/10.1093/pubmed/fdw085
Reuben, A., Caspi, A., Belsky, D. W., Broadbent, J., Harrington, H., Sugden, K., et al. (2017). Association of childhood blood lead levels with cognitive function and socioeconomic status at age 38 years and with IQ change and socioeconomic mobility between childhood and adulthood. *JAMA*, *317*(12), 1244–1251. https://doi.org/10.1001/jama.2017.1712
Rouillon, M., Taylor, M. P., & Dong, C. (2017). Reducing risk and increasing confidence of decision making at a lower cost: In-situ PXRF assessment of metal-contaminated sites.
Sanders, G. D., Neumann, P. J., Basu, A., Brock, D. W., Feeny, D., Krahn, M., et al. (2016). Recommendations for conduct, methodological practices, and reporting of cost-effectiveness analyses. *JAMA*, *316*(10), 1093–1103. https://doi.org/10.1001/jama.2016.12195
Schwartz, J. (1994). Low-level lead exposure and children's IQ: A metaanalysis and search for a threshold. *Environmental Research*, *65*(1), 42–55. https://doi.org/10.1006/enrs.1994.1020
Semlali, R. M., Dessogne, J., Monna, F., Bolte, J., Azimi, S., Navarro, N., et al. (2004). Modeling lead input and output in soils using lead isotopic geochemistry. *Environmental Science & Technology*, *38*(5), 1513–1521. https://doi.org/10.1021/ES0341384
StataCorp. LP (2017). Stata Statistical Software: Release 15. College Station, TX.
Sun, L. C., & Meinhold, C. B. (1997). Gastrointestinal absorption of plutonium by the Marshall islanders. *Health Physics*, *73*(1), 167–175. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9199226
Tirima, S., Bartrem, C., von Lindern, I., von Braun, M., Lind, D., Anka, S. M., & Abdullahi, A. (2016). Environmental remediation to address childhood lead poisoning epidemic due to artisanal gold mining in Zamfara, Nigeria. *Environmental Health Perspectives*, *124*(9), 1471–1478. https://doi.org/10.1289/ehp.1510145
US Census Bureau, D. I. S. (2016). International programs, international data Base.
U.S. Environmental Protection Agency (USEPA) (1998). Lead; identification of dangerous levels of lead. *Federal Register*. Retrieved from https://www.gpo.gov/fdsys/pkg/FR-1998-06-03/pdf/98-14736.pdf
US EPA, OSWER, O (2016). Lead at superfund sites: Software and users' manuals. Retrieved from https://www.epa.gov/superfund/lead-superfund-sites-software-and-users-manuals
U.S. Environmental Protection Agency (USEPA) (2010). Approach for developing lead dust hazard standards for public and commercial buildings. Washington, DC. Retrieved from https%3A%2F%2Fyosemite.epa.gov%2Fsab%2Fsabproduct.nsf%2F0%2F9C733206A5D6425785257695004F0CB1%2F%24File%2FPub%26amp%3BCommBldgPbDust.pdf
von Lindern, I., Spalinger, S., Stifelman, M. L., Stanek, L. W., & Bartrem, C. (2016). Estimating children's soil/dust ingestion rates through retrospective analyses of blood lead biomonitoring from the Bunker Hill superfund site in Idaho. *Environmental Health Perspectives*, *124*(9), 1462–1470. https://doi.org/10.1289/ehp.1510144
Wilson, B. (2002). Environmentally sound management of lead-acid batteries in the Caribbean and Central America: Visit reports 3—Santa Domingo, MetaloXsa. Retrieved from http://www.ilmc.org/Basel project/Dominican Republic/visit reports/English/PDF/visit report 3 Domincan Republic Santa Domingo metaloxa.Pdf
World Bank (2017). GDP per capita (constant 2010 US$) | Data. Retrieved May 22, 2017, from http://data.worldbank.org/indicator/NY.GDP.PCAP.KD?locations=DO
World Health Organization (2016). WHO metrics: Disability-adjusted life year (DALY). Retrieved October 16, 2016, from http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/
World Health Organization (WHO) (2013). WHO methods and data sources for global burden of disease estimates 2000–2011. *Global Health Estimates Technical Paper WHO/HIS/HSI/GHE/2013.4*, (November), 81. Retrieved from http://www.who.int/healthinfo/statistics/GlobalDALYmethods_2000_2011.pdf?ua=1
World Health Organization (WHO) (2014). Global health estimates 2014 summary tables. Health Statistics and Information Systems Web site. Updated 2014. Retrieved October 10, 2016, from http://www.who.int/entity/healthinfo/global_burden_disease/GHE_DALY_2012_country.xls?ua=1
XE (2017). Currency table: DOP–Dominican Peso. Retrieved May 22, 2017, from http%3A%2F%2Fwww.xe.com%2Fcurrencytables%2F%3Ffrom%3DDOP%26amp%3Bdate%3D2009-12-01
Zaher, C., Halbert, R., Dubois, R., George, D., & Nonikov, D. (2004). Smoking-related diseases: The importance of COPD. *The International Journal of Tuberculosis and Lung Disease: The Official Journal of the International Union against Tuberculosis and Lung Disease*, *8*(12), 1423–1428. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15636487

Erratum

In the originally published version of this article, a donor was omitted from the acknowledgments. The acknowledgments have since been updated, and this version may be considered the authoritative version of record.

Environmental Research 161 (2018) 181–187

Contents lists available at ScienceDirect

Environmental Research

journal homepage: www.elsevier.com/locate/envres

Improving human health outcomes with a low-cost intervention to reduce exposures from lead acid battery recycling: Dong Mai, Vietnam

Bret Ericson[a,b,c,*], Thi To Duong[d], John Keith[a], Trong Cuu Nguyen[e], Deborah Havens[f], William Daniell[f], Catherine J. Karr[f], Doan Ngoc Hai[h], Lo Van Tung[h], Tran Thi Nhi Ha[h], Brian Wilson[g], David Hanrahan[a], Gerry Croteau[f], Mark Patrick Taylor[b]

[a] Pure Earth, 475 Riverside Drive, Suite 860, New York, NY 10025, USA
[b] Department of Environmental Sciences, Faculty of Science and Engineering, Macquarie University, Sydney, NSW 2109, Australia
[c] College of Global Public Health, New York University, 41 East 11th Street, New York, NY 10003, USA
[d] Centre for Environment and Community Development, House No.23, Alley No.1104, De La Thanh street, Hanoi, Vietnam
[e] Department of Planning and Finance, Vietnam Environment Administration, 10 Ton That Thuyet Street, Hanoi, Vietnam
[f] Department of Environmental and Occupational Health Sciences, University of Washington, Seattle, WA 98195, USA
[g] International Lead Management Centre, 525 Meridian Parkway, Suite 100, Research Triangle Park, NC 27713, USA
[h] National Institute of Occupational and Environmental Health, 57. Le Quy Don, Hai Ba Trung, Ha Noi, Vietnam

ARTICLE INFO

Keywords:
Soil lead dust intervention
Education
House dust intervention
Used lead acid battery
Low- and middle-income countries

ABSTRACT

This study details the first comprehensive evaluation of the efficacy of a soil lead mitigation project in Dong Mai village, Vietnam. The village's population had been subject to severe lead poisoning for at least a decade as a result of informal Used Lead Acid Battery (ULAB) recycling. Between July 2013 to February 2015, Pure Earth and the Centre for Environment and Community Development (Hanoi, Vietnam) implemented a multi-faceted environmental and human health intervention. The intervention consisted of a series of institutional and low-cost engineering controls including the capping of lead contaminated surface soils, cleaning of home interiors, an education campaign and the construction of a work-clothes changing and bathing facility. The mitigation project resulted in substantial declines in human and environmental lead levels. Remediated home yard and garden areas decreased from an average surface soil concentration of 3940 mg/kg to < 100 mg/kg. One year after the intervention, blood lead levels in children (< 6 years old) were reduced by an average of 67%—from a median of 40.4 μg/dL to 13.3 μg/dL. The Dong Mai project resulted in significantly decreased environmental and biological lead levels demonstrating that low-cost, rapid and well-coordinated interventions could be readily applied elsewhere to significantly reduce preventable human health harm.

1. Introduction

In high-income countries (HICs), regulatory controls, notably bans on lead in widely used and available products (e.g. residential paint, gasoline), have resulted in significant lowering of population blood lead levels (Kristensen et al., 2017; Needleman, 2004; Schwartz and Pitcher, 1989). In Low and Middle Income Countries (LMICs) key sources of environmental lead exposure include mining (both legacy and active), used lead acid battery (ULAB) processing, and lead-based ceramic glazes, among other sources (Farías et al., 2014; Lo et al., 2012; Meyer et al., 2008; Yabe et al., 2015). Used lead acid battery processing in particular is known to cause significant environmental contamination and human health exposure (Farías et al., 2014; Lo et al., 2012; Meyer et al., 2008; Yabe et al., 2015). In the context of limited regulatory oversight the extent and severity of lead poisoning in LMICs is less well documented but is suspected to be prevalent (Braithwaite, 2006; Chatham-Stephens et al., 2013; Dowling et al., 2016; Ericson et al., 2013). Lead is a known neurotoxicant and can result in an IQ decrement in children and cardiovascular disease in adults, among other adverse health outcomes (ATSDR, 2007). On a societal level, lead exposure has been associated with increased levels of aggravated assault and decreased economic output (Gould, 2009; Mielke and Zahran, 2012; Prüss-Üstün et al., 2010).

Multiple studies have documented very high blood lead levels (BLLs) in communities where informal ULAB processing occurs (Daniell et al., 2015; Haefliger et al., 2009; Matte et al., 1991). This activity is typically undertaken in residential areas and is characterized by poor or no hazard control and migration of material offsite (Shen et al., 2016).

* Corresponding author at: Department of Environmental Sciences, Faculty of Science and Engineering, Macquarie University, Sydney, NSW 2109, Australia.
E-mail address: bret@pureearth.org (B. Ericson).

https://doi.org/10.1016/j.envres.2017.10.042
Received 1 August 2017; Received in revised form 20 September 2017; Accepted 24 October 2017
Available online 15 November 2017

A recent study has estimated that between 10,599 to 29,241 such sites exist in 90 different LMICs, placing the health of 6–16 million people at risk (Ericson et al., 2016). A limited number of projects have been executed at comparable lead contaminated sites to mitigate exposures, with most utilizing a combination of in situ and ex situ engineering controls coupled with community education (Laidlaw et al., 2016; Pure Earth, 2017). However, there is an absence of peer-reviewed studies evaluating the efficacy of remediation strategies at informal ULAB and remediation more broadly in LMICs.

1.1. Study location and background

In Vietnam, informal industry including ULAB recycling is commonly centered in 'craft villages'. These small to medium sized areas produce a range of consumer and industrial goods and are typically characterized by inadequate waste management practices (Mahanty and Dang, 2013). Craft village industrial activities are also characteristically household-based, with individual homeowners often working in concert to complete sequential tasks in the production of a single good (Mahanty and Dang, 2013). This research focuses on the outcomes of a multi-faceted intervention to reduce lead exposures in the Dong Mai village, Chi Dao Commune, Hung Yen Province. Dong Mai village has been involved in ULAB recycling activities since 1978 (Tung, 2011).

The recycling process involved the collection of automotive batteries from outside the village, battery breaking for lead plate removal, smelting to form new lead ingots, and manually recovering and processing the resulting waste tinker and slag for re-smelting. These processes were replicated across the village with the majority of households participating in some stage of the recycling process. Consequently, the impact of the recycling activities resulted in pervasive contamination across the whole village.

Several previous studies have described the contamination in Dong Mai (Daniell et al., 2015; Noguchi et al., 2014; Tung, 2011). A 2006 National Institute of Occupational and Environmental Health (NIOEH) study found elevated lead concentrations in air, wastewater and soil (Tung, 2011). A separate effort by a Japanese research team in 2011 found severely elevated blood and urine lead levels due to occupational exposure in adults. The study evaluated 93 individuals, including 23 children, and found an average BLL of 34 µg/dL (Noguchi et al., 2014).

The most comprehensive study of exposures to date was completed by a joint effort of the NIOEH and the University of Washington School of Public Health (USA) (referred to hereafter as 'the University of Washington'). In these assessments, lead in surface soil and dust in 11 different homes along with capillary blood samples of 109 children (age 0–10 years) were evaluated. The results revealed BLLs ranged between 12– > 65 µg/dL (the detection limit of the LeadCare® II analytical equipment) and extensive soil contamination with two-thirds of samples above the USEPA reference level for bare soil in children's play are as of 400 mg/kg (Daniell et al., 2015; EPA, 2015). For context, the equivalent Vietnamese standard is 70 mg/kg (Vietnam, 2015). Of the 109 children evaluated 33% had BLLs of 10–29.9 µg/dL; 37% 30–44.9 µg/dL; 16% 45–64.9 µg/dL, and 14% > 65 µg/dL (Daniell et al., 2015).

Following the 2006 NIOEH study (Tung, 2011) the People's Committee of Hung Yen province established an industrial park for Chi Dao Commune to consolidate ULAB recycling activities and extricate the activity from Dong Mai village. The new industrial park covered 200,000 m^2 and was located about 1 km south of the village's residential areas. Subsequently, from around 2012, the majority of ULAB industrial activity was relocated to the industrial area, although a minority continued recycling activities in the village. About 66,000 m^2 of the new industrial park is currently in use.

In 2012, Pure Earth, an international non-profit organization dedicated to solving pollution problems in low- and middle-income countries where human health is at risk, became aware of the site through its Toxic Sites Identification Program (Ericson et al., 2013). From 2013–2015 Pure Earth worked jointly with the Vietnamese Centre for Environment and Community Development (referred to hereafter as 'CECoD') to assess the extent and severity of contamination and execute a targeted intervention. The intervention was supported by national and international organizations: the Centre for Environmental Consultancy and Technology of the Vietnam Environment Administration (referred to hereafter as the 'Environmental Administration') (Hanoi, Vietnam), the International Lead Management Centre (Research Triangle Park, USA), the University of Washington, and local community and industry partners. This study details the intervention and assesses its efficacy and potential for wider application in similarly impacted LMICs, particularly where financial resources are limited.

Assessment of the key sources of lead exposure in Dong Mai included contaminated indoor dust and soils in outdoor residential and public spaces. Soil has long been identified as a significant pathway of lead exposure (Mielke and Reagan, 1998). Children in particular ingest high levels of dust from soil and soil itself (Abrahams, 2002; Stanek and Calabrese, 1995).

At the study site, a primary source of contamination was identified as legacy waste from previous recycling activities, which because of its scale had resulted in exposures across the village. In addition to the legacy waste sources, ongoing recycling activities were also identified as a secondary source of contemporary contamination. These recyclers were engaged in manual tinker separation, battery breaking and smelter operations. Lead dust contained on all worker's clothing was also an important source of exposure to the workers and their families (Daniell, 2015). A further source of contamination involved the loss of primary lead material during its transport through the village on motorbikes and small trucks to the formal industrial area for processing.

2. Materials and methods

The approach employed in Dong Mai involved a series of increasingly detailed environmental assessments to guide targeted interventions. Environmental and human exposure monitoring were used to assess their efficacy.

2.1. Environmental assessment

Assessments of environmental contamination were carried out on an ongoing basis, beginning in December 2012 with a rapid qualitative assessment of contamination sources and exposure pathways by CECoD investigators. The rapid assessment confirmed earlier reports of poor work practices including breaking and open smelting of batteries in residential areas, lack of personal protective equipment and the storage and transport of hazardous material in the village.

A detailed assessment of the extent of soil contamination was conducted by Pure Earth in May 2013. In situ surface soil lead measurements at 235 sites were completed over two days in residential areas and public spaces using a handheld portable InnovX Delta series X-ray fluorescence instrument (pXRF) with a lower detection limit for lead of 5 mg/kg. The instrument was calibrated twice daily with a 316 steel clip provided by the manufacturer. Following calibration, certified reference materials produced by the National Institute of Standards and Technology (2702: Inorganics in Marine Sediment) were used to confirm the accuracy of lead detection (Gonzalez et al., 2016). In situ pXRF analysis has been shown to be consistent with more commonly used wet chemistry techniques (e.g. Inductively Coupled Plasma Atomic Emission Spectrometry and Inductively Coupled Plasma Mass Spectrometry), particularly in the context of high density sampling like that carried out here (Rouillon et al., 2017; Rouillon and Taylor, 2016). Water samples were not collected by the assessment team as previous data indicated this lead exposure pathway was low risk (Anh, 2008).

From September 2013 to February 2014 the Environmental Administration conducted a qualitative assessment of every village residential yard (n = 546). At that time 269 households were identified as having earthen yards or gardens. Investigators were unable to access 14 of these yards. The balance (n = 255) of yards were assessed in detail with > 5 surface samples per yard analyzed using the pXRF. Analysis of lead in soil across individual yards was evenly spaced in order to capture acurately contamination levels in areas accessed by residents. To assess the depth of contamination in the soils, a limited number (n = 10) of samples from contaminated yards were assessed to a maximum depth of 1 m.

Results of the surface soil lead testing were compiled using ESRI ArcMap 10.5 and analyzed for proximity to roadways (ESRI, 2015). Statistical analysis was conducted with Stata 14 (StataCorp LP, 2015).

2.2. Lead contamination mitigation

The primary mitigation work was conducted over a 4-month period from December 2013 to March 2014. An additional phase conducting work in 11 homes and lasting one month was executed in January 2015. The soil mitigation strategy consisted of covering contaminated earthen yards with a geotextile fabric followed by 20 cm of compacted clean soil and was explicitly based on the method described by Mielke et al. (2011). Alluvial soils were procured for the capping and tested for lead content with a pXRF and in all cases were confirmed to be < 50 mg/kg. In cases where residents opted to pay the incremental cost of capital improvement, other materials were used in addition to the compacted clean soil. These included paver stones and concrete. Overall, the interventions had the same intent - isolating the contaminated soils from causing potential human exposures. Capping with a clean layer of soil ≥ 10 cm is an internationally accepted approach to dealing with soil lead contamination and has been used in the United States and Australia, for example (Mielke et al., 2011; Yang and Cattle, 2017). By contrast, capping with soil ≤ 5 cm has been ineffective at mitigating potential exposures (Harvey et al., 2016).

Due to budget constraints, mitigation work was prioritized based on the severity of contamination. Three thresholds were set: 400 mg/kg – 800 mg/kg (low priority); 800–1200 mg/kg (medium priority); and > 1200 mg/kg (high priority). The lowest value, 400 mg/kg, represents the USEPA guideline level for bare soil in children's play areas, while 1200 mg/kg represents the USEPA guideline for bare soil where children do not play (EPA, 2015). A soil lead level of 800 mg/kg was chosen to further stratify the homes.

Out of the 255 yards assessed in detail, the project team undertook mitigation in 49. An additional 47 homeowners mitigated their own yards utilizing the project's protocol. Thus mitigation work was executed in a total of 96 yards. The total area of land capped during the project was 11,370 m^2. Twelve homes identified with average surface soil concentrations between 400–800 mg/kg were not mitigated (Fig. 1).

Home interiors were cleaned using a Pure Earth protocol developed on previous lead exposure mitigation projects (Keith and Ericson, 2013). The protocol was translated into the Vietnamese language and photographs of local residents were used to demonstrate cleaning approaches. The project team utilized High Efficiency Particulate Air (HEPA) vacuums in the 49 homes targeted by the project. The remaining homes, including the 47 that capped their own yards, were internally cleaned using the HEPA vacuums followed with spot checks of dust by the project team with a pXRF.

In parallel with the Pure Earth intervention, a Vietnamese rural development scheme was engaged by residents to provide co-financing for the concreting of streets in the village. As a result more than 80% of secondary roads in Dong Mai were covered with concrete after the project compared with none before the project.

2.3. Community education

A community education and engagement campaign covering health risks and exposure pathways was undertaken by CECoD. The campaign

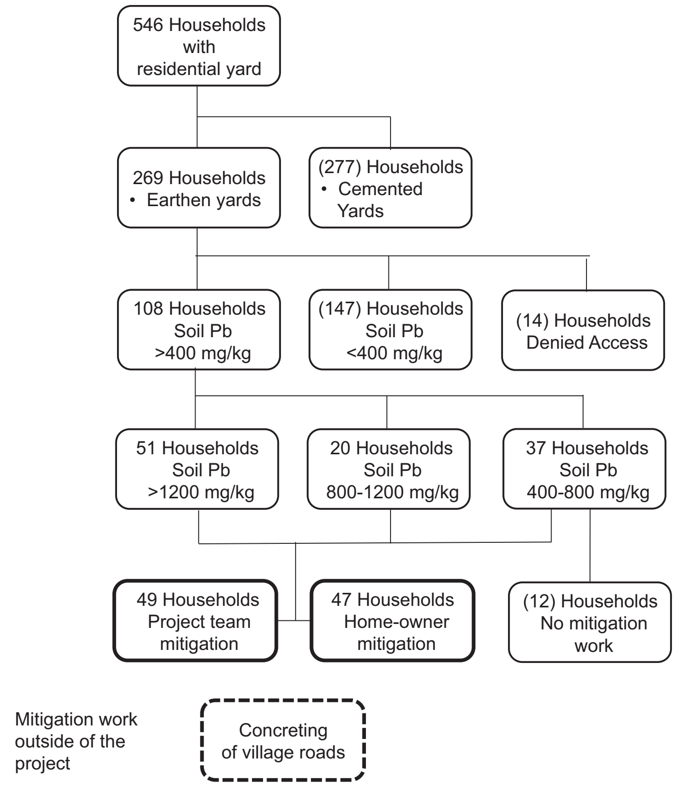


Fig. 1. Flow chart of assessment and mitigation activities.

included a three-day workshop where a USD $10 stipend was provided, resulting in the attendance of 540 households (from a total of 546). In addition a door-to-door education campaign was conducted and regular announcements were made on the village's loudspeaker system.

2.4. Improving ULAB workshop work practices

At the beginning of the project 34 informal processors were identified in the residential area of the village. These processors were included in stakeholder workshops and were prioritized for community education activities. Other than this, they were not engaged differently than the community as a whole.

An International Lead Management Centre representative (ilmc.org) conducted an assessment of the formal facility and industrial zone in September 2013 and made multiple recommendations on improving workplace practices (Wilson, 2013). One significant outcome of the assessment was the design and building of a 'clean-in, clean-out' changing room for workers. The purpose of the clean-in clean-out changing room was to mitigate the migration of material offsite on workers' clothing. The facility was co-financed by a private smelter owner who provided USD$15,000 in labor and a site for the new building. The PE project provided USD$12,500 and the building design. The importance of using the facility and a number of recommendations for improved hygiene were covered in the community education workshops discussed above.

2.5. Blood lead level (BLL) assessment

The University of Washington and NIOEH conducted pre- and post-intervention blood lead testing in December of 2013 and September of 2014 using a LeadCare® II instrument and capillary blood samples. Two hundred and four children (< 6 years old) were sampled at both time points. Using US Census data for foreign countries we calculated that 10.8% of the village's estimated population of 2600, or 281 children, fell within this age group, indicating that the study captured BLLs for

73% of the population under 6 years of age (US Census Bureau, 2016). The age distribution of the 2013–2014 cohort was as follows: 7% ≤12 months, 23% 12–24 months, 20% 24–36 months, 14% 36–49 months, 17% 48–60 months, and 19% 60–72 months at the time of the initial test. Institutional Review Board approval was given by the Human Subjects Division of the University of Washington and by the NIOEH Institutional Review Committee. In May 2015 NIOEH collected a further 196 intravenous blood samples from village children (< 6 years old), which were assessed for lead concentration using atomic absorption spectrometry (NIOEH, 2015). The age distribution of the 2015 cohort was as follows: 7% ≤12 months, 18% 12–24 months, 28% 24–36 months, 17% 36–49 months, 12% 48–60 months, and 18% 60–72 months at the time of the test.

3. Results

3.1. Soil Lead Levels

Average soil concentrations in Dong Mai before the intervention were 3940 mg/kg (95% CI: 1567–6312 mg/kg; median = 648 mg/kg). Yards assessed in detail are represented by their average concentration and are labeled as 'Composite' (Fig. 2). The contamination resulted from multiple hotspots occurring sporadically throughout the village rather than a single source. No association could be identified between surface level lead concentrations and proximity to roads. Samples taken within 3 m of a roadway averaged 3774 mg/kg; samples between 3 and 10 m of a roadway averaged 5391 mg/kg, while those more than 10 m from a road averaged 2505 mg/kg. Contamination was evident in deeper soils and in some cases increased with depth. This finding was consistent with anecdotal evidence that much of the village had been constructed upon slag infill.

Detailed household assessment work undertaken by the Environmental Administration showed that 34 of the 546 homes in the village had active ULAB processing before the project. Just over 50% of all homes (269) had earthen yards and approximately 25% (108) had average surface soil concentrations below 400 mg/kg. A smaller number of homes exceeded the following surface soil concentrations: 400–800 mg/kg (37 homes); 800–1200 mg/kg (20 homes); > 1200 mg/kg (51 homes).

At the close of the project, average surface soil lead concentrations in all 96 targeted yards were confirmed to be below the cleanup threshold value of 100 mg/kg. A 2016 pXRF survey of 20 randomly selected points throughout the village was unable to identify lead in surface soils above the instrument detection limit of 5 mg/kg. A detailed survey of yards after the project was not undertaken.

3.2. Improving ULAB workshop work practices

At the start of the project 34 homes were actively processing batteries in the residential area. A 2016 survey revealed that all processors had either closed or had relocated to the new industrial area. Unfortunately, the same survey also revealed under utilization of the changing room, with most workers preferring to change and bathe at home.

3.3. Blood Lead Levels

The BLLs of 204 Dong Mai children aged 0–6 years were obtained at the beginning of the intervention in December 2013 and six months after its completion in September 2014 with the LeadCare® II. Assessment of BLLs before and after the intervention revealed median blood lead concentrations that decreased by 37%, from 40.35 μg/dL (IQR = 30–59.2) to 25.35 μg/dL (IQR = 19.05–36.85), indicating the intervention helped lower children's lead exposures. Of the 204 children tested, 86% had decreased BLLs (n = 176), 3% showed no change (n = 7), and 14% had increased BLLs during this time period (n = 21).

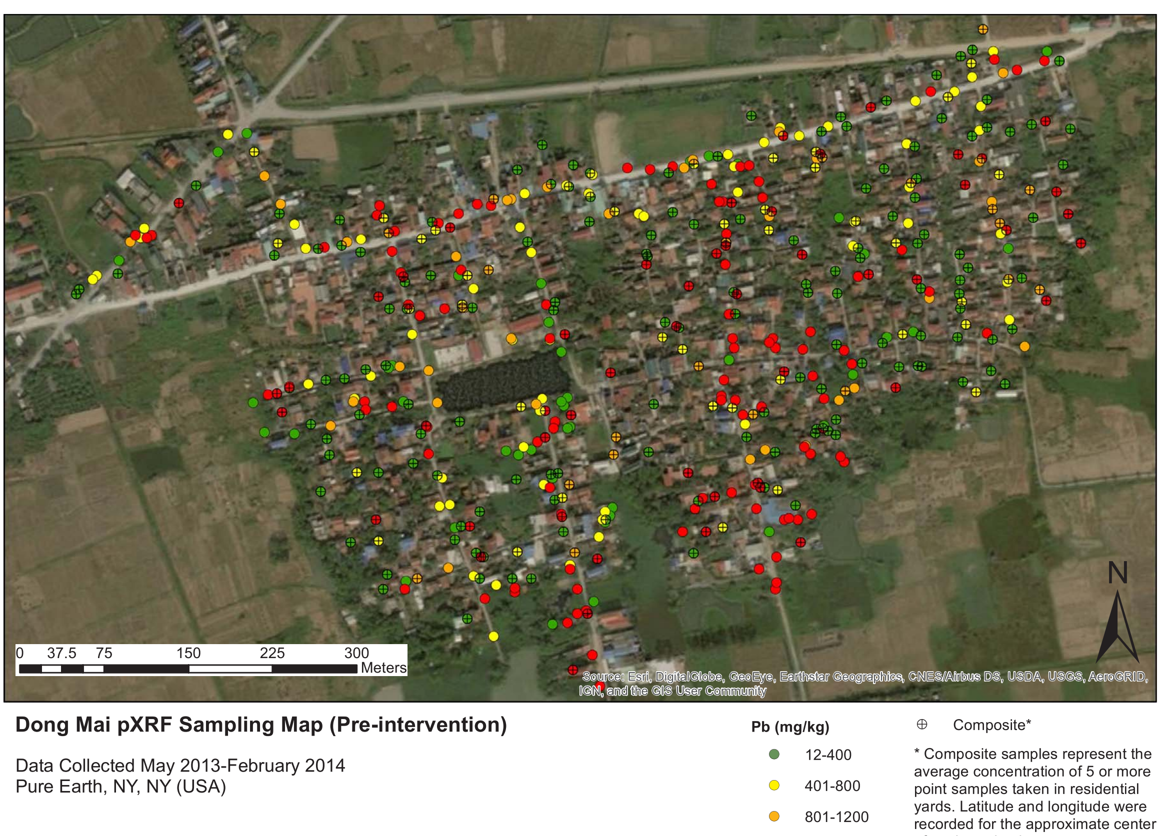


Fig. 2. Surface soil lead concentrations before the intervention. Samples with crosshairs indicate residential yard averages consisting of 5 or more point samples.

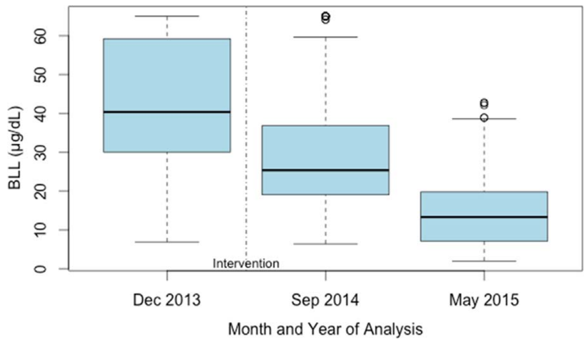


Fig. 3. Results of blood lead levels (BLL) analysis of Dong Mai children (< 6 years) before and after the intervention. Assessment of post remediation BLLs in May 2015 showed exposures were statistically lower than pre-remediation values collected in December 2013 ($t(192) = 21.3511$, $p < .0005$).

The effectiveness of the intervention was benchmarked by additional blood lead analysis in 2015 that comprised 196 children aged 0–6 years, which found further declines in exposures. The median of samples analyzed in 2015 was 13.3 µg/dL (IQR = 7.1–19.8), down from 40.35 µg/dL in December 2013 and 26.35 µg/dL in September 2014. Importantly, when comparing the 2015 analysis to the results 2013 and 2014 data, it is worth noting that the most recent data were derived from analysis of blood using atomic absorption. The 2013 and 2014 analyses were conducted using a LeadCare® II. Fig. 3 summarizes graphically the stepped reduction in blood lead levels from assessments between 2013 and 2015.

Forty-nine (24%) of the children assessed in 2013 had BLLs exceeding the upper detection limit of the LeadCare® II device (65 µg/dL). This number decreased to 11 (5%) in 2014 and 0 in 2015. Because of the large number of children above the upper detection limit in 2013 the median presented for that year is likely much lower than the actual population-wide median.

4. Discussion

It is well-established that lead exposure can result in a number of lifelong health and socioeconomic outcomes including cardiovascular disease, intellectual disability and reduced lifetime earnings (ATSDR, 2007; Lanphear, 2015; Reuben et al., 2017). Other studies have found an association between environmental lead exposure and societal violence (Mielke and Zahran, 2012). In NIOEH's (2015) report on blood lead levels in Dong Mai, they indicate that 16.7% of the children tested showed signs of mental illness, defined as mental retardation, attention deficit hyperactivity, low development of language skills or having difficulties with studying. Pediatric lead exposure is a well established risk factor for these important childhood morbidities (e.g. Baghurst et al., 1992; David, 1976; David et al., 1972; Dietrich et al., 1993; Grandjean and Landrigan, 2006; Lanphear et al., 2005).

In the most severe cases, acute lead poisoning can be fatal. A major lead contamination event in Senegal in 2010 from informal recycling of car batteries resulted in the death of 20 children (Haefliger et al., 2009). A separate event in the Zamfara state of Nigeria in 2012 resulted in the death of more than 500 children in 2012 (Lo et al., 2012). While there were no reported deaths in Dong Mai attributable to lead pollution, chronic lead poisoning can also result in increased morbidity and mortality from a range health effects including cardiovascular disease (Fewtrell et al., 2003). Aerial deposition of lead from previous leaded gasoline emissions globally has been estimated to be responsible for nearly 500,000 excess deaths annually (Forouzanfar et al., 2016). Lead is highly immobile in the environment and likely to remain in surface soils where exposure can continue to occur (Komárek et al., 2008; Kabala and Singh, 2001; Semlali et al., 2004). Therefore without physical intervention, lead contaminated sites in residential environments will continue to pose a risk to human health indefinitely. In the case of informal ULAB sites in LMICs, there is a need to develop cost effective intervention strategies that can be employed using local resources. The magnitude of contamination from ULAB is a major global problem with an estimated 10,599 to 29,241 sites across 90 different LMICs, posing a risk of harm to the health of between 6 and 16 million people (Ericson et al., 2016).

Resources to execute lead exposure mitigation projects in LMICs are typically limited. Gross National Incomes per person in this income group are below USD $12,475 and no existing multilateral agreement to facilitate funding of lead remediation exists (European Commission, 2017; World Bank, 2016a). It is therefore necessary to both prioritize the most severe sites and identify cost-effective approaches to mitigating exposures. In the case of Dong Mai the total project cost was USD $118,750. Future efforts might endeavor to evaluate this project's cost effectiveness relative to other public health interventions (cf. Gould, 2009).

The mitigation method employed by the project offers a number of advantages in the resource-poor context of LMICs when compared to other in-situ and ex-situ approaches (Laidlaw et al., 2016). There is a general dearth of hazardous waste repositories in LMICs, including in Vietnam (Mmereki et al., 2016; Thai, 2009). One facility in the region located some 40 km from Dong Mai agreed to store the material and quoted a disposal cost to the project of $ 400 per m^3. Excavation and disposal of 11,370 m^2 of contaminated surface soils versus capping with clean soils would have had significant budget implications. Assuming excavation of the top 20 cm of soil only, the cost of disposal (before labor, supplies, and transport) would have been approximately USD $909,600, or USD$9475 per house; 4 times the Vietnamese GDP per person (World Bank, 2016b). Thus, the cost of such an approach would have been prohibitive. By contrast, capping a single yard as part of the project incurred total costs of less than USD $1000 and has been shown to be effective at reducing exposure (Laidlaw et al., 2016; Mielke et al., 2011).

Moreover, as has been observed elsewhere, ex-situ methods also potentially carry risks associated with re-mobilizing and removing contaminated soil (Kuppusamy et al., 2016; Wuana and Okieimen, 2011). In this project, Pure Earth identified this as a potential high risk. Factors contributing to this assessment included the likely spillage of material by local haulage trucks of varying quality that would be needed to transfer it through the narrow streets of the village to the waste facility more than 40 km away.

Other in-situ options were also explored, including soil amendments and capping with an impermeable surface. Soil amendments can be blended with lead contaminated soils to reduce the percentage of bioavailable lead, primarily through decreasing its solubility. Phosphorus, bone char, and compost, among others, have all been shown to be effective with decreases of bioavailable lead of up to 66% in laboratory conditions and typically 50% or below in field tests (Brown et al., 2004; Chen et al., 2006; Farfel et al., 2005; Hettiarachchi et al., 2001). Given the high concentrations of lead in soil (average 3940 mg/kg at Dong Mai), amendments would have insufficiently reduced bioavailable lead in this case. Furthermore, soil amendments also carry risks including increased eutrophication and groundwater contamination (Kilgour et al., 2008; Wuana and Okieimen, 2011).

Capping with a more permanent covering of contaminated yards with concrete, tile, paver stones, or other impermeable surface was also explored. Based on concerns of possible perverse incentives, the project opted not to pay for these improvements. Specifically, it was considered possible that the prospect of a capital improvement could inadvertently encourage a homeowner to intentionally contaminate his or her own yard. Soil capping sidesteps this issue providing no capital improvement to earthen yards. In a limited number of cases, homeowners opted to invest in these capital improvements themselves.

This project placed a high value on developing a rapid response. By way of example an early visit resulted in 235 geo-referenced surface samples. A map projecting these samples across the village was provided to the village leadership within two days of the site visit. Any blood lead levels taken within the context of the project were provided to the patient immediately by their local clinician. The duration of the first phase of the project from assessment to completion was 11 months. In addition to urgency, the project emphasized cross-sectional representation of the community in decision-making, accepting the public as a legitimate partner. The importance of this in promoting effective cleanup in lead contaminated environments has been observed previously by the US EPA (Covello and Allen, 1992).

A number of endogenous factors benefitted this project and contributed to the subsequent lowering of blood lead levels in the community. Among these is the fact that the Vietnamese government funded the construction of a new industrial zone before any project intervention work was initiated. In addition, the works undertaken by the Vietnam rural development program to cover every major road contributed to reducing the recirculation of contaminated road dust, which has been identified elsewhere as an the potential source of lead exposure (Zahran et al., 2013). A number of cultural and social factors including near universal literacy, which helped to augment the community education program, are also likely contributors to the lowering of blood lead levels. While these measures are difficult to formally quantify, they formed part of a multi-faceted approach.

Collectively, the direct involvement and ownership of the problem and solution by community was a likely contributor to the broader socialization of project efforts. Similar outcomes in environmental projects have been identified elsewhere (Lester and Temple, 2006). In the case of Dong Mai, the community engagement and ownership is exampled by the road improvement program, self-financed mitigation and the self-relocation of the majority of the informal ULAB recycling activities out of the village. Forward momentum in maintaining and further lowering BLLs in the community is likely to be achieved by continued media attention (e.g. Vietnam Television, 2014) and ongoing government support.

Despite the effectiveness of the intervention, BLLs at Dong Mai remain elevated above acceptable international levels with the most recent median blood leads for children (< 6 years) at 13.3 μg/dL. The CDC recommends that public health action be initiated when BLLs exceed 5 μg/dL (Centers for Disease Control and Prevention, 2017). A significant limitation that remains unaddressed is the ongoing underutilization of the clean-in, clean-out changing room, which would limit exposure pathways from the processing plant back to residential environments. In order to increase its use, deeper and more committed engagement with the recyclers is required, particularly with respect to worker education and hygiene.

This project utilized the USEPA soil screening levels for the purpose of prioritizing yards for intervention. These have recently come under criticism for being insufficiently protective (Jackson, 2009). California for example, maintains a current screening level of 80 mg/kg for residential soils as risk assessments indicate that this level of soil lead equates to a increased BLL < 1 μg/dL, which in turn is < 1 point IQ decrement (Integrated Risk Assessment Branch Office of Environmental Health Hazard Assessment, 2009).

Given the chronic and severe nature of the exposure in the community preceding the intervention, it is likely that skeletal bone in Dong Mai residents will remain a significant reservoir of lead exposure, which poses life-long risks to the community (Silbergeld, 1991; Silbergeld et al., 1992). The half-life of lead in bone is estimated to be from 5 to 19 years, indicating that BLLs will likely remain elevated for some time (Rabinowitz, 1991). Future investigations could target children born after 2015 to better evaluate the efficacy of the intervention and lingering sources so as to target remediation to effect a long-term reduction in adverse exposures.

5. Conclusion

Informal ULAB processing sites in LMICs can produce high environmental lead levels and significant human health exposures. The Dong Mai project resulted in significantly decreased environmental and childhood lead levels. This success resulted from a rapid, well-coordinated response and a focus on a cost-effective execution that could be replicated elsewhere.

Acknowledgments and funding

Project funding was provided by Green Cross Switzerland, the Marilyn S. Broad Foundation, the European Commission, International Lead Management Centre and the University of Washington School of Public Health. Funding for the manuscript was provided in part by the United States Agency for International Development (Cooperative Agreement No. AID-OAA-A-16–00019). BE is a recipient of an International Macquarie University Research Excellence Scholarship (No. 2015275).

References

Abrahams, P.W., 2002. Soils: their implications to human health. Sci. Total Environ. 291, 1–32. http://dx.doi.org/10.1016/S0048-9697(01)01102-0.
Anh, N.D., 2008. Evaluation of Environment and Learning Conditions at Some Craft Villages and its Effects on School Children's Health (Final report). Recommendations of intervention measures, Hanoi, Vietnam.
ATSDR, 2007. ATSDR – Toxicological Profile: Lead [WWW Document]. 〈https://www.atsdr.cdc.gov/toxprofiles/tp.asp?id=96&tid=22〉 (Accessed 11 October 2016).
Baghurst, P.A., McMichael, A.J., Wigg, N.R., Vimpani, G.V., Robertson, E.F., Roberts, R.J., Tong, S.-L., 1992. Environmental exposure to lead and children's intelligence at the age of seven years. N. Engl. J. Med. 327, 1279–1284. http://dx.doi.org/10.1056/NEJM199210293271805.
Braithwaite, J., 2006. Responsive regulation and developing economies. World Dev. 34, 884–898. http://dx.doi.org/10.1016/j.worlddev.2005.04.021.
Brown, S., Chaney, R., Hallfrisch, J., Ryan, J.A., Berti, W.R., 2004. In situ soil treatments to reduce the phyto- and bioavailability of lead, zinc, and cadmium. J. Environ. Qual. 33, 522. http://dx.doi.org/10.2134/jeq. 2004.5220.
Census Bureau, D.I.S, U.S., 2016. International Programs, International Data Base.
Centers for Disease Control and Prevention, 2017. CDC - Lead - Home Page [WWW Document]. URL 〈https://www.cdc.gov/nceh/lead/〉 (Accessed 26 May 2017).
Chatham-Stephens, K., Caravanos, J., Ericson, B., Sunga-Amparo, J., Susilorini, B., Sharma, P., Landrigan, P.J., Fuller, R., 2013. Burden of disease from toxic waste sites in India, Indonesia, and the Philippines in 2010. Environ. Health Perspect. 121, 791–796.
Chen, S.-B., Zhu, Y.-G., Ma, Y.-B., McKay, G., 2006. Effect of bone char application on Pb bioavailability in a Pb-contaminated soil. Environ. Pollut. 139, 433–439. http://dx.doi.org/10.1016/j.envpol.2005.06.007.
Covello, V.T., Allen, F.W., 1992. Seven Cardinal Rules of Risk Communication. US Environmental Protection Agency.
Daniell, W.E., Van Tung, L., Wallace, R.M., Havens, D.J., Karr, C.J., Bich Diep, N., Croteau, G.A., Beaudet, N.J., Duy Bao, N., Daniell, W.E., Van Tung, L., Wallace, R.M., Havens, D.J., Karr, C.J., Bich Diep, N., Croteau, G.A., Beaudet, N.J., Duy Bao, N., 2015. Childhood lead exposure from battery recycling in Vietnam. Biomed. Res. Int. 2015, 1–10. http://dx.doi.org/10.1155/2015/193715.
David, O., 1976. Low lead levels and mental retardation. Lancet 308, 1376–1379. http://dx.doi.org/10.1016/S0140-6736(76)91918-8.
David, O., Clark, J., Voeller, K., 1972. Lead and hyperactivity. Lancet 300, 900–903. http://dx.doi.org/10.1016/S0140-6736(72)92534-2.
Dietrich, K.N., Berger, O.G., Succop, P.A., Hammond, P.B., Bornschein, R.L., 1993. The developmental consequences of low to moderate prenatal and postnatal lead exposure: intellectual attainment in the cincinnati lead study cohort following school entry. Neurotoxicol. Teratol. 15, 37–44. http://dx.doi.org/10.1016/0892-0362(93)90043-N.
Dowling, R., Caravanos, J., Grigsby, P., Rivera, A., Ericson, B., Amoyaw-Osei, Y., Akuffo, B., Fuller, R., 2016. Estimating the prevalence of toxic waste sites in low- and middle-income countries. Ann. Glob. Heal. 0, 11028–11033. http://dx.doi.org/10.1016/J.AOGH.2016.07.008.
EPA, 2015. Hazard Standards for Lead in Paint, Dust and Soil (TSCA Section 403).
Ericson, B., Caravanos, J., Chatham-Stephens, K., Landrigan, P., Fuller, R., 2013. Approaches to systematic assessment of environmental exposures posed at hazardous waste sites in the developing world: the Toxic Sites Identification Program. Environ. Monit. Assess. 185, 1755–1766.
Ericson, B., Landrigan, P., Taylor, M.P., Frostad, J., Caravanos, J., Keith, J., Fuller, R., 2016. The global burden of lead toxicity attributable to informal used lead-acid battery (ULAB) sites. Ann. Glob. Heal. Print. http://dx.doi.org/10.1016/J.AOGH.2016.10.009.
ESRI, 2015. ArcGIS Deskt.
European Commission, 2017. Multilater. Agreem. - Environ. -Eur. Comm. [WWW Doc.].

URL. ⟨http://ec.europa.eu/environment/international_issues/agreements_en.htm⟩ (Accessed 6 November 2017).
Farfel, M., Orlova, A., Chaney, R., Lees, P., Rohde, C., Ashley, P., 2005. Biosolids compost amendment for reducing soil lead hazards: a pilot study of Orgro? Amendment and grass seeding in urban yards. Sci. Total Environ. 340, 81–95. http://dx.doi.org/10.1016/j.scitotenv.2004.08.018.
Farías, P., Álamo-Hernández, U., Mancilla-Sánchez, L., Texcalac-Sangrador, J., Carrizales-Yáez, L., Riojas-Rodríguez, H., 2014. Lead in school children from Morelos, Mexico: levels, sources and feasible interventions. Int. J. Environ. Res. Public Health 11, 12668–12682. http://dx.doi.org/10.3390/ijerph111212668.
Fewtrell, L., Kaufmann, R., Prüss-Üstün, A., 2003. Lead: Assessing the Environmental Burden of Disease at National and Local Levels, WHO Environmental Burden of Disease Series, No. 2. World Health Organization.
Forouzanfar, M., Murray, C.J., Afshin, A., 2016. GBD 2015 risk factors collaborators. Global, regional, and national comparative risk assessment of 79 behavioral, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease S. Lancet 388, 1659–1724.
Gonzalez, C.A., Choquette, S.J., Beck, C., Butler, R., Oflaz, D., Howard, M.E., Lindstrom, R.M., Long, S.E., Mackey, E.A., Mann, J.L., Murphy, K.E., Paul, R.L., Sieber, J.R., Vocke, R.D., Wood, L.J., Yu, L.L., Zeisler, R.L., Willie, S., Lam, J.W.H., Scriver, C., Yang, L., Wilson, S.A., Adams, M., Briggs, P.H., Lamothe, P., Siems, D., Taggart, J., 2016. Certif. Anal.
Gould, E., 2009. Childhood lead poisoning: conservative estimates of the social and economic benefits of lead hazard control. Environ. Health Perspect. 117, 1162–1167. http://dx.doi.org/10.1289/ehp.0800408.
Grandjean, P., Landrigan, P.J., 2006. Developmental neurotoxicity of industrial chemicals. Lancet (Lond., Engl.) 368, 2167–2178. http://dx.doi.org/10.1016/S0140-6736(06)69665-7.
Haefliger, P., Mathieu-Nolf, M., Lociciro, S., Ndiaye, C., Coly, M., Diouf, A., Faye, A.L., Sow, A., Tempowski, J., Pronczuk, J., Filipe Junior, A.P., Bertollini, R., Neira, M., 2009. Mass lead intoxication from informal used lead-acid battery recycling in dakar, senegal. Environ. Health Perspect. 117, 1535–1540. http://dx.doi.org/10.1289/ehp.0900696.
Harvey, P.J., Taylor, M.P., Kristensen, L.J., Grant-Vest, S., Rouillon, M., Wu, L., Handley, H.K., 2016. Evaluation and assessment of the efficacy of an abatement strategy in a former lead smelter community, Boolaroo, Australia. Environ. Geochem. Health 38, 941–954. http://dx.doi.org/10.1007/s10653-015-9779-8.
Hettiarachchi, G.M., Pierzynski, G.M., Ransom, M.D., 2001. In situ stabilization of soil lead using phosphorus. J. Environ. Qual. 30, 1214. http://dx.doi.org/10.2134/jeq.2001.3041214x.
Integrated Risk Assessment Branch Office of Environmental Health Hazard Assessment, 2009. Revised California Human Health Screening Levels for Lead.
Jackson, L., 2009. EPA Lead. Stand. Petition.
Kabala, C., Singh, B.R., 2001. Fractionation and mobility of copper, lead, and zinc in soil profiles in the vicinity of a copper smelter. J. Environ. Qual. 30, 485. http://dx.doi.org/10.2134/jeq. 2001.302485x.
Keith, J., Ericson, B., 2013. House Cleaning Protocol III.
Kilgour, D.W., Moseley, R.B., Barnett, M.O., Savage, K.S., Jardine, P.M., 2008. Potential negative consequences of adding phosphorus-based fertilizers to immobilize lead in soil. J. Environ. Qual. 37, 1733. http://dx.doi.org/10.2134/jeq. 2007.0409.
Komárek, M., Ettler, V., Chrastný, V., Mihaljevič, M., 2008. Lead isotopes in environmental sciences: A review. Environ. Int. 34 (4), 562–577. http://dx.doi.org/10.1016/j.envint.2007.10.005.
Kristensen, L.J., Taylor, M.P., Flegal, A.R., 2017. An odyssey of environmental pollution: the rise, fall and remobilisation of industrial lead in Australia. Appl. Geochem. http://dx.doi.org/10.1016/j.apgeochem.2017.02.007.
Kuppusamy, S., Palanisami, T., Megharaj, M., Venkateswarlu, K., Naidu, R., 2016. Ex-situ remediation technologies for environmental pollutants: a critical perspective. Rev. Environ. Contam. Toxicol. 236, 117–192.
Laidlaw, M.A.S., Filippelli, G.M., Brown, S., Paz-Ferreiro, J., Reichman, S.M., Netherway, P., Truskewycz, A., Ball, A.S., Mielke, H.W., 2016. Case studies and evidence-based approaches to addressing urban soil lead contamination. Appl. Geochem. http://dx.doi.org/10.1016/j.apgeochem.2017.02.015.
Lanphear, B.P., 2015. The impact of toxins on the developing brain. Annu. Rev. Public Health 36, 211–230. http://dx.doi.org/10.1146/annurev-publhealth-031912-114413.
Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., Canfield, R.L., Dietrich, K.N., Bornschein, R., Greene, T., Rothenberg, S.J., Needleman, H.L., Schnaas, L., Wasserman, G., Graziano, J., Roberts, R., 2005. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. Environ. Health Perspect. 113, 894–899. http://dx.doi.org/10.1289/ehp.7688.
Lester, C., Temple, M., 2006. Health impact assessment and community involvement in land remediation decisions. Public Health 120, 915–922. http://dx.doi.org/10.1016/j.puhe.2006.05.011.
Lo, Y.-C., Dooyema, C.A., Neri, A., Durant, J., Jefferies, T., Medina-Marino, A., de Ravello, L., Thoroughman, D., Davis, L., Dankoli, R.S., Samson, M.Y., Ibrahim, L.M., Okechukwu, O., Umar-Tsafe, N.T., Dama, A.H., Brown, M.J., 2012. Childhood lead poisoning associated with gold ore processing: a village-level investigation—Zamfara State, Nigeria, October–November 2010. Environ. Health Perspect. 120, 1450–1455. http://dx.doi.org/10.1289/ehp.1104793.
Mahanty, S., Dang, T.D., 2013. Crafting sustainability? The potential and limits of institutional design in managing water pollution from Vietnam's Craft Villages. Soc. Nat. Resour. 26, 717–732. http://dx.doi.org/10.1080/08941920.2012.708822.
Matte, T.D., Figueroa, J.P., Ostrowski, S., Burr, G., Jackson-Hunt, L., Baker, E.L., 1991. Lead exposure from conventional and cottage lead smelting in Jamaica. Arch. Environ. Contam. Toxicol. 21, 65–71. http://dx.doi.org/10.1007/BF01055558.
Meyer, P.A., Brown, M.J., Falk, H., 2008. Global approach to reducing lead exposure and poisoning. Mutat. Res. Mutat. Res. 659, 166–175. http://dx.doi.org/10.1016/j.mrrev.2008.03.003.
Mielke, H.W., Reagan, P.L., 1998. Soil is an important pathway of human lead exposure. Environ. Health Perspect. 217–229.
Mielke, H.W., Zahran, S., 2012. The urban rise and fall of air lead (Pb) and the latent surge and retreat of societal violence. Environ. Int. 43, 48–55. http://dx.doi.org/10.1016/j.envint.2012.03.005.
Mielke, H.W., Covington, T.P., Mielke, P.W., Wolman, F.J., Powell, E.T., Gonzales, C.R., 2011. Soil intervention as a strategy for lead exposure prevention: the New Orleans lead-safe childcare playground project. Environ. Pollut. 159, 2071–2077. http://dx.doi.org/10.1016/j.envpol.2010.11.008.
Mmereki, D., Baldwin, A., Hong, L., Li, B., 2016. The management of hazardous waste in developing countries. In: Management of Hazardous Wastes. InTech, http://dx.doi.org/10.5772/63055.
Needleman, H., 2004. Lead poisoning. Annu. Rev. Med. 55, 209–222. http://dx.doi.org/10.1146/annurev.med.55.091902.103653.
NIOEH, 2015. Blood Test Results, Dong Mai, May 2015. Hanoi, Vietnam.
Noguchi, T., Itai, T., Tue, N.M., Agusa, T., Ha, N.N., Horai, S., Trang, P.T.K., Viet, P.H., Takahashi, S., Tanabe, S., 2014. Exposure assessment of lead to workers and children in the battery recycling craft village, Dong Mai, Vietnam. J. Mater. Cycles Waste Manag. 16, 46–51. http://dx.doi.org/10.1007/s10163-013-0159-0.
Prüss-Üstün, A., Fewtrell, L., Landrigan, P.J., Ayuso-Mateos, J.L., 2010. Lead exposure. In: Comparative Quantification of Health Risks. World Health Organization, Geneva.
Pure Earth, 2017. Completed Projects - Pure Earth [WWW Document]. URL ⟨http://www.pureearth.org/projects/completed-projects/⟩ (Accessed 9 August 2017).
Rabinowitz, M.B., 1991. Toxicokinetics of bone lead. Environ. Heal. Perspect. Vo 91, 33–37.
Reuben, A., Caspi, A., Belsky, D.W., Broadbent, J., Harrington, H., Sugden, K., Houts, R.M., Ramrakha, S., Poulton, R., Moffitt, T.E., 2017. Association of childhood blood lead levels with cognitive function and socioeconomic status at age 38 years and with IQ change and socioeconomic mobility between childhood and adulthood. Jama 317, 1244. http://dx.doi.org/10.1001/jama.2017.1712.
Rouillon, M., Taylor, M.P., 2016. Can field portable X-ray fluorescence (pXRF) produce high quality data for application in environmental contamination research? Environ. Pollut. 214, 255–264. http://dx.doi.org/10.1016/j.envpol.2016.03.055.
Rouillon, M., Taylor, M.P., Dong, C., 2017. Reducing risk and increasing confidence of decision making at a lower cost: in-situ pXRF assessment of metal-contaminated sites.
Schwartz, J., Pitcher, H., 1989. The relationship between gasoline lead and blood lead in the United States. J. Off. Stat. 5, 421–431.
Semlali, R.M., Dessogne, J., Monna, F., Bolte, J., Azimi, S., Navarro, N., Denaix, L., Loubet, M., Chateau, C., van Oort, F., 2004. Model. Lead. Input Output Soils Using Lead. Isot. Geochem. http://dx.doi.org/10.1021/ES0341384.
Shen, H., Peters, T.M., Casuccio, G.S., Lersch, T.L., West, R.R., Kumar, A., Kumar, N., Ault, A.P., 2016. Elevated concentrations of lead in particulate matter on the neighborhood-scale in Delhi, india as determined by single particle analysis. Environ. Sci. Technol. 50, 4961–4970. http://dx.doi.org/10.1021/acs.est.5b06202.
Silbergeld, E.K., 1991. Lead in bone: implications for Aation. Environ. Health Perspect. 91, 63–70.
Silbergeld, E.K., Sauk, J., Somerman, M., Todd, A., McNeill, F., Fowler, B., Fontaine, A., van Buren, J., 1992. Lead in bone: storage site, exposure source, and target organ. Neurotoxicology 14, 225–236.
Stanek, E.J., Calabrese, E.J., 1995. Daily estimates of soil ingestion in children. Environ. Health Perspect. 103, 276–285.
StataCorp, L.P., 2015. Stata Stat. Softw.: Release 14.
Thai, N.T.K., 2009. Current status of hazardous industrial waste in Vietnam. J. Mater. Cycles Waste Manag 11, 258–262. http://dx.doi.org/10.1007/s10163-009-0239-3.
Tung, L.Van., 2011. Lead Recycling Practice and Childhood Lead Exposure in a Village Setting of Vietnam (Unpublished project proposal). Hanoi, Vietnam.
Vietnam, T.S.R., 2015. National technical regulation on the allowable limits of heavy metals in the soils. Vietnam.
Vietnam Television, 2014. Skill Escape: Living in the environment of lead pollution [WWW Document]. VTV Online. URL ⟨http://vtv.vn/video-dac-sac/ki-nang-thoat-hiem-song-trong-moi-truong-o-nhiem-chi-130104.htm⟩ (Accessed 1 February 2017).
Wilson, B., 2013. Visit Report, Dong Mai.
World Bank, 2016a. World Bank Ctry. Lend. Groups – World Bank Data Help Desk-. [WWW Doc.]. URL. ⟨https://datahelpdesk.worldbank.org/knowledgebase/articles/906519⟩ (Accessed 10 October 2016).
World Bank, 2016b. GDP per Capita (Curr. US$) Data [WWW Doc.]. URL. ⟨http://data.worldbank.org/indicator/NY.GDP.PCAP.CD⟩ (Accessed 11 October 2016).
Wuana, R.A., Okieimen, F.E., 2011. Heavy metals in contaminated soils: a review of sources, chemistry, risks and best available strategies for remediation. Isrn Ecol. 2011.
Yabe, J., Nakayama, S.M.M., Ikenaka, Y., Yohannes, Y.B., Bortey-Sam, N., Oroszlany, B., Muzandu, K., Choongo, K., Kabalo, A.N., Ntapisha, J., Mweene, A., Umemura, T., Ishizuka, M., 2015. Lead poisoning in children from townships in the vicinity of a lead–zinc mine in Kabwe, Zambia. Chemosphere 119, 941–947. http://dx.doi.org/10.1016/j.chemosphere.2014.09.028.
Yang, K., Cattle, S.R., 2017. Effectiveness of cracker dust as a capping material for Pb-rich soil in the mining town of Broken Hill, Australia. CATENA 148, 81–91. http://dx.doi.org/10.1016/j.catena.2016.02.022.
Zahran, S., Laidlaw, M.A.S., McElmurry, S.P., Filippelli, G.M., Taylor, M., 2013. Linking source and effect: resuspended soil lead, air lead, and children's blood lead levels in Detroit, Michigan. Environ. Sci. Technol. 47, 2839–2845. http://dx.doi.org/10.1021/es303854c.

INFORME ANUAL DE ACTIVIDADES

COLOMBIA 2017

1. Introducción

Pure Earth es una organización sin fines de lucro con base en Nueva York que colabora con gobiernos, ONGs y grupos comunitarios para solucionar problemas ambientales que amenazan la vida en países de ingresos bajos y medios. Además de dirigir el Programa de Identificación de Sitios Contaminados (TSIP, por sus siglas en ingles), Pure Earth conduce proyectos de intervención para mitigar riesgos de salud en sitios contaminados.

Pure Earth ha desarrollado proyectos en países de Latinoamérica como Perú, Bolivia, Brasil, Argentina y Uruguay entre otros. Para el mes de octubre de 2016 se pudo establecer un proyecto de cooperación para Colombia bajo la financiación de la Agencia de los Estados Unidos para el Desarrollo Internacional – USAID, y la aceptación por parte del gobierno de Colombia a través del Ministerio de Ambiente y Desarrollo Sostenible (MADS).

El proyecto consiste en la aplicación del Programa Para la Identificación de Sitios Contaminados o Tóxicos - TSIP (Toxic Site Investigación Program) en Colombia, Jamaica, Bangladesh, Filipinas, Vietnam, Senegal, India y Mongolia. El programa tiene un periodo de ejecución desde abril de 2016 hasta septiembre de 2018.

Los objetivos del proyecto son:

- Hacer el mayor número de investigaciones de sitios en sospecha de investigación.
- Lograr el involucramiento de las entidades de gobierno central y regional en las investigaciones.
- Desarrollar el diseño de proyectos pilotos de intervención en sitios considerados como prioritarios.

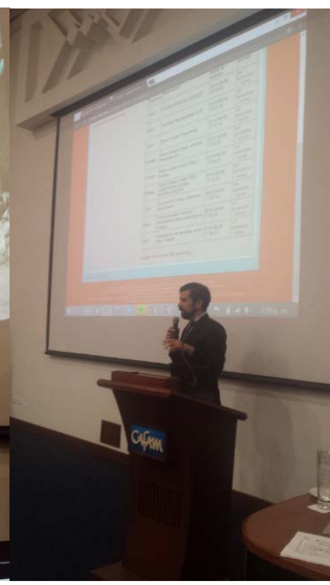
Fondos adicionales para el trabajo en Colombia se han recibido por parte de la Comisión Europea y de la Organización de las Naciones Unidas para el Desarrollo Industrial (UNIDO)

Para mayor sobre este y otro proyectos de Pure Earth puede visitarnos en www.pureearth.org

2. Curso de entrenamiento programa TSIP

En el mes de diciembre de 2016 se llevó a cabo el curso de entrenamiento para el Programa Para la Identificación de Sitios Contaminados o Tóxicos - TSIP. Este curso fue dirigido principalmente a los investigadores de Pure Earth que desarrollaron las investigaciones durante el 2017 y a funcionarios de las diferentes autoridades ambientales regionales (Corporaciones Ambientales), Secretarias de Ambiente y Ministerio de Ambiente y Desarrollo Sostenible.

El curso tuvo lugar en la ciudad de Bogotá en el Centro de Convenciones de Cafam de la Floresta y fue impartido por los siguientes entrenadores:

John Keith (TAB Pure Earth) | Daniel Estrada (Pure Earth Mexico) | Alfonso Rodriguez (Pure Earth Colombia)

Fueron entrenados 11 investigadores de diferentes profesiones como microbiología, ingenieros ambientales e ingenieros químicos con experiencia en evaluaciones ambientales, de los cuales fuero 4 hombres y 7 mujeres. La base de estos investigadores es Bogotá, Barranquilla y Cali.

Grupo de investigadores Pure Earth Colombia

Por parte de las entidades de gobierno se entrenaron 22 personas de las cuales 5 eran del Ministerio de Ambiente y Desarrollo Sostenible y 17 de las Corporaciones Ambientales de Cundinamarca, Atlántico, Valle del Cauca, Nariño, Secretaria de Ambiente de Bogotá y DAGMA de Cali y EPA Cartagena. La distribución por genero fue de 10 hombres y 11 mujeres.

Grupo de funcionarios de autoridades ambientales en Colombia

Como parte del curso de entrenamiento se desarrolló una visita a uno de los sitios con sospecha de contaminación; este sitio corresponde a una antigua cantera de extracción de roca y que según indicios de la Corporación Ambiental de Cundinamarca está siendo utilizada como sitio de disposición de residuos peligrosos. El sitio está ubicado en el sector de Soacha (1 hora de Bogotá) en donde el 100% de los asistentes del curso tuvo la oportunidad de interactuar en la toma de muestras de suelo y recolección de información primaria que será ingresada a la base de datos del programa TSIP de Pure Earth. Posterior a la visita en campo los asistentes recibieron la capacitación de manejo y uso de la base de datos, la cual es utilizada a nivel por Pure Earth para la compilación de la información.

Visita a campo en entrenamiento de TSIP - Colombia

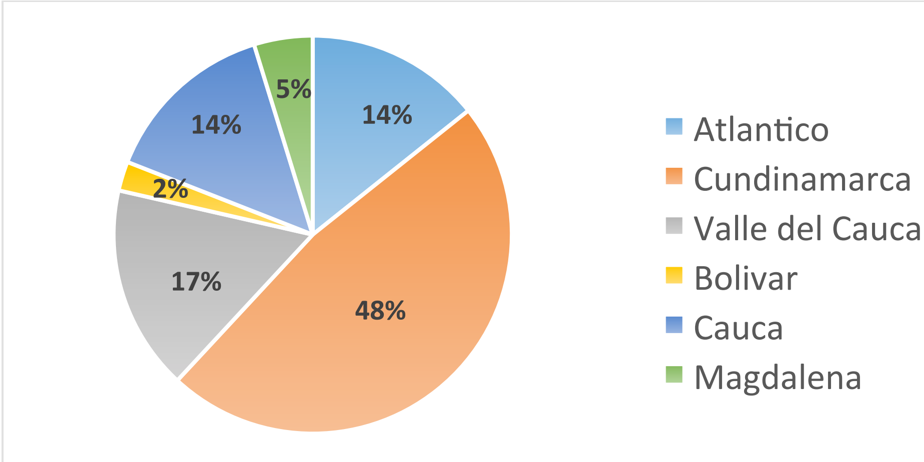
3. Investigaciones de sitios

Por direccionamiento del Ministerio de Ambiente y Desarrollo Sostenible, se escogieron 5 zonas del territorio colombiano para iniciar las investigaciones a sitios, estas zonas fueron: Atlántico, Nariño, Valle del Cauca, Cauca y Cundinamarca, incluyendo a Bogotá. Igualmente se establecieron como contaminantes prioritarios Pesticidas, Poli Cloro Bifenilos (PCB) y metales pesados como plomo, cadmio, arsénico, cromo y cobre. Aunque en un principio mercurio no era parte del esquema fue tenido en cuenta acorde a las necesidades de las diferentes corporaciones ambientales que estuvieron involucradas.

La identificación de los sitios partió principalmente de información proporcionada por el MADS, Corporaciones Autónomas regionales de Cundinamarca, Atlántico, Valle del Cauca, Bolívar, la Secretaria de Ambiente de Bogotá, Secretaria de Salud de Cundinamarca, Ministerio de Salud y Protección Social, el Dagma entre otras. Así mismo para muchas de las visitas de campo la presencia de funcionarios de las autoridades ambientales fue fundamental para el levantamiento de información.

En el año 2017 se realizaron 42 investigaciones de sitios con sospecha de investigación bajo el programa TSIP distribuidas geográficamente de la siguiente forma:

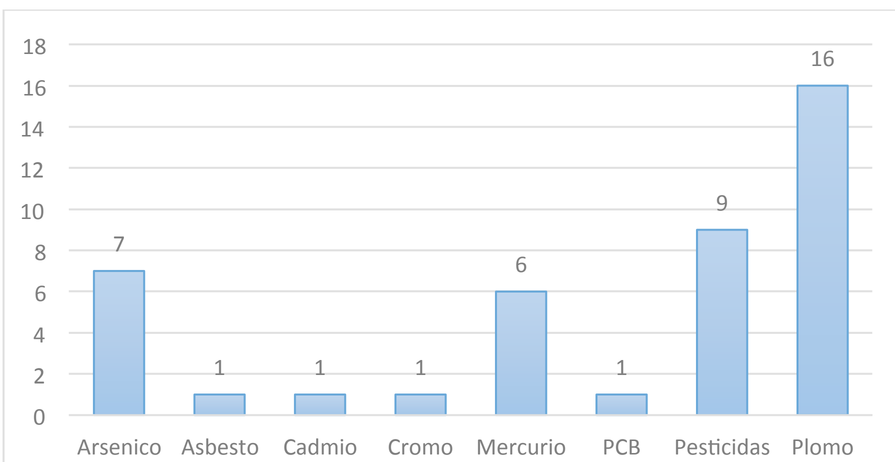
Departamento	***Nro de Investigaciones***
Atlántico	6
Cundinamarca	20
Valle del Cauca	7
Bolívar	1
Cauca	6
Magdalena	2



Distribución Geográfica de Investigaciones en el Programa TSIP en Colombia

La mayor cantidad de investigaciones se desarrollaron en el departamento de Cundinamarca, esto debido a la cantidad de información suministrada por la Corporación Autónoma Regional (CAR) y la Secretaria de Salud de Cundinamarca, los cuales han sido actores muy activos en el proceso.

De igual forma la distribución de las investigaciones por los tipos de contaminantes se muestra en la siguiente gráfica



Distribución de Investigaciones en el Programa TSIP en Colombia por tipo de Contaminante

El mayor número de investigaciones por tipo de contaminante corresponde al Plomo con un total de 16 investigaciones (Cundinamarca 6, Atlántico 4, Valle del Cauca 4, Bolívar 1 y Magdalena 1). Este dato corresponde al contaminante tomado como contaminante principal para la investigación, ya que para muchas investigaciones se tomaron varios tipos de contaminantes en su análisis, toda la información detallada de análisis de cada contaminante se encuentra consignada en la base de datos del programa TSIP.

Base de datos TSIP

La información contenida en la base de datos es de carácter público y su acceso se puede hacer por medio del sitio web www.co.dbisa.org, sin embargo es necesario solicitar un usuario y clave de acceso por control de consulta.

Esta base de datos almacena la información divida en seis (6) secciones las cuales son:

1. Información referente al Riesgo
2. Descripción física
3. Movilización del contaminante
4. Partes interesadas
5. Descripción de la intervención propuesta
6. Informes e imágenes de soporte

Uno de los objetivos principales de la base de datos es centralizar la información que se levanta de las investigaciones a nivel mundial la cual llega a más de 3,400 sitios en 47 países, otro objetivo corresponde a determinar la prioridad de intervención a sitios que se consideren de alto riesgo por medio del cálculo de un índice denominado el "Índice Black Smith", el cual en un rango de 0 a 10 otorga un nivel de intervención siendo "0" un nivel que no requiere intervención hasta el "10" que corresponde a un sitio que requiere intervención prioritario y urgente.

Cabe aclarar que el programa TSIP no tienen dentro de su alcance la intervención del sitio, únicamente el diseño de una posible intervención en sitios prioritarios.

4. Investigaciones detalladas

Acorde a la información recolectada por las investigaciones TSIP del año 2017 se pudo identificar que existían niveles representativos de Plomo en el ambiente en tres municipios de Colombia, uno corresponde a Malambo en el Departamento del Atlántico, otro al corregimiento de la Dolores, más específicamente al sector Del Paso pertenecientes al municipio dePalmira del Departamento del Valle del Cauca y uno último en Soacha Cundinamarca.

Para estos dos sitios con sospecha de contaminación se decidió ejecutar una serie de investigaciones detalladas con el fin de comprobar el nivel de afectación por plomo (Pb) a las personas residentes de los sitios y así mismo diseñar un plan de intervención para reducir o evitar la exposición a esta contaminación. A continuación se describen los dos màs relevantes en el proyecto.

4.1. La Dolores, Sector el Paso (Palmira, Valle del Cauca)

La parcelación industrial La Dolores es un corregimiento ubicado en el perímetro rural de Palmira en el departamento del Valle del Cauca, Colombia. Geográficamente, se localiza al occidente del municipio de Palmira limita al noroeste con el municipio de Yumbo y al oeste con el Municipio de Cali, el cual se encuentra separado por el río Cauca. El acceso al corregimiento es por la vía Cali-Palmira. Es una zona de tipología reticulada, esto es, una estructura conformada por una evidente malla urbana que ordena unas manzanas muy bien definidas

4.1.1. Antecedentes

De acuerdo a información facilitada por uno de los líderes de la comunidad, la cual fue recolectada en la fase de campo inicial de las investigaciones TSIP, hace aproximadamente 6 años se han radicado quejas y derechos de petición ante la

Corporación Autónoma Regional del Valle del Cauca-CVC, Secretaria de Salud Palmira y Alcaldía de Palmira por el impacto que la comunidad del sector El Paso recibe a diario en sus hogares debido a emisiones de gases aparentemente no controladas de las industrias ubicadas en ese sector por la recuperación de plomo. Como respuesta a las quejas presentadas por la comunidad, en febrero del año 2015, la Secretaria de Salud de Palmira efectuó a través del laboratorio Clínico & Microbiológico Elmer Arboleda un tamizaje de plomo en sangre a 51 individuos del corregimiento La Dolores. La selección de la población osciló entre los 16 y 78 años de edad, 61% mujeres y 38% hombres. Según reporte de la Secretaria de Salud de Palmira del 04 de Marzo de 2015, se considera intoxicación desde 77 µg /dL y en población no expuesta al plomo es aceptable hasta 38 µg /dL. En tal caso, ninguno de los 51 casos analizados presenta exposición, no obstante, de acuerdo a la Organización Mundial de la Salud-OMS *"Incluso las concentraciones en sangre que no superan los 5 µg/dl –nivel hasta hace poco considerado seguro– pueden entrañar una disminución de la inteligencia del niño, así como problemas de comportamiento y dificultades de aprendizaje*" (http://www.who.int/ipcs/features/lead..pdf). Igualmente, El Centro para el Control de Enfermedades (CDC) de los Estados Unidos reporta que los niveles a los cuales se debe considerar atención de seguimiento tanto para niños y como adultos es de 5 µg /dL

Entre el 2015 y el 2017, se realizaron dos estudios de material particulado PM 10, PM 2.5 y Plomo realizado por la Corporación Autónoma Regional del Valle del Cauca -CVC. El primero de ellos realizó un monitoreo entre septiembre del 2015 y junio del 2016 que evidenció el incumplimiento en los criterios de emisión conforme a la Resolución 610/2010 del Ministerio de Ambiente y Desarrollo Sostenible- MADS. El segundo informe tuvo un monitoreo corto entre diciembre 2016 y enero 2017, en una época de lluvia. Los resultados indicaron concentraciones de plomo inferiores a los valores de referencia conforme a lo declarado por la Res. 610/2010.

Para estos dos sitios con sospecha de contaminación se decidió ejecutar una serie de investigaciones detalladas con el fin de comprobar el nivel de afectación por plomo (Pb) a las personas residentes de los sitios y así mismo diseñar un plan de intervención para reducir o evitar la exposición a esta contaminación.

Cabe anotar que según acuerdo 109 por el cual se adopta el Plan de Ordenamiento Territorial del municipio de Palmira (POT), la parcelación industrial La Dolores está clasificada como un núcleo especializado y su asignación de los usos del suelo se determina como Área de Actividad Industrial Mixta. Los núcleos especializados son aquellos cuyas características y usos principales corresponden a industrial manufacturero, agroindustrial e investigación científica con actividades complementarias de apoyo al uso principal.

4.1.2. Inspección, toma de muestras y resultados

PureEarth realizó la primera visita de inspección durante los días 14 y 15 de junio de 2017 en donde se seleccionaron 9 puntos que se describen enseguida y que se encuentran asociados en el informe CO-5399 de la base de Datos de Sitios Contaminados de PureEarth. Es importante resaltar que cinco de las nueve muestras seleccionadas se tomaron dentro de las viviendas más expuestas porque fue en ellas que se identificó un ambiente notablemente denso de material particulado, así mismo el vapor metálico que emanan ambas plantas de recuperación de plomo se percibe intenso, fuerte y algunas veces sofocante. Igualmente se desarrollaron entrevistas con la comunidad, docentes, policía, líderes comunales, gerente de una de las fábricas fundidora de plomo, registro de evidencias fotográficas, coordenadas del sitio y de los puntos de muestreo seleccionados.

Toma de muestras de suelo superficial en predios residenciales de La Dolores

De acuerdo al informe de ensayo BO1705638 y BO1705639 entregado por el laboratorio SGS se puede concluir que tres de las nueve muestras tomadas en el sitio La Dolores arrojan valores de plomo por encima del valor permisible para suelo residencial, esto es, según la Agencia de Protección Ambiental de Estados Unidos (EPA) de 400 mg/kg. En cambio, las muestras de agua están dentro del valor de referencia de 5,000 µg/L para agua de irrigación. Sin embargo, se debe hacer una revisión más profunda de esta agua ya que los límites permisibles para agua potable están en el orden de 10 a 15 µg/L y aunque la comunidad expresa que el agua de lluvia que recolectan se utiliza para labores domésticas, también algunos vecinos mencionaron que el agua puede ser utilizada para dar de beber a los animales. La siguiente tabla muestra el detalle de los resultados.

Muestra No.	Tipo de muestra	Características de la recolección	Coordenadas	Concentración reportada
1	Agua	Tubería que proviene de tanque aéreo (Acumulación de aguas lluvias con posible material particulado. Lejos de las industrias referentes.	Long:76.474915 Lat:3.501042;	5.4 µg/L
2	Agua	2 días expuesta a la intemperie	Long:76.483137 Lat:3.498254	88 µg/L
3	Agua	Caneca del tercer piso de la vivienda con aparentes partículas metálicas visibles. Tiempo de permanencia > 1 día	Long: 76.483379 Lat:3.498099	370 µg/L
4	Suelo	Mezcla de suelo de plantas del último piso y barrido de casa (partículas que se asientan en la ropa y piso)	Long:76,483379 Lat:3.498099	6,423 mg/kg
5	Agua	De tanque de lavado de ropa (t permanencia<1 día)	Long:76.483232 Lat:3.498183	81 µg/L
6	Suelo	Mezcla suelo de plantas del segundo piso más barrido de casa	Long:76.484022 Lat:3.497592	86 mg/kg
7	Suelo	Cultivo de caña cercano a la población.	Long: 76.484706 Lat:3.497566	23 mg/kg
8	Suelo	Canal de agua que desemboca a entrada principal de una de las industrias fundidoras	Long: 76.482814 Lat:3.49672	8,937 mg/kg
9	Suelo	Frente a entrada de otra industria fundidora	Long: 76.482814 Lat:3.49672	7,663 mg/kg

Resultado muestras en el Sector del Paso, La Dolores

La muestra No. 4 se considera la de mayor impacto en el resultado de las mediciones ya que se tomó de una vivienda que está localizada justo detrás de una de las fábricas de fundición de plomo. La muestra No. 4 confirma la presencia de plomo en el aire que se libera como material particulado (emisión atmosférica) y se deposita posteriormente en el suelo. Las muestras No. 8 y 9 provienen de las entradas vehiculares de las fábricas fundidoras de Plomo activas, sendas industrias están localizadas atrás del sector residencial afectado.

La muestra No. 8 presentó una concentración de 8,937 mg/kg Pb. Se tomó en la desembocadura de una canal de agua que viene de una de las industrias activas lo cual puede dar una idea de las características de su proceso y del plan de manejo ambiental al interior de sus instalaciones. Las concentraciones de las muestras de agua No. 2, 3 y 5 se tomaron de tanques de agua y se han señalado en amarillo porque pueden ser potencialmente toxicas respecto al tiempo de permanencia de la caneca expuesta al aire libre y a su uso. Una de las razones por las que se muestrearon las canecas de recolección de aguas lluvias que dispone la comunidad del sector El Paso es porque este tipo de prácticas hace parte de la cultura del sitio afectado y actualmente continúa siendo una hábito recoger el agua lluvia para lavado de ropa, riego y limpieza en general. El potencial impacto radica en que la caneca puede permanecer 1 día o más de 5 días a la intemperie antes de ser usada, por lo que puede representar una fuente de acumulación de partículas de plomo que caen por gravedad o por acción facilitada de la lluvia.

4.1.3. Análisis con XRF

El equipo técnico de PureEarth y los representantes de USAID realizaron el 23 de agosto de 2017 una visita al sitio de la Dolores. El objetivo de la visita fue hacer una confirmación de los datos obtenidos en la primera investigación haciendo mediciones in-situ con la pistola de XRF con el fin de determinar la extensión de la contaminación en el sitio.

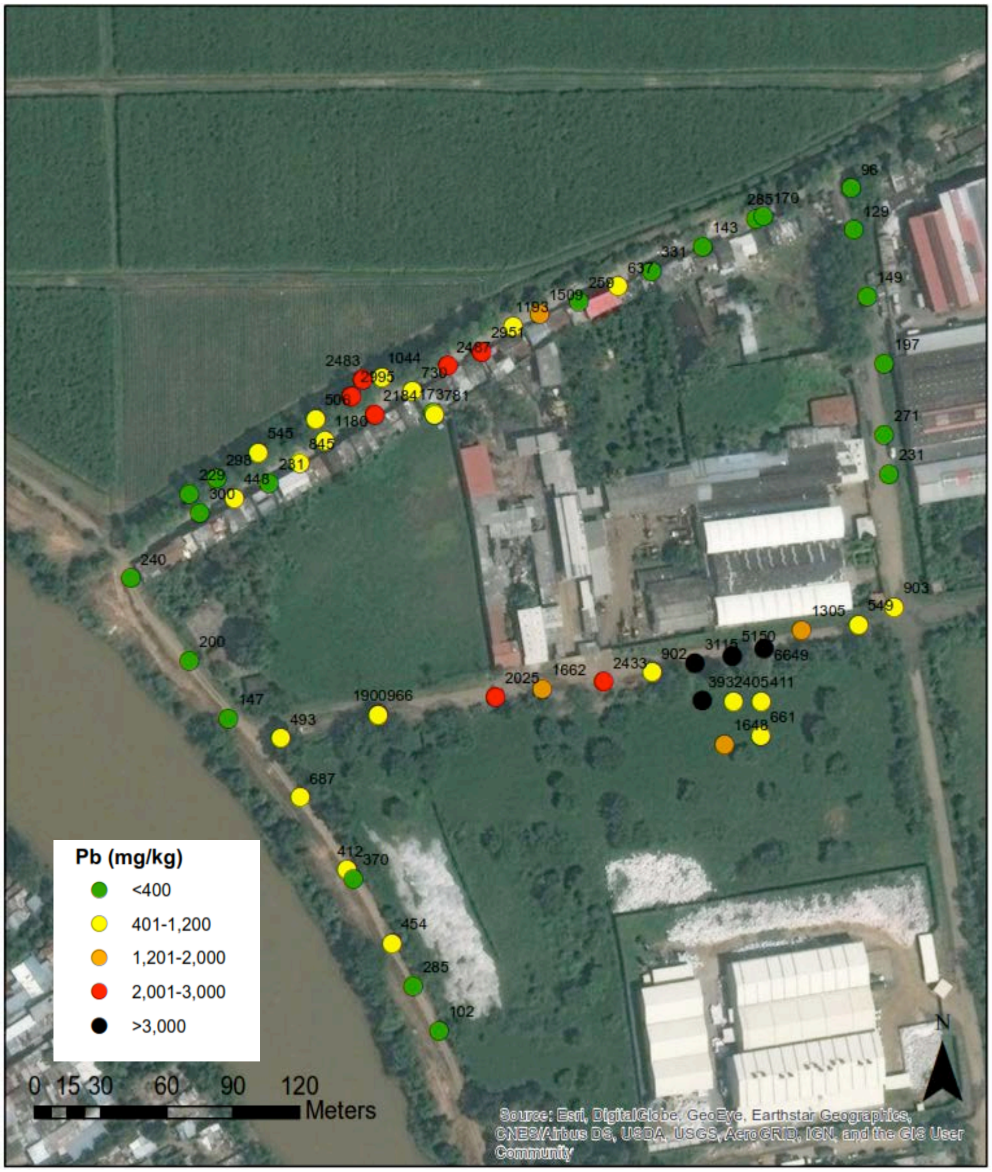
El XRF (X-RayFluorescence) es un equipo de fluorescencia de rayos X que permite la identificación de metales pesados presentes en el sitio de la lectura. Este equipo puede ser calibrado acorde a las necesidades de identificación y para este estudio está calibrado acorde a los parámetros de calibración y certificación europeos ERM y del Instituto Nacional de Tecnología y Estándares de Estado Unidos.

Toma de lecturas con XRF en predios residenciales de La Dolores

En el sector, se realizaron mediciones in-situ con el equipo XRF desde la zona de mayor influencia del contaminante, esto es calle 3 entre transversal 1 y 0, recorriendo toda la manzana del sector Paso del Comercio entre calle 2 y 3 y finalizando por la transversal 0. La trayectoria que se realizó fue la siguiente: Inicialmente, se tomaron muestras de suelo cerca de las casas (entre 1 y 2 m) contiguas a las industrias de fundición de plomo activas. Posteriormente, en suelo agrícola, a menos de 50 m de las viviendas, donde se localiza un extenso cultivo de caña de azúcar hacia el nororiente de Cali. Después por la Calle 3 girando por la transversal 0. También se realizaron lecturas en suelo cubierto de vegetación sin asentamientos de ningún tipo. El recorrido siguió por la calle 2 donde se ubican las entradas principales de las dos industrias fundidoras de plomo reconocidas hasta finalizar la calle. Por último, se continuó por la transversal 0 en el sentido de la Calle 3 hasta completar prácticamente toda la manzana.

La frecuencia de las lecturas del XRF se realizó cada 10 m durante todo el recorrido, se identificó y se registró para cada medición las coordenadas correspondientes con ayuda del equipo GPS.

Se evidenciaron valores de plomo muy por encima del valor de referencia (400ppm) establecido por la EPA, los cuales son mostrados en su distribución en el mapa siguiente.



Distribución de valores de plomo tomados con XRF, sector el Paso, La Dolores

En puntos relativamente distantes de la zona de influencia, la concentración de plomo también arrojó niveles altos indicando la dispersión de polvo por corrientes de aire o tránsito de vehículos pesados permanentes que pueden trasladar el material particulado suspendido en el aire o generar remolinos de polvo y partículas que se dispersan por todo el sector.

Llama la atención que existen lecturas superiores a 2,000 mg/kg en el área residencial del sector El Paso en La Dolores frente a las casas y en zonas verdes de acceso disponible, donde los residentes están en continua exposición.

4.1.4. Campaña de sensibilización

Comunidad Adulta

El 4 de diciembre de 2017 se realizó una reunión con la comunidad adulta de la población de La Dolores donde se presentó el programa de evaluaciones detallada que se ha venido desarrollando durante el año 2017 y los resultados de las mediciones ambientales ejecutadas a nivel de laboratorio y del XRF.

Igualmente se presentó el plan intervención a desarrollar en el corregimiento de la Dolores, el cual incluye tomas de muestra de plomo en sangre a una muestra de la población expuesta, esto debido a los altos niveles de concentración de plomo encontrados en las evaluaciones.

Finalmente se expusieron los problemas a la salud que pueden adquirirse por la exposición continua a plomo y a su vez las diferentes recomendaciones para evitar su exposición e ingreso al cuerpo por vía de inhalación, ingestión o contacto dérmico. Estas recomendaciones fueron entregadas en un material tipo calendario a la población con el fin que frecuentemente recuerden los medios de prevención.

Reunión de sensibilización con la Comunidad Adulta de La Dolores

Comunidad Infantil

Para el día 5 de diciembre de 2017 una población cercana a los 120 niños del sector del Paso en La Dolores fue convocada en el colegio Sebastián de Belalcazar, con el fin de hacer una actividad lúdica y de recreación enfocada a tratar temas de contaminación por plomo.

Esta actividad fue soportada por un docente especialista en este tipo de actividades sociales, quien utilizó elementos que de manera transversal se conjugan para que la temática de la contaminación logre un carácter lúdico-pedagógico. Esta característica de la actividad se llevó a cabo en cuatro etapas conformadas por narración oral y ronda, video cortometraje, gymkhana y actividad manual para comunicar el mensaje a los niños sobre los problemas de la exposición a plomo y como evitar estar en contacto con este contaminante.

(Actividad Lúdica y de sensibilización con la Comunidad Infantil de La Dolores)

Al final de esta actividad se entregó un cuaderno de notas para el año escolar 2018, el cuál fue diseñado con un cuento infantil en su interior con ayuda de una profesional social, el cual cuenta la historia de un personaje villano llamado "El Plomo" y cómo se puede prevenir su contacto.

4.1.5. Toma de muestras de sangre

Muestreo

Los días 4 y 5 de diciembre de 2017 se llevó a cabo la jornada de toma de muestras de sangre a la población seleccionada en el puesto de salud de La Dolores prestado por la Secretaria de Salud de Palmira. Para poder desarrollar esta toma de muestras en humanos y poder determinar si existe algún nivel de plomo en ellas, fue necesario desarrollar un protocolo que fue avalado por el Comité de Ética Internacional de Pure Earth. El protocolo aprobado consistió en los siguientes pasos:

a) Comunicación del procedimiento a la persona seleccionada, la cual registraba su consentimiento con la firma de un documento escrito en el cual admite conocer el procedimiento a seguir y los riesgos a los cuales se enfrenta.

b) En el caso que la persona seleccionada fuera un menor de edad, un acudiente, especialmente sus padres, debían firmar el consentimiento correspondiente con el fin de aceptar la toma de muestra y así mismo hacerse responsable de los posibles riesgos.

c) Los datos de las personas seleccionadas para la toma de muestras se registraron en una base de datos privada en donde a cada persona se le asignaba un código, con el cual sería marcada su muestra y posteriormente su entrega del resultado. Cabe anotar que todos los datos registrados en la base de datos son netamente confidenciales y solo podrán ser compartidos con aquellas instituciones competentes en el área de la salud, en este caso corresponde a la Secretaria de Salud del Municipio quien recibirá el 100% de la información incluyendo el detalle de los resultados obtenidos.

d) La toma de las muestras fue realizada por personal de la salud, en condiciones completamente higiénicas garantizando la preservación de la muestra según el protocolo para su análisis.

Toma de muestras de sangre en población adulta e Infantil de La Dolores

e) Las muestras fueron analizadas antes de las 24 horas a través del equipo LEAD CARE II, el cual cuenta con un rango desde la "no detección" hasta un valor máximo de 65 µg/dL de plomo en sangre. El tiempo de procesamiento que requiere el equipo por cada muestra es de 3 minutos.

Lectura de plomo en sangre por equipo Lead Care II

f) El valor obtenido por el equipo se registró en un formato de resultados, el cual solo cuenta con el código del individuo muestreado para ser ingresado a la base de datos privada.

g) El resultado fue entregado a cada una de las personas muestreadas en forma individual y confidencial, dando a conocer el resultado y su nivel acorde a lo estipulado en el protocolo. Para aquellas personas cuyo resultado registraba algún valor, el resultado se acompañaba con una hoja informativa en la cual se dan las instrucciones y recomendaciones a seguir en casa, la dieta y estilo de vida con el fin de reducir o evitar la exposición al plomo.

h) Se recomienda a todas aquellas personas que reportaron valores de plomo en sangre que soliciten un análisis de muestra confirmatoria por parte de la entidad de salud que corresponda.

i) Según el protocolo avalado por el comité de ética de Pure Earth, para todas aquellas personas que reportaron valores de plomo en sangre se hará un monitoreo en sus lugares de residencia, para poder determinar la causa y fuente de exposición y a su vez brindar las recomendaciones pertinentes para romper la exposición al contaminante.

j) Igualmente, el protocolo incluye una nueva jornada de medición de plomo en sangre en un periodo de 6 meses.

k) El número de muestras de sangre tomadas y analizadas fueron:

Adultos	102
Niños	66
Total	168

Resultados

Los resultados obtenidos para todas las muestras tomadas son:

Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)
D001	11,90	D035	36,20	D069	0,00	D103	14,00	D137	18,90
D002	10,10	D036	38,20	D070	0,00	D104	10,80	D138	8,50
D003	9,60	D037	3,60	D071	0,00	D105	9,60	D139	10,00
D004	24,00	D038	9,60	D072	6,70	D106	0,00	D140	5,00
D005	20,40	D039	14,90	D073	11,00	D107	0,00	D141	9,40
D006	16,50	D040	18,50	D074	0,00	D108	0,00	D142	10,10
D007	23,10	D041	51,70	D075	8,20	D109	9,60	D143	6,90
D008	16,20	D042	16,90	D076	9,10	D110	3,80	D144	3,90
D009	15,10	D043	12,80	D077	3,60	D111	20,40	D145	8,60
D010	20,10	D044	12,20	D078	0,00	D112	10,10	D146	8,80
D011	8,70	D045	4,20	D079	3,80	D113	5,70	D147	7,80
D012	6,50	D046	8,30	D080	5,40	D114	0,00	D148	10,50
D013	9,80	D047	16,60	D081	3,60	D115	9,10	D149	22,20
D014	7,30	D048	11,60	D082	8,70	D116	65,00	D150	11,30
D015	18,60	D049	10,80	D083	0,00	D117	0,00	D151	10,50
D016	24,90	D050	16,00	D084	11,80	D118	19.2	D152	0,00
D017	14,00	D051	3,30	D085	32,10	D119	0,00	D153	0,00
D018	4,00	D052	15,60	D086	0,00	D120	12,50	D154	0,00
D019	12,70	D053	20,20	D087	7,20	D121	18,00	D155	0,00
D020	10,60	D054	12,20	D088	65,00	D122	4,70	D156	0,00
D021	26,70	D055	4,90	D089	20,40	D123	N.D	D157	3,60
D022	25,40	D056	25,40	D090	31,20	D124	21,90	D158	16,80
D023	18,90	D057	0,00	D091	9,40	D125	12,30	D159	4,20
D024	14,30	D058	9,70	D092	0,00	D126	29,00	D160	7,20
D025	8,00	D059	19,10	D093	5.3	D127	3,80	D161	0,00
D026	42,10	D060	15,10	D094	34,70	D128	5,20	D162	0,00
D027	16,20	D061	20,40	D095	23,60	D129	13,10	D163	0,00
D028	36,10	D062	11,50	D096	19,40	D130	14,20	D164	18,20
D029	19,00	D063	10,30	D097	54,40	D131	10,80	D165	0,00
D030	21,30	D064	5,60	D098	20,80	D132	20,60	D166	0,00
D031	11,70	D065	15,80	D099	33,50	D133	7,30	D167	0,00
D032	21,60	D066	4,70	D100	24,50	D134	0,00	D168	0,00
D033	21,40	D067	20,10	D101	0,00	D135	13,60		
D034	16,50	D068	3,90	D102	6,10	D136	5,10		

*Datos presentados con dos (2) enteros y dos (2) decimales.

Teniendo en cuenta la información disponible presentamos a continuación un análisis de los datos con algunas anotaciones:

- Los valores presentados en cero “0”, corresponden a lecturas no detectables por el equipo, es decir que la muestra se encuentra libre de plomo.
- Los valores presentados como “65 µg/dL”, corresponden a lecturas máximas que otorga el equipo, es decir que el valor de plomo puede estar mucho más alto en la muestra procesada.
- Para un mejor análisis y consistencia en los datos 3 valores fueron descartados por no contar con la información de la edad de las personas, sin embargo, estas muestras corresponden a personas de la tercera edad y su resultado fue cero “0”, es decir no detectable para plomo en sangre.
- Un análisis estadístico de la población adulta es:

Años de Edad									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
99	48,84	16,63	18.00-84.00	26,50	18,00	36,50	48,00	63,00	84,00

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
99	11,18	11,93	0-65.00	11,75	0	3,60	8,8	15,35	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)**	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
76	14,56	11,67	3.6-65.0	11,38	3,6	7,30	10,8	18,68	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.
** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 23.

- Un análisis estadístico de la población infantil es:

Años de Edad									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
66	7,99	4,56	0.33-16.00	7,75	0,33	4,25	8,50	12,00	16,00

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
66	15,27	10,97	0.00-65.00	11,90	0,00	8,50	14,15	20,4	65,00

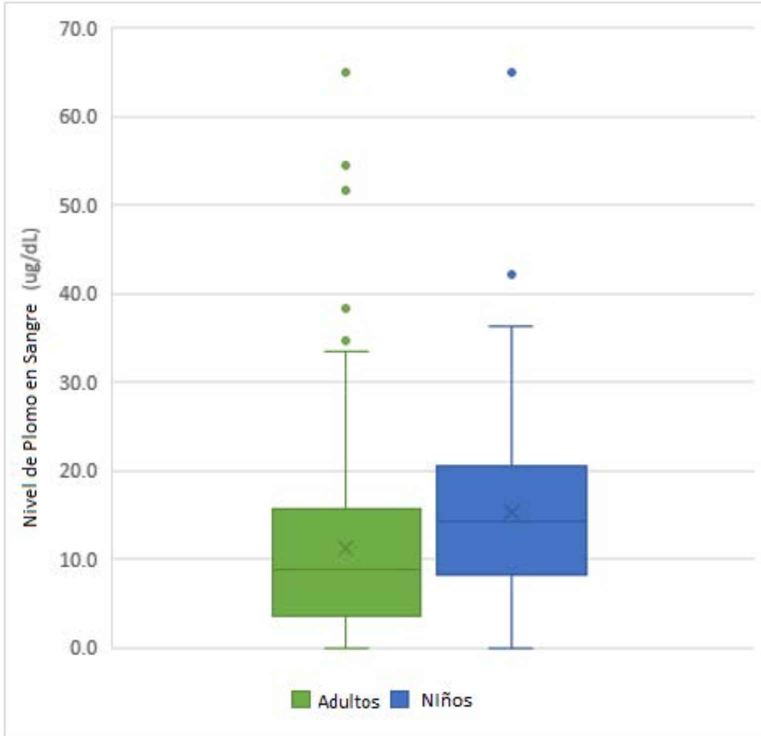
* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)**	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
62	16,26	10,58	3.0-65.00	11,05	3,30	9,65	15	20,70	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.
** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 4.

IQR= El rango intercuartílico (IQR) es una medida de la variabilidad, cuyo valor es igual a la diferencia del tercer y primer cuartil de un conjunto de datos. Análogamente a cómo una desviación estándar (SD) puede modificar un promedio, se presenta un IQR junto con una mediana, o el segundo cuartil de un conjunto de datos, para describir la variabilidad de un conjunto de datos dado.

Debido a la naturaleza de estos datos de BLL, los valores de la mediana son una mejor medida de la tendencia central que los valores promedio. Específicamente, estos datos no se distribuyen normalmente y el conjunto de datos contiene valores cero (niveles de plomo en sangre de 0 mg / dl), lo que hace que los valores promedio estén sesgados. Además, la tecnología LeadCare II utilizada para medir BLL tiene un valor de umbral superior de 65.00 µg / dL, lo que significa que los valores verdaderos para algunos individuos pueden haber sido más altos que los valores máximos en este conjunto de datos. Por lo tanto, los valores medios son mediciones más adecuadas, ya que no se ven afectados por los extremos superior e inferior.



Resultado Promedio de Niveles de plomo en Sangre en Población de La Dolores

Los diagramas de caja ilustran rangos intercuartílicos con barras, cada una de las cuales contiene una línea que denota el valor mediano. Los puntos se extienden en cualquier extremo de las barras hacia el cuartil cero (o el valor mínimo) y el cuarto cuartil. Los puntos representan valores atípicos, o puntos de datos individuales que están significativamente alejados de los datos restantes. Por último, los valores promedio en estos diagramas de caja están representados por una "x"

Hallazgos

Teniendo en cuenta la información analizada es posible identificar algunos hallazgos, los cuales serán tenidos en cuenta para la generación de los planes de acción y monitoreo, al igual de la búsqueda de estrategias en forma conjunta con la Secretaria de Salud de Palmira y la CVC.

Algunos puntos importantes son:

- El 84% de las muestras realizadas reportan valor de plomo en Sangre.
- El 39 % de la población muestreada corresponde a población infantil.
- El promedio de edad fue de 48.80 años para adultos y de 7.99 para niños.
- El valor promedio de plomo en sangre fue de 11.18 µg/dL para adultos y de 15.27 µg/dL para niños.
- Dos muestras reportaron valores de "65 µg/dL", una corresponde a un adulto y a otra a un niño.
- Se evidencia que las personas residentes están en una exposición constante a niveles de plomo que se encuentra en el ambiente.

4.2. Malambo (Atlántico)

4.2.1. Antecedentes

En la comunidad de La Bonga, ubicada en Malambo, Colombia, se informó sobre un posible envenenamiento grave por plomo, que incluye varias muertes. Un estudio de 2014 realizado por la Universidad Nacional, la universidad pública más grande de Colombia, mostró que la población de esta comunidad está expuesta al plomo en el medio ambiente. El envenenamiento por plomo es especialmente peligroso para los niños, causando retraso mental y retrasos en el desarrollo, disminución del crecimiento óseo y muscular y daños al sistema nervioso, los riñones y la audición. Los niños de La Bonga fueron documentados con niveles de plomo en la sangre más de 5 veces el nivel que requiere la intervención del CDC.

Las fundidoras Reciclal y Metcaribe iniciaron sus operaciones en el año 2007, contratando a los habitantes de la vereda como trabajadores de la misma. Después de 5 años de funcionamiento, se presentó la muerte de 3 miembros de una misma familia vecina de las instalaciones de la fundidora, un niño, un anciano, y un adulto; hecho que consterno al municipio y puso en aviso a las autoridades ambientales y administrativas de la región. La Secretaria de Salud Departamental realizo un monitoreo de aguas en el pozo de consumo para La Bonga el cual arrojo cantidades importantes de Plomo y procedieron a la suspensión de la licencia y cierre de las fundidoras. Fue luego del 30 de mayo de 2014, que por decreto No. 123 de 2014, el alcalde del municipio ordeno el cierre y desmantelamiento definitivo de las 5 fundidoras dispersas en todo el territorio.

Lo anterior apoyándose en el criterio de la CRA y en los estudios realizados por la secretaria de salud del departamento del Atlántico en conjunto con el Instituto Nacional de Salud (INS) en 2013, en donde afirman la presencia de plomo en sangre en la población de La Bonga obtenida mediante la inhalación de los gases de fundición del metal pesado y recomiendan someterse a un tratamiento de desintoxicación.

El 16 de agosto de 2016, uno de los principales canales de televisión con señal abierta, RCN, emitió un documental llamado "Plomo: Veneno Invisible" en donde se expuso la situación de los afectados por plomo en La Bonga, Malambo. En contraste, la vereda El Carmen solo conto con la fundidora, Recuperaciones del Caribe LTDA, la cual estuvo en funcionamiento por más de 10 años, los impactos ambientales generados no tienen igual en el departamento, pues afecto profundamente la fertilidad del suelo y contamino el cauce del Arroyo San Blas, cuyas aguas se usan para contacto primario y llegan a la Ciénaga de Malambo para desembocar en el Rio Magdalena.

4.2.2. Inspección detallada con XRF

Teniendo en cuenta los antecedentes presentados, Pure Earth en el mes de marzo de 2017 decide iniciar una serie de evaluaciones detalladas, en las cuales se midió la concentración de metales con un analizador portátil de suelo denominado XRF, que utiliza fluorescencia de rayos X para medir concentraciones de metales pesados en la superficie del suelo. Las mediciones de XRF permiten conocer las concentraciones superficiales de diversos metales en el suelo, sin embargo, no indican la profundidad de la contaminación. En algunas áreas, se realizó una excavación superficial (solamente algunos centímetros) para obtener información sobre la profundidad de la contaminación de los metales. Las lecturas con el XRF evidenciaron que las concentraciones de plomo (Pb) eran mucho más bajas a partir de los 3 a 5 centímetros (Excepto en las áreas de relleno contaminado).

Se tomaron las coordenadas geográficas para cada punto utilizando una unidad de GPS portátil marca Garmin, la cual permite proporcionar información sobre la ubicación exacta y la distribución espacial de la concentración de metales detectada. Los datos de las concentraciones de metales del XRF y las coordenadas del GPS se combinaron en una hoja de cálculo Excel y se utilizaron en software ARC-GIS para preparar mapas de distribución de metales.

Adicionalmente, durante las investigaciones, el personal de Pure Earth recolectó algunas muestras de suelo y agua para su análisis en el Laboratorio Microbiológico de Barranquilla. Las muestras de agua fueron recolectadas para evaluar el impacto potencial del plomo en las fuentes de agua y para comparar las concentraciones del plomo detectadas con el XRF con las del laboratorio. Los resultados presentan que el agua de los pozos muestreados está libre de contaminación de plomo, mientras para suelo reporta niveles por encima de 10,000 ppm.

Durante el trabajo de campo, se consideró que las concentraciones de plomo mayores de 400 PPM eran elevadas y representaban un mayor riesgo para la salud humana, de acuerdo a la regulación vigente de la Agencia de Protección Ambiental en los Estados Unidos.
(https://www.epa.gov/sites/production/files/documents/403fs01.pdf).

Los días 6, 7 y 8 de marzo de 2017, el equipo de investigación realizó el mapeo en el Municipio de Malambo, Departamento de Atlántico, cerca de la ciudad de Barranquilla. A continuación, se describe los hallazgos de los muestreos en el barrio La Bonga y la Vereda El Carmen, en donde se encontraron niveles elevados de plomo y en los que se ve un riesgo alto de exposición a la población:

- En la vereda La Bonga, donde se han reportado impactos severos en la salud y envenenamiento por plomo, los puntos de muestreo incluyeron una escuela primaria (Colegio La Bonga), varias residencias y 2 plantas de reciclaje de plomo o metal (Fundidoras Reciclal y Fundidora Metcaribe), actualmente fuera de operación. En general se encontraron niveles altos de metales en las Fundidoras, no obstante, en las zonas residenciales solo se encontraron concentraciones altas en una muestra de la Escuela La Bonga y en varias propiedades junto al sitio de

Reciclal. No se encontraron concentraciones de plomo en las muestras de agua de la Bonga, lo que indica que los niveles de plomo en el suelo superficial no han impactado el agua subterránea.

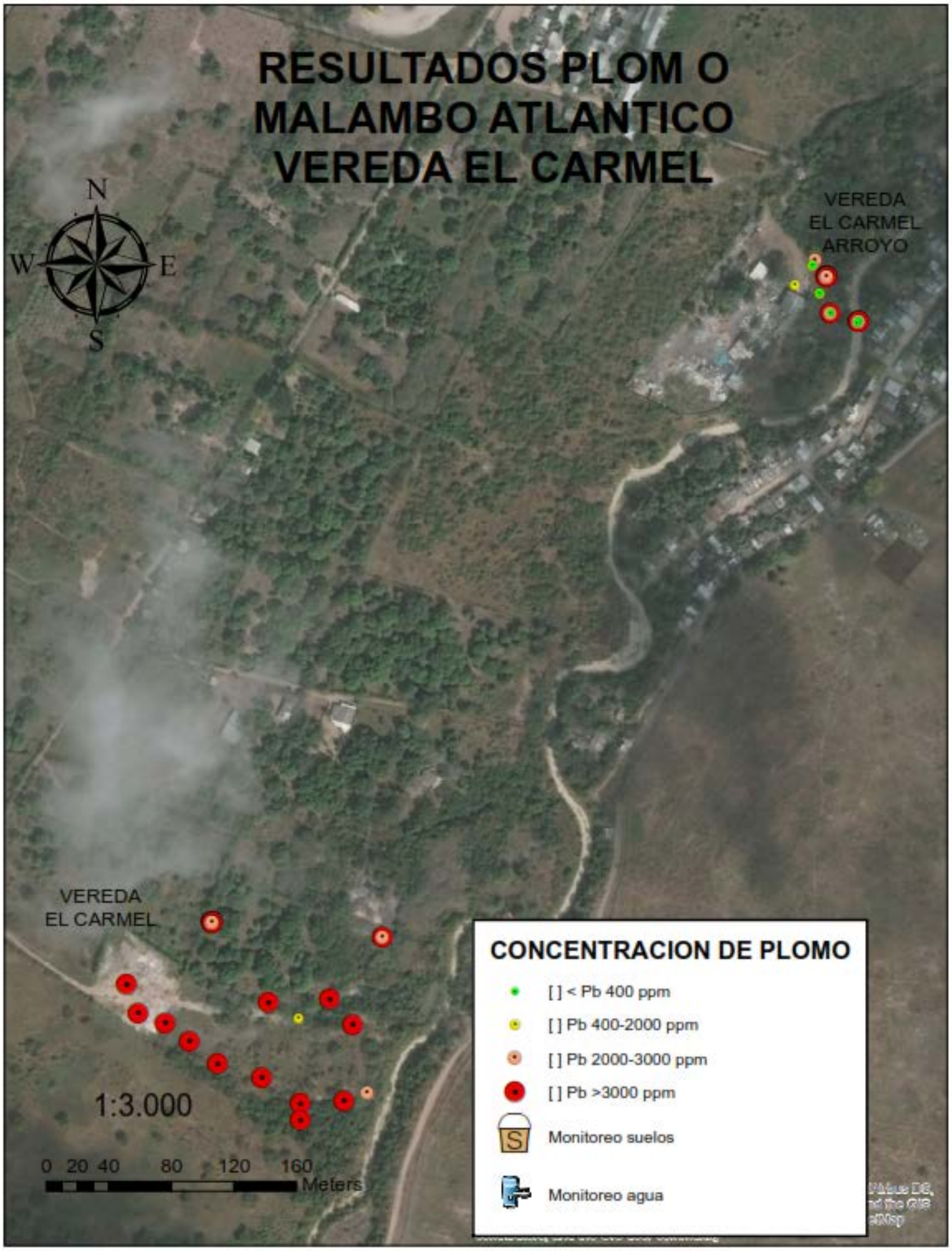
Toma de lecturas con el XRF de plomo la vereda la Bonga

- Un sitio en el que antiguamente operaba una Fundidora y un sitio de reciclaje de baterías (Vereda El Carmen), el cual no tiene edificios ni residencias visibles, presentó concentraciones muy altas de plomo y de otros metales, basura de baterías y escoria de fundición. Este sitio está ubicado en una zona de alto desarrollo urbano y se encuentra en el afluente de Arroyo San Blas que conduce a zonas residenciales aguas abajo, el centro de Malambo y los humedales de Ciénaga.

Toma de lecturas con el XRF de plomo la vereda el Carmen

Los otros sitios muestreados no presentaron niveles altos de metales o no se ven asociados con población cercana que pueda estar expuesta a la contaminación. Por tal razón no se presentan con detalle en este reporte.

Los mapas con la distribución y concentraciones de plomo encontradas se muestran a continuación.



Distribución de valores de plomo tomados con XRF, Vereda el Carmen, Malambo, Atlántico

4.2.3. Campaña de sensibilización

Comunidad Adulta

El pasado 28 de noviembre de 2017 se realizó reunión con la comunidad adulta de la población de malambo donde se presentó el programa de evaluaciones detallada que se ha venido desarrollando durante el año 2017 y los resultados de las mediciones ambientales ejecutadas a nivel de laboratorio y del XRF.

Igualmente se presentó el plan intervención a desarrollar en el municipio de Malambo, el cual incluye tomas de muestra de plomo en sangre a una muestra de la población expuesta y una intervención de encapsulamiento de escoria de plomo en la vereda El Carmen, esto debido a los altos niveles de concentración de plomo encontrados en las evaluaciones.

Finalmente se expusieron los problemas a la salud que pueden adquirirse por la exposición continua a plomo y a su vez las diferentes recomendaciones para evitar su exposición e ingreso al cuerpo por vía de inhalación, ingestión o contacto dérmico. Estas recomendaciones fueron entregadas en un material tipo calendario a la población con el fin que frecuentemente recuerden los medios de prevención.

Reunión de sensibilización con la Comunidad Adulta de Malambo

Comunidad Infantil

El 29 de noviembre de 2017 una población cercana a los 150 niños de las veredas de la Bonga y la vereda el Carmen fue convocada en el colegio de la Bonga, con el fin de hacer una actividad lúdica y de recreación enfocada a tratar temas de contaminación del plomo.

Esta actividad fue soportada por una prestigiosa empresa de recreación del país, la cual utilizó herramientas lúdicas como obras de teatro de títeres, juegos, canciones y cuentos para comunicar el mensaje a los niños sobre los problemas de la exposición a plomo y como evitar estar en contacto con este contaminante. Miembros de la Fuerza Área del Ejercito de Colombia se unieron a esta actividad, donde aportaron un inflable tipo saltarín para que los niños jugaran por un espacio de tiempo en él.

Actividad Lúdica y de sensibilización con la Comunidad Infantil de Malambo

Al final de esta actividad se entregó un cuaderno de notas para el año escolar 2018, el cuál fue diseñado con un cuento infantil en su interior con ayuda de una profesional social, el cual cuanta la historia de un personaje villano llamado “El Plomo” y como se puede prevenir su contacto. Los miembros de la Fuerza área también se unieron a esta actividad entregando a los niños un cepillo de dientes para su aseo personal.

4.2.4. Toma de muestras de sangre

Muestreo

Para poder desarrollar la toma de muestras de sangre en humanos y poder determinar si existe algún nivel de plomo en la ellas, fue necesario desarrollar un protocolo que fue avalado por el Comité de Ética Internacional de PureEarth. El protocoló aprobado consistió en los siguientes pasos:

1. Comunicación del procedimiento a la persona selecciona, la cual registraba su consentimiento con la firma de un documento escrito en el cual admite conocer el procedimiento a seguir y los riesgos a los cuales se enfrenta.
2. En el caso que la persona seleccionada fuera un menor de edad, un acudiente, especialmente sus padres, debían firmar el consentimiento correspondiente con el fin de aceptar la toma de muestra y así mismo hacerse responsable de los posibles riesgos.
3. Los datos de las personas seleccionadas para la toma de muestras se registraron en una base de datos privada en donde a cada persona se le asignaba un código, con el cual sería marcada su muestra y posteriormente su entrega del resultado. Cabe anotar que todos los datos registrados en la base de datos son netamente confidenciales y solo podrán ser compartidos con aquellas instituciones competentes en el área de la salud, en este caso corresponde a la Secretaria de Salud del Municipio quien recibirá el 100% de la información incluyendo el detalle de los resultados obtenidos.
4. La toma de las muestras fue realizada por personal de la salud, aportado por la Secretaria de Salud del Municipio de Malambo, en condiciones 100% higiénicas garantizando la preservación de la muestra según el protocolo para su análisis.

Toma de muestras de sangre en población adulta en Malambo

5. Las muestras fueron analizadas a través del equipo LEAD CARE II, el cual cuenta con un rango desde la “no detección” hasta un valor máximo de 65 ug/dl de plomo en sangre. El tiempo de procesamiento de la muestra por el equipo es de 3 minutos por cada una de las muestras.
6. El valor obtenido por el equipo se registró en un formato de resultados, el cual solo cuenta con el código del individuo muestreado para ser ingresado a la base de datos privada.
7. El resultado fue entregado a cada una de las personas muestreadas en forma individual y confidencial, dando a conocer el resultado y su nivel acorde a lo estipulado en el protocolo. Para aquellas personas cuyo resultado registraba algún valor, el resultado se acompañaba con una hoja informativa en la cual se dan las instrucciones y recomendaciones a seguir en casa, la dieta y estilo de vida con el fin de reducir o evitar la exposición al plomo.
8. Se recomienda a todas aquellas personas que reportaron valores de plomo en sangre que soliciten un análisis de muestra confirmatoria por parte de la entidad de salud que corresponda.
9. Según el protocolo avalado por el comité de ética de PureEarth, para todas aquellas personas que reportaron valores de plomo en sangre se hará un monitoreo en sus lugares de residencia, para poder determinar la causa y fuente de exposición y a su vez brindar las recomendaciones pertinentes para romper la exposición al contaminante.

10. Igualmente, el protocolo incluye una nueva jornada de medición de plomo en sangre en un periodo de 6 meses.
11. El número de muestras de sangre tomadas y analizadas fueron:

Adultos	80
Niños	101
Total	181

Resultados

Los resultados obtenidos para el 100% de las muestras fueron:

Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)
M001	0,00	M038	8,50	M075	28,50	M111	11,00	M148	26,40
M002	3,50	M039	13,70	M076	30,60	M112	18,60	M149	4,00
M003	0,00	M040	3,90	M077	8,80	M113	65,00	M150	3,70
M004	4,50	M041	4,90	M078	15,30	M114	7,60	M151	7,90
M005	9,00	M042	8,90	M079	0,00	M115	65,00	M152	0,00
M006	3,50	M043	5,30	M080	0,00	M116	12,60	M153	16,50
M007	8,40	M044	0,00	M081	20,80	M117	43,80	M154	0,00
M008	6,60	M045	9,10	M082	29,40	M118	17,70	M155	8,40
M009	9,40	M046	8,10	M083	19,30	M119	23,20	M156	4,90
M010	0,00	M047	10,40	M084	26,00	M120	0,00	M157	7,70
M011	8,50	M048	0,00	M085	4,20	M121	0,00	M158	11,30
M012	16,40	M049	0,00	M086	14,00	M122	36,50	M159	11,70
M013	17,80	M050	23,20	M087	18,60	M123	4,20	M160	23,40
M014	10,00	M051	12,10	M088	6,30	M125	0,00	M161	9,00
M015	12,40	M052	7,10	M089	5,40	M126	0,00	M162	14,20
M017	9,60	M053	5,10	M090	5,20	M127	3,40	M163	13,50
M018	5,50	M054	12,40	M091	7,20	M128	18,60	M164	3,70
M019	16,50	M056	5,60	M092	13,60	M129	18,60	M165	0,00
M020	29,70	M057	10,10	M093	45,00	M130	14,40	M166	9,80
M021	24,80	M058	21,10	M094	48,30	M131	3,40	M167	12,20
M021	3,90	M059	4,80	M095	24,60	M132	4,80	M168	4,50
M022	9,00	M060	4,80	M096	20,50	M133	3,90	M169	16,60
M023	6,80	M061	6,80	M097	11,60	M134	5,40	M170	19,70
M024	0,00	M062	5,90	M098	54,00	M135	0,00	M171	0,00
M025	9,30	M063	19,70	M099	38,10	M136	0,00	M172	65,00
M026	4,20	M064	19,80	M100	64,00	M137	65,00	M173	65,00
M027	24,60	M065	29,60	M101	22,60	M138	16,10	M174	22,90
M029	16,70	M066	32,50	M102	8,10	M139	44,70	M175	65,00
M030	18,90	M067	5,60	M103	8,20	M140	27,00	M176	65,00
M031	4,20	M068	0,00	M104	5,20	M141	3,70	M177	31,40
M032	5,90	M069	4,10	M105	15,80	M142	4,90	M178	35,10
M033	15,60	M070	12,70	M106	15,20	M143	3,40	M179	65,00
M034	5,30	M071	3,50	M107	7,60	M144	0,00	M180	65,00
M035	3,60	M072	5,40	M108	20,10	M145	29,70	M181	65,00
M036	23,30	M073	10,00	M109	15,20	M146	32,00	M182	20,60
M037	12,20	M074	20,60	M110	9,70	M147	25,20	M183	14,20

**Datos presentados con dos (2) enteros y dos (2) decimales.*

Teniendo en cuenta la información disponible presentamos a continuación un análisis de los datos con algunas anotaciones:

- Los valores presentados en cero “0”, corresponden a lecturas no detectables por el equipo, es decir que la muestra se encuentra libre de plomo.
- Los valores presentados como “65 ug/dL”, corresponden a lecturas máximas que otorga el equipo, es decir que el valor de plomo puede estar mucho más alto en la muestra procesada.
- Para un mejor análisis y consistencia en los datos 3 valores fueron descartados por mal procesamiento y no contar con la información completa.
- Un análisis estadístico de la población adulta es:

Años de Edad									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
80	37,51	13,05	18.0-70.0	17,8	18,0	27,8	36,0	45,5	70,0

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
80	11,57	17,01	0.0-65.0	8,8	0,0	3,5	5,6	12,3	65,0

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)**	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
61	15,17	18,04	3.4-65.0	11,30	3,4	5,20	7,6	16,50	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 19

- Un análisis estadístico de la población infantil es:

Años de Edad									
Total (N)	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
101	8,48	4,21	1.0-40.0	7,0	1,0	5,0	9,0	12,0	17,0

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
101	18,95	15,24	0.0-65.0	16,1	0,0	8,5	15,3	24,6	65,0

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

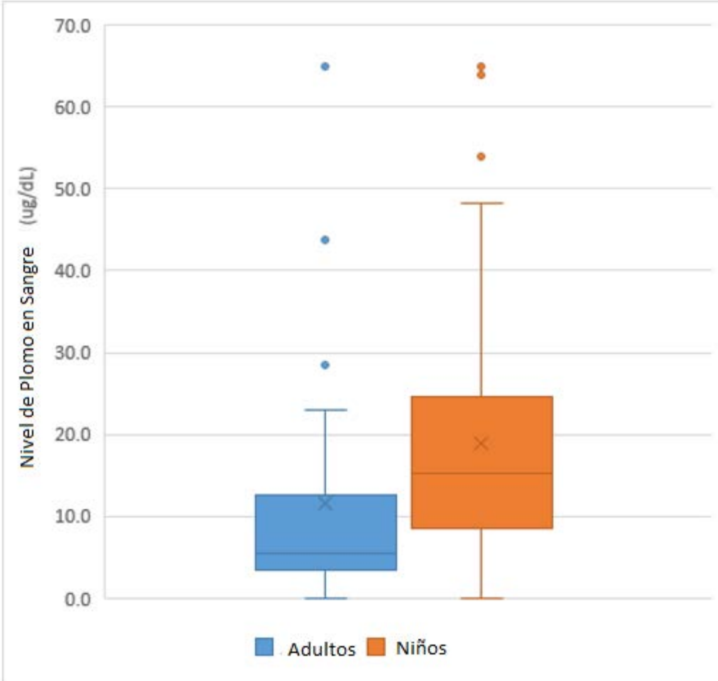
Nivel de Plomo en Sangre (ug/dL)*									
Total (N)**	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
98	19,53	15,10	3.4-65.0	15,75	3,4	9,00	15,7	24,75	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

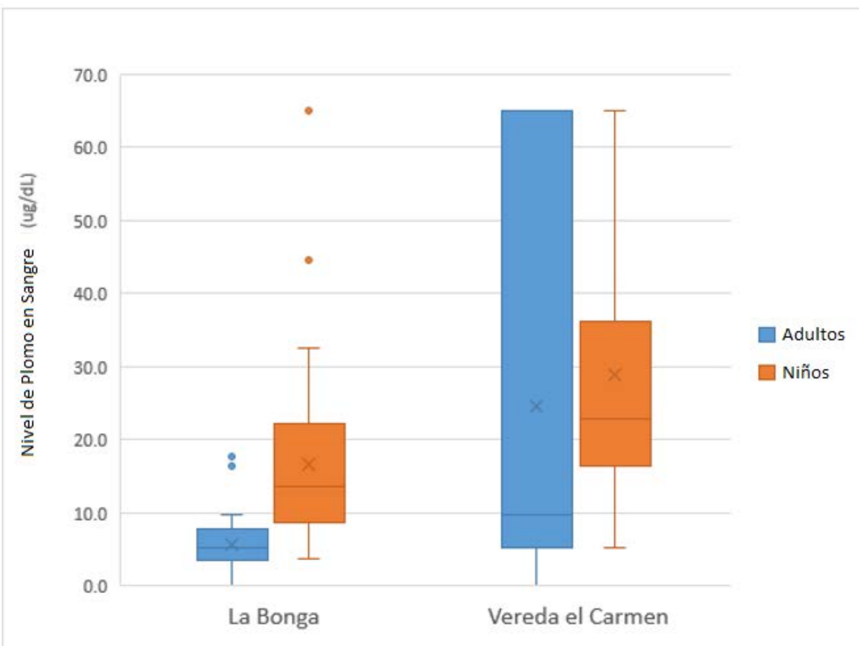
** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 3.

IQR=El rango intercuartílico (IQR) es una medida de la variabilidad, cuyo valor es igual a la diferencia del tercer y primer cuartil de un conjunto de datos. Análogamente a cómo una desviación estándar (SD) puede modificar un promedio, se presenta un IQR junto con una mediana, o el segundo cuartil de un conjunto de datos, para describir la variabilidad de un conjunto de datos dado.

Debido a la naturaleza de estos datos de BLL, los valores de la mediana son una mejor medida de la tendencia central que los valores promedio. Específicamente, estos datos no se distribuyen normalmente y el conjunto de datos contiene valores cero (niveles de plomo en sangre de 0 mg / dl), lo que hace que los valores promedio estén sesgados. Además, la tecnología LeadCare II utilizada para medir BLL tiene un valor de umbral superior de 65.00 □g / dL, lo que significa que los valores verdaderos para algunos individuos pueden haber sido más altos que los valores máximos en este conjunto de datos. Por lo tanto, los valores medios son mediciones más adecuadas, ya que no se ven afectados por los extremos superior e inferior.



Resultado Promedio de Niveles de plomo en Sangre en Población de Malambo



Resultado Promedio de Niveles de plomo en Sangre en Población de la Vereda de La Bonga y el Carmen

Los diagramas de caja ilustran rangos intercuartílicos con barras, cada una de las cuales contiene una línea que denota el valor mediano. Los puntos se extienden en cualquier extremo de las barras hacia el cuartil cero (o el valor mínimo) y el cuarto cuartil. Los puntos representan valores atípicos, o puntos de datos individuales que están significativamente alejados de los datos restantes. Por último, los valores promedio en estos diagramas de caja están representados por una "x"

Hallazgos

Teniendo en cuenta la información analizada es posible identificar algunos hallazgos, los cuales serán tenidos en cuenta para la generación de los planes de acción y monitoreo, al igual de la búsqueda de estrategias en forma conjunta con la Secretaria de Salud de Malambo, Secretaria de Ambiente de Malambo y la Corporación Autónoma Regional del Atlántico CRA.

Algunos puntos importantes son:

- El 87,8 % de las muestras realizadas reportan valor de plomo en Sangre.
- El 55,8 % de la población muestreada corresponde a población infantil.
- El promedio de edad fue de 37.5 años para adultos y de 8.48 para niños.
- El valor promedio de plomo en Sangre fue de 11.57 ug/dL para adultos y de 18.95 ug/dL para niños.
- Diez muestras reportaron valores de “65 ug/dl”, una corresponde 6 a población adulta y 4 a población infantil.
- Se evidencia que las personas residentes están en una exposición constante a niveles de plomo que se encuentra en el ambiente.

4.2.5. Intervención vereda el Carmen.

El plan de intervención aquí descrito fue consultado y aprobado previamente por la Corporación Ambiental del Atlántico, quienes en su juicio cumplía con todos los requerimientos exigidos por la legislación nacional vigente. El diseño y selección de este plan de intervención fue discutido por la Junta de Asesores Técnicos (TAB) de Pure Earth comparando diferentes alternativas de acuerdo al presupuesto disponible. Cabe anotar que este plan de intervención se diseñó en forma temporal mientras el gobierno local de Malambo encuentra otra alternativa de forma definitiva.

Descripción

El sitio de Vereda El Carmen es un antiguo negocio de reciclaje de baterías de plomo ácido y fundición de plomo. El sitio es plano y no tiene estructuras restantes, pero hay losas de concreto y cimientos parciales que indican los sitios de construcción anteriores. Había un área de aproximadamente 500 m^2 de desechos de escoria de horno visibles en la superficie, y todo el sitio tenía cubiertas de batería dispersas y polvo de plomo omnipresente en la superficie con concentraciones de plomo medidas superiores a 400 ppm. Durante una inspección en marzo de 2017, también encontramos los restos de un horno de bloques de concreto y un tanque de fibra de vidrio que se usaba para contener los fluidos de la batería.

Hay un arroyo de drenaje natural con varias ramas pequeñas que corren dentro y a lo largo del límite de la propiedad. Este drenaje se utilizó evidentemente para la eliminación de residuos de baterías y de hornos de fundición. Durante nuestra excavación, descubrimos áreas enterradas de escoria de fundición, cenizas y desechos ricos en plomo de hasta 2 metros de profundidad en el pequeño arroyo cerca del antiguo horno de fundición. Este desecho fue excavado y dispuesto las celdas de encapsulamiento revestidos.

Alcance del trabajo de intervención

El trabajo de campo propuesto para limpiar los desechos de plomo en Vereda El Carmen fue descrito en la carta de Pure Earth a la CRA el 15 de noviembre de 2017. Este trabajo se completó entre el 27 de noviembre y el 8 de diciembre de 2017. El Ejército Nacional nos prestó una gran retroexcavadora y un camión de volteo, para usar como equipo de excavación. También contratamos una excavadora, una retroexcavadora y dos volquetas de volteo, y cuatro trabajadores locales.

Maquinaria donada por el Ejército Nacional de Colombia para la Intervención en Malambo

Todos los trabajadores y operadores de equipos recibieron capacitación en seguridad de residuos de plomo, y usaron equipo de protección personal para este proyecto (los trabajadores del sitio recibieron respiradores, casco, traje de trabajo, guantes y botas).

Trabajadores locales contratados para el proyecto de intervención

Además de la excavación y el enterramiento de desechos de plomo en pozos secos con geomembrana, ampliamos el alcance del trabajo durante nuestro trabajo de campo. Se realizó un trabajo adicional para excavar más áreas con zonas más profundas de relleno de desecho (para eliminar los desechos de plomo de los arroyos) con el fin de transportar y compactar suelo limpio a áreas con niveles de plomo restante encima de 400 ppm que corresponden a áreas de los patios residenciales cercanos y en vías comunitarias, este suelo se utilizó para cubrir la parte superficial contaminada por plomo. Un tanque de fibra de vidrio del trabajo de reciclaje de la batería fue triturado, excavado y agregado a la celda de encapsulamiento.

Resultados

El alcance completo del trabajo incluyó:

- Elaboración de 2 excavaciones para un volumen total de aproximadamente 1.600 m^3 (una excavación de 550 M^3, una excavación de 1050 M^3). Las dimensiones de la excavación fueron de 5 metros por 25 metros, por 4 metros de profundidad (celda pequeña), y 10 metros por 25 metros, por 4 metros de profundidad (celda grande). El suelo de ambas excavaciones se analizó en busca de plomo (limpios por debajo de 0,2 metros. Ambas excavaciones estaban revestidas con geotextil y geomembrana pesada antes de colocar el relleno contaminado en ellas). La ubicación de las celdas de se seguridad se puede observar en el siguiente mapa.

Ubicación Geográfica de las Celdas de Seguridad

Celda de encapsulamiento para material de escoria contaminado con plomo

- El suelo limpio de la excavación se analizó en busca de plomo, luego se usó como tierra limpia para cubrir en jardines residenciales y se extendió como una cubierta en las antiguas áreas de vertederos de desechos en el sitio. Aproximadamente 1000 m^3 de suelo limpio de la excavación de las áreas de encapsulación se utilizaron como relleno limpio en áreas con plomo residual en la superficie superior a 400 ppm.
- Se hizo la Instalación de Geotextile Nt-2000 en excavación, que hace una protección de contacto entre el suelo y la geomembrana para evitar rupturas y fisuras. Este es un material ligero colocado entre el revestimiento pesado y el suelo.
- La geomembrana utilizada fue de referencia HDPE 40 Mils, 100% impermeable y con termosellado entre costuras, para dar forma a la membrana según la excavación. Este forro resistente es un material excelente para el revestimiento del vertedero y crea una barrera física al movimiento.
- Sellado completo de las juntas de geomembrana, utilizando una máquina de termosellado patentada. Este sellado no permitirá la entrada o descarga de agua por filtración o lixiviado del material contenido.

Termosellado de la geomembrana

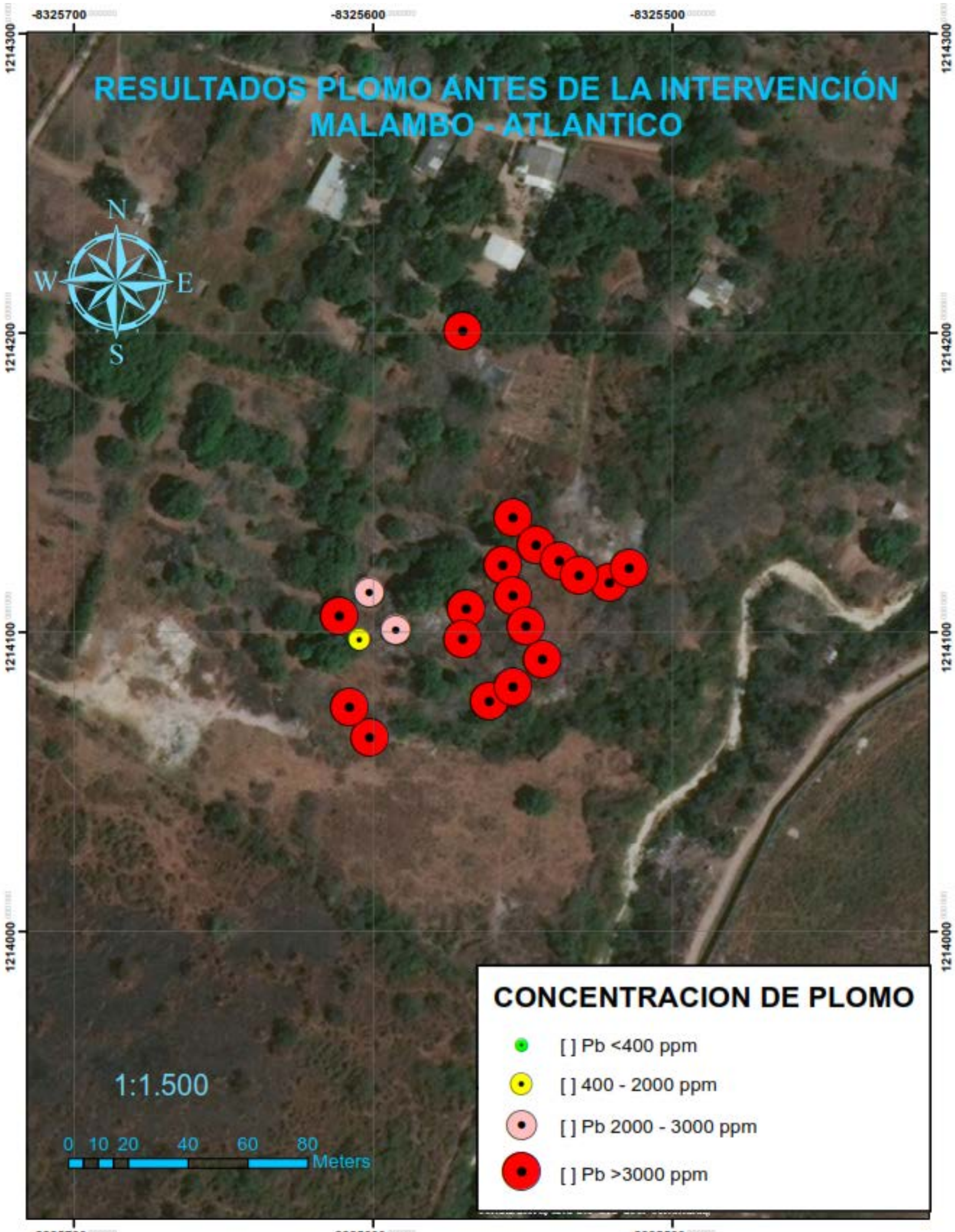
- Los residuos contaminados con plomo se colocaron en la celda en “pisos” de aproximadamente 0,5 metros de grosor sobre la geomembrana mediante volquetas, luego se compactaron utilizando el cucharón de la excavadora y las bandas de rodamiento (la excavadora conduce sobre el material en la excavación). La geomembrana cubrió el material completamente y posteriormente se sobrepuso una capa de aproximadamente 0,75 metros de tierra compactada y limpia. La superficie fue nivelada con un montículo sobre la excavación, para permitir algún asentamiento de la excavación.
- Monitoreo del suelo y la superficie excavados con lecturas frecuentes con el equipo de fluorescencia de rayos X (XRF) para la lectura directa de las concentraciones de plomo y la verificación de que las concentraciones de la superficie son inferiores a 400 ppm.

Lecturas de medición de Plomo con el XRF

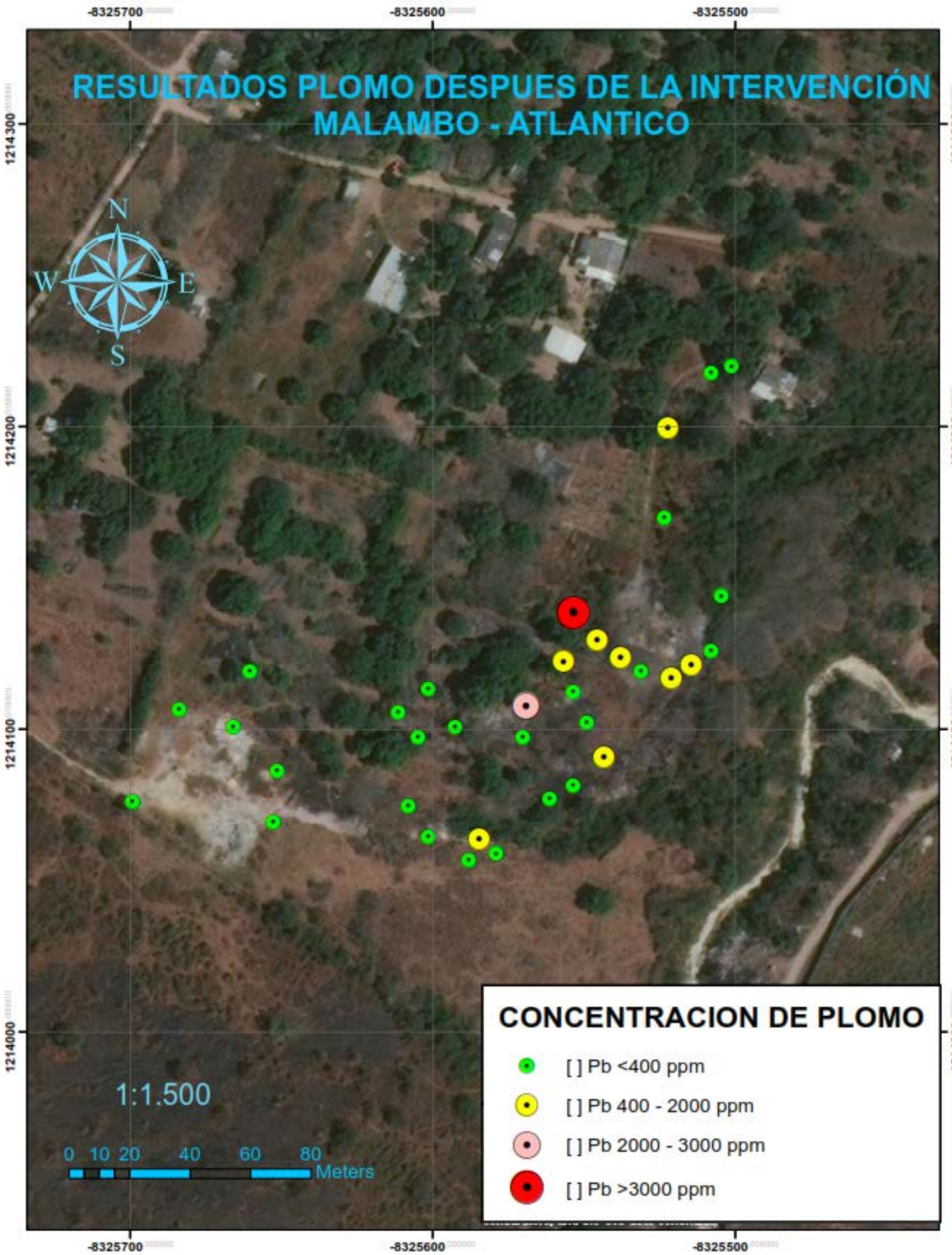
- Cubrir el área de excavación y las áreas con los desechos superficiales restantes con tierra limpia (suelo no contaminado con plomo) y restaurar el nivel del suelo.
- No se encontró agua subterránea en ninguna de las excavaciones, a una profundidad de 4 metros.

Secuencia de la construcción y sellamiento de la celda de disposición

- Los siguientes mapas evidencias la efectividad de la intervención hecha a razón de la disminución de la concentración de plomo en el ambiente, anotando que existen áreas por seguir monitoreando y controlar a futuro.



Niveles de Plomo en la Vereda el Carmen antes de la intervención



Niveles de Plomo en la Vereda el Carmen después de la intervención

Recomendaciones Especifica de la intervención

Dentro de las recomendaciones generadas a partir de la intervención realizada están:

- Prohibir toda actividad de reciclaje de baterías de plomo en el área por parte de las autoridades competentes.
- Agregue señalización que indique que esta propiedad contiene niveles peligrosos de desechos de plomo y reforzar con cercas para evitar el tráfico peatonal.
- No permitir la excavación en el sitio, a menos que se apruebe un plan para la protección del trabajador y la eliminación adecuada de los desechos de plomo.
- El desarrollo futuro del sitio debe ser comercial o industrial, no se recomienda destinar el sitio para viviendas residenciales.
- No permitir que el sitio sea destinado como relleno de basura o desechos industriales, se debe procurar mantener el sitio limpio y libre de material extraño.
- Verificar con una frecuencia de 2 veces por año la excavación, nivelación o vertido no autorizado.
- Registrar la información sobre el trabajo de excavación del sitio en las oficinas municipales, en Malambo, en caso de propuestas de desarrollo futuro.

5. Global Alliance Health and Pollution (GAHP)

La Alianza Global de Contaminación y Salud (GAHP, por sus siglas en Ingles) es un organismo de colaboración internacional encargado de coordinar recursos yactividades para resolver problemas de contaminación por químicos y tóxicos en países de bajos y medianos ingresos.

Muchos países en desarrollo enfrentan desafíos sanitarios, ambientales y económicos asociados conproductos químicos y contaminación que quedaron de actividades económicas mencionadas anteriores. Abordar la contaminación tóxica requiereesfuerzo internacional concertado y enfoque innovador que se basa en el valor agregado de diferentespartes interesadas internacionales.

Teniendo en cuenta el rol que puede representar cada institución de gobierno haciendo parte de esta alianza se han logrado el involucramiento de las siguientes instituciones en Colombia, enviando invitación formal de participación:

- Ministerio de Ambiente y Desarrollo Sostenible
- Ministerio de Salud y Protección Social
- Instituto Nacional de Salud
- Departamento Administrativo de Gestión del Medio Ambiente (DAGMA)
- Ministerio de Relaciones Exteriores

Se espera que para el año 2018 la participación de las instituciones del gobierno colombiano se incremente en forma importante, ya que no se requiere ningún aporte o compromiso algunno. Para lograr más información y una invitación formal del GAHP puede contactar a la secretaria del GAHP Rachael Kupka (rachael@pureearth.org).

The Lancet Report

Uno de los logros por apoyo del GAHP fue la publicación hecha por “The Lancet” del reporte mundial sobre la contaminación, la cual está disponible desde el mes de octubre de 2017 en el link http://www.thelancet.com/pb-assets/Lancet/stories/commissions/pollution-2017/spanish_translation.pdf.

Este reporte evidencia como la contaminación causa la muerte de una manera desproporcionadamente mayor en los individuos pobres y vulnerables. Cerca del 92% de las muertes relacionadas con la contaminación se producen en los países de ingresos bajos y medianos y, en los países de cualquier nivel de ingresos, la enfermedad causada por la contaminación tiene su máxima prevalencia en los grupos minoritarios y en los individuos marginados. Los niños tienen un riesgo elevado de enfermedad relacionada con la contaminación e incluso la exposición a dosis extremadamente bajas de contaminantes durante los periodos de especial vulnerabilidad en la vida intrauterina y la primera infancia puede conducir a la enfermedad, invalidez y muerte en la infancia y a lo largo de toda la vida.

6. Plan de Acción en Salud y Contaminación (HPAP)

En octubre de 2017 se inició en Colombia el programa "Plan de Acción en Salud y Contaminación" (HPAP, por sus siglas en inglés) financiado por Agencia de los Estados Unidos para el Desarrollo Internacional – USAID y la Organización de las Naciones Unidas para el Desarrollo Industrial - ONUDI. Este programa está diseñado para ayudar a los gobiernos de los países de ingresos bajos y medios a desarrollar e implementar soluciones a los problemas de salud relacionados con la contaminación. El Programa HPAP es facilitado por la Alianza Mundial sobre Salud y Contaminación (GHAP por sus siglas en inglés), el cual es un consorcio de Ministerios Nacionales de Salud y Medio Ambiente, bancos internacionales de desarrollo, Organismos de las Naciones Unidas, agencias bilaterales de desarrollo, organizaciones no gubernamentales y otros actores que trabajan en el tema de la contaminación (www.ghap.net). El programa HPAP reúne a los Ministerios Nacionales de Medio Ambiente, Salud, Producción/Industria, Transporte, Energía, Minería, Agricultura y otros para avanzar en acciones concretas del tema de la contaminación. En los países donde un Plan de Acción Nacional de Salud Ambiental (NEHAP por sus siglas en inglés) ya ha sido desarrollado con el apoyo de la OMS, el programa HPAP está destinado a apoyar la puesta en práctica de las prioridades clave.

Los objetivos del programa HPAP son:

1. Ayudar a los gobiernos a identificar, evaluar y priorizar los desafíos de contaminación existentes basados en los impactos en la salud.
2. Establecer la contaminación como una prioridad para la acción dentro de los organismos nacionales y planes de desarrollo.
3. Definir y promover intervenciones concretas para reducir la exposición a la contaminación y las enfermedades relacionadas.

Dependiendo del contexto nacional, el alcance del HPAP puede incluir la contaminación del aire en interiores y exteriores, agua contaminada y saneamiento inadecuado, la contaminación química del suelo, y la exposición ocupacional a contaminantes. El proceso HPAP es flexible y adaptado a las necesidades de cada país, pero en general incluye las siguientes etapas:

Fase 1. Recolección, recopilación y análisis de la información disponible sobre los efectos de la contaminación en la salud y los programas existentes de gestión de la contaminación por parte de los Ministerios de Salud, Medio Ambiente e Industria / Producción, con la asistencia de la Secretaría del GAHP.

Fase 2. Reunión inicial para priorizar los asuntos de contaminación y definir los próximos pasos, incluyendo roles y responsabilidades de las partes interesadas, a través de un proceso participativo.

Fase 3. Preparación de un proyecto de HPAP que describa los contaminantes prioritarios, las fuentes de contaminación, los impactos en la salud, las intervenciones rentables para reducir la exposición, los recursos necesarios y las fuentes potenciales de financiación por un Grupo de Trabajo Nacional conjunto con participantes de los Ministerios de Salud, Medio Ambiente, Transporte, Agricultura, Energía, Industria y Minería con el apoyo de la Secretaría del GAHP.

Fase 4. Se distribuye un borrador del Plan de Acción a las partes interesadas nacionales e internacionales, las cuales están invitadas a presentar comentarios. El Grupo de Trabajo Nacional integra los comentarios de las partes interesadas y se crea un HPAP final. Las partes interesadas se reúnen para respaldar y validar oficialmente el Plan de Acción y discutir los próximos pasos hacia la implementación de las acciones sugeridas.

Fase 5. Difusión, promoción, recaudación de fondos, ejecución, seguimiento y revisión del HPAP a través de iniciativas nacionales e internacionales, en colaboración con los miembros del GAHP, bajo la dirección de un equipo de coordinación conjunta entre los Ministerios de Salud y Medio Ambiente.

El 18 de octubre de 2017 se realizó la reunión técnica con más de 20 asistentes de diferentes instituciones de gobierno que tienen directa relación con el tema del programa en donde se expusieron los alcance y se recibieron las sugerencias y necesidades de cada una de las entidades presentes.

Para el 19 de octubre de 2017 se realizó la reunión de alto nivel con más de 10 representantes directivas de las mismas instituciones de gobierno y en donde se logró establecer un documento de inicio del HPAP para Colombia y el apoyo incondicional de las personas designadas por cada una de las instituciones en el desarrollo del programa por parte de Pure Earth y ONUDI. Las instituciones presentes en estas reuniones fueron:

- Ministerio de Ambiente y Desarrollo Sostenible
- Ministerio de Salud y Protección Social
- Ministerio de Minas y Energía
- Ministerio de Relaciones Exteriores - Cancillería
- Secretaria de Salud de Cundinamarca
- Corporación Autónoma Regional de Cundinamarca - CAR
- Secretaría Distrital de Ambiente
- Secretaría Distrital de Salud de Bogotá.
- Instituto de Hidrología, Meteorología y Estudios Ambientales – IDEAM
- Contraloría General de la República.
- Agencia Nacional de Licencias Ambientales - ANLA

7. Planes de Acción 2018

A continuación de presentan las actividades programadas a desarrollar durante el año 2018.

Programa TSIP

Por parte de USAID se confirma la continuidad del proyecto para el año en curso, en donde se estima realizar por lo menos cincuenta (50) investigaciones a sitios con sospecha de contaminación, ampliando el alcance de cobertura a otras zonas del país no investigadas hasta el momento en el programa como son Boyacá, Santanderes y Bolívar entre otras.

Como parte de soporte técnico a estas investigaciones esta disponibles el uso del Equipo de Fluoerencia de Rayos X (XFR) para la determinación de metales en suelo y el uso de unos 58 Kits portátiles para la determinación de posible contaminación por pesticidas clorados, los cuales están a ser usados en el momento que cualquier institución de gobierno nos lo solicite.

Contaminación por Plomo (Malambo y La Dolores)

Para las dos poblaciones afectadas por contaminación de plomo, se ha definido una serie de actividades específicas en campo con el fin de hacer seguimiento a las intervenciones hasta ahora desarrolladas como son:

Actividad	**Fecha programada de ejecución**
Diseño de protocolos para hacer monitoreo en residencias y estilo de vida a los individuos que reportaron valores de plomo en sangre. El objetivo es levantar información detallada de la residencia, estilo de vida y generar recomendaciones específicas a las persona monitoreadas y muestreadas. Se incluirá muestreo aleatorio de polvo en la casa usando toallas húmedas absorbentes y la lectura del XRF.	Febrero – Junio 2018
Jornada de capacitación a funcionarios de la autoridad ambientales y de las secretarias de salud, en la inspección e identificación de anomalías en los procesos de fundición de plomo. (Capacitación que	Abril 2018

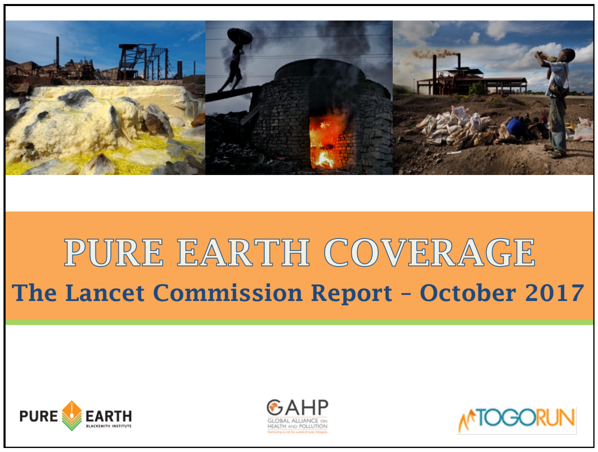
per mite certificación por parte de la Asociación Internacional de Plomo –ILA-).	
Visita de inspección y seguimiento a las plantas de fundición de plomo con el fin de aplicar los conocimientos adquiridos en la capacitación de procesos de fundición de plomo.	Abril 2018
Diseño de seguimiento evaluaciones médicas con fines epidemiológicos y de seguimiento a niveles de plomo en sangre y sus posibles afectaciones.	Mayo – Junio 2018
Jornada de monitoreo de seguimiento para toma de muestra de sangre y determinación de plomo en población ya estudiada en el mes de Diciembre de 2017.	Junio 2018

Plan de Acción en Salud y Contaminación (HPAP)

Por parte de Pure Earth y ONUDI se desarrollará las 4 fases restantes del programa de "Plan de Acción en Salud y Contaminación" en donde el esquema de trabajo inicial consta de:

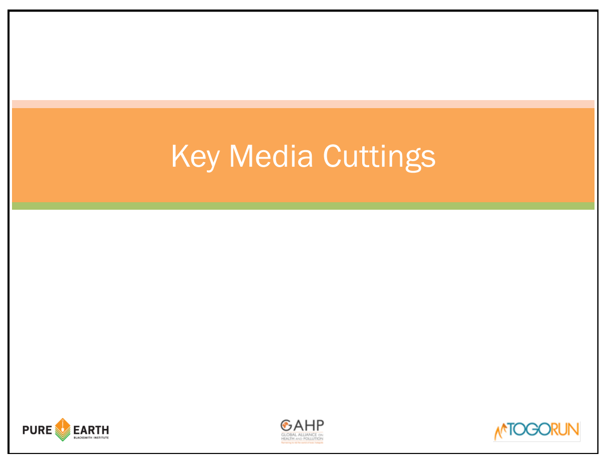
- Recopilación secundaria y primaria de información disponible y relevante al tema de contaminación ambiental y salud pública.
- Entrevistas individuales con cada una de las instituciones identificadas como relevante en el proceso, con el fin de identificar necesidades puntuales y construir los objetivos de trabajo en el plan de acción.
- Construcción del un plan de acción a ser presentado en una reunión técnica a mediados del 2018 con el fin de ajustar el plan en temas de política interna integral.
- Hacer presentación del Plan ajustado a los miembros de Alto Nivel de cada una de las instituciones identificadas en una reunión conjunta.
- El plan de acción incluirá "Notas de Concepto" sobre ideas de proyectos realistas e implementables en corto y mediano plazo que apunten a los objetivos construidos en el Plan de acción.
- Soporte Jurídico del Van Center a través de la firma Macias & Asociados en Colombia para los temas relacionados con la contaminación y salud pública en Colombia

Esta publicación es posible gracias el generoso apoyo del pueblo estadounidense a través de la Agencia Para el Desarrollo Internacional


PURE EARTH COVERAGE
The Lancet Commission Report - October 2017
PURE EARTH
GAHP
TOGORUN


Traditional media coverage
Multi channel coverage in over 61 publications across ten European countries and the US with almost 40 top tier articles.
Reaching over 1,8 billion people internationally.
The story was covered in top tier media including international TV networks such as BBC, France 24 & CNN.
BBC NEWS
FRANCE 24
CNN
INDEPENDENT
CNBC
REUTERS
itv
THE TIMES
The Sun
Le Monde
EL MUNDO
EveningStandard.
theguardian
The Washington Post
Bloomberg
PURE EARTH
GAHP
TOGORUN


Social media coverage
The Lancet Report gained high levels of coverage and international engagement in 70 countries.
Over 191K impressions of #pollutioncommission were recorded on twitter in the first days after the release.
PURE EARTH
GAHP
TOGORUN


Key Media Cuttings
PURE EARTH
GAHP
TOGORUN

United Kingdom

Total Top Tier Articles: 13
Total Reach: 1,399,733,500

PURE EARTH · GAHP · TOGORUN

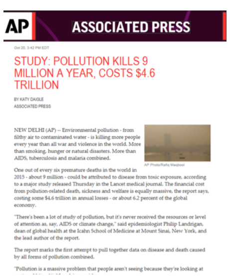
Publication: BBC World News
Date: 20 October 2017

Unique Monthly Visits:
85,000,000

Link:
http://www.bbc.co.uk/programmes/p05kh6mv

PURE EARTH · GAHP · TOGORUN

United Kingdom



AP ASSOCIATED PRESS

Oct 20, 3:42 PM EDT

STUDY: POLLUTION KILLS 9 MILLION A YEAR, COSTS $4.6 TRILLION

BY KATY DAIGLE
ASSOCIATED PRESS

NEW DELHI (AP) -- Environmental pollution - from filthy air to contaminated water - is killing more people every year than all war and violence in the world. More than smoking, hunger or natural disasters. More than AIDS, tuberculosis and malaria combined.

AP Photo/Rafiq Maqbool

One out of every six premature deaths in the world in 2015 - about 9 million - could be attributed to disease from toxic exposure, according to a major study released Thursday in the Lancet medical journal. The financial cost from pollution-related death, sickness and welfare is equally massive, the report says, costing some $4.6 trillion in annual losses - or about 6.2 percent of the global economy.

"There's been a lot of study of pollution, but it's never received the resources or level of attention as, say, AIDS or climate change," said epidemiologist Philip Landrigan, dean of global health at the Icahn School of Medicine at Mount Sinai, New York, and the lead author of the report.

The report marks the first attempt to pull together data on disease and death caused by all forms of pollution combined.

"Pollution is a massive problem that people aren't seeing because they're looking at

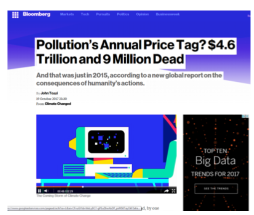
Publication: Associated Press
Date: 20 October 2017

Unique Monthly Visits:
3,270,200

Link:
http://hosted.ap.org/dynamic/stories/G/GLOBAL_POLLUTION_ASOL-?SITE=AP&SECTION=HOME&TEMPLATE=DEFAULT

PURE EARTH · GAHP · TOGORUN

United Kingdom



Publication: Bloomberg
Date: 20 October 2017

Unique Monthly Visits:
26,189,000

Link:
https://www.bloomberg.com/news/articles/2017-10-19/pollution-s-annual-pricetag-4-6-trillion-and-9-million-dead

PURE EARTH · GAHP · TOGORUN

United Kingdom

Publication: BBC

Date: 20 October 2017

Unique Monthly Visits: 94,230,000

Link: http://www.bbc.co.uk/news/health-41678533

PURE EARTH GAHP TOGORUN

United Kingdom

Publication: Daily Mail

Date: 20 October 2017

Unique Monthly Visits: 62,515,000

Link: http://www.dailymail.co.uk/wires/ap/article-5000310/Countries-highest-pollution-deaths-mortality-rates.html

PURE EARTH GAHP TOGORUN

United Kingdom

Publication: The Evening Standard

Date: 20 October 2017

Unique Monthly Visits: 3,833,100

Link: https://www.standard.co.uk/news/uk/pollution-killing-50000-in-the-uk-every-year-research-finds-a3663371.html

PURE EARTH GAHP TOGORUN

United Kingdom

Publication: The Express

Date: 20 October 2017

Unique Monthly Visits: 19,450,000

Link: http://www.express.co.uk/news/uk/868757/world-crisis-pollution-deaths-smog-uk-europe-usa-weather-health-risks

PURE EARTH GAHP TOGORUN

United Kingdom

Publication: Financial Times

Date: 19 October 2017

Unique Monthly Visits:

8,554,200

Link:

https://www.ft.com/content/1dd234a8-b4d6-11e7-a398-73d59db9e399

United Kingdom

Publication: The Guardian

Date: 20 October 2017

Unique Monthly Visits:

72,485,000

Link:

https://www.theguardian.com/environment/2017/oct/19/global-pollution-kills-millions-threatens-survival-human-societies

United Kingdom

Publication: Huffington Post UK

Date: 20 October 2017

Unique Monthly Visits:

3,307,400

Link:

http://www.huffingtonpost.co.uk/entry/pollution-is-killing-50000-people-in-the-uk-every-year_uk_59e9a808e4b0df10767c15ff

United Kingdom

Publication: The Independent

Date: 19 October 2017

Unique Monthly Visits:

28,207,000

Link:

http://www.independent.co.uk/environment/pollution-air-clean-water-vehicles-diesel-car-tax-lancet-report-deaths-fatal-disease-a8009751.html

United Kingdom

International Business Times

Business | Economy

Pollution is deadlier than war, disaster, hunger and costs the global economy $4.6trn

- **Study finds cost from pollution-related death, sickness and welfare around the planet is massive.**

Environmental pollution — from filthy air to contaminated water — is killing more people every year than all war and violence in the world. More than smoking, hunger or natural disasters. More than Aids, tuberculosis and malaria combined.

One out of every six premature deaths in the world in 2015 — about 9 million — could be attributed to disease from toxic exposure, according to a major study released in the Lancet medical journal. The financial cost from pollution-related death, sickness and welfare is equally massive, the report says, costing some $4.6trn (£3.49trn) in annual losses — or about 6.2% of the global economy.

More business news

- Goldman Sachs boss hints at further Brexit moves away from London
- Chinese official warns of 'Minsky Moment' 30 years on from Black Monday
- Lacklustre economic data takes shine off the pound

"There's been a lot of study of pollution, but it's never received the resources or level of attention as, say, Aids or climate change," said epidemiologist Philip Landrigan, dean of global health at the Icahn School of Medicine at Mount Sinai, New York, and the lead author on the report.

Publication: The International Business Times

Date: 20 October 2017

Unique Monthly Visits:

6,471,300

Link:

http://www.ibtimes.co.uk/pollution-deadlier-war-disaster-hunger-costs-global-economy-4-6trn-1643933

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

United Kingdom

ITV REPORT 20 October 2017 at 2:59am

One in six global deaths 'linked to pollution'

Credit: PA

One in six of all deaths globally was caused by pollution in 2015, according to a major study.

In the UK, 8.39% of deaths - more than 50,000 people - were due to pollution, a higher proportion than in many other European countries. Only Belgium had a worse record of the western European countries in the study.

In the most severely affected countries, including India, Pakistan, China, Bangladesh, Madagascar, and Kenya, up to a quarter of all deaths were caused by pollution.

The research, published in The Lancet, says pollution claimed nine million lives in 2015 globally, with air pollution from vehicles and factories the biggest killer, accounting for 6.5 million deaths.

More than 155,000 people were killed by pollution in the US, but those deaths made up just

Publication: ITV

Date: 20 October 2017

Unique Monthly Visits:

4,166,700

Link:

http://www.itv.com/news/2017-10-20/one-in-six-global-deaths-linked-to-pollution/

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

United Kingdom

REUTERS

Study links pollution to millions of deaths worldwide

Reuters Staff

LONDON (Reuters) - Pollution is killing millions of people worldwide, mostly through the diseases it causes including heart conditions, strokes and lung cancer, according to a large international study.

Publication: Reuters

Date: 20 October 2017

Unique Monthly Visits:

6,182,200

Link:

https://www.reuters.com/article/us-health-pollution/study-links-pollution-to-millions-of-deaths-worldwide-idUSKBN1CO39B

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

United Kingdom

The Sun | & SHOWBIZ | NEWS | FABULOUS | MONEY | MOTORS

DEAD AIR Pollution kills up to 50,000 people a year in the UK as the world reaches 'crisis point'

Globally, air pollution from vehicles and factories was the biggest killer, blamed for 6.5m deaths. Polluted water caused 1.8m deaths

POLLUTION kills more people in Britain than almost anywhere else in Europe, damning research reveals.

It was blamed for 50,000 deaths in 2015 and the death rate was higher than every European country except Belgium.

Pollution was blamed for 50,000 deaths in Britain in 2015

Publication: The Sun

Date: 20 October 2017

Unique Monthly Visits:

16,592,000

Link:

https://www.thesun.co.uk/news/4725783/pollution-kills-up-to-50000-people-a-year-in-the-uk-as-the-world-reaches-crisis-point/

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

United Kingdom

Diesel fumes make British streets among most toxic in West

Britons are about twice as likely to die from pollution as people in Sweden, New Zealand, Australia, Canada and Ireland, with diesel vehicles being blamed

Polluted air has made Britain one of the most toxic countries in the developed world, a global analysis has found.

Britons are about twice as likely to die from pollution as people in Sweden, New Zealand, Australia, Canada and Ireland, with diesel vehicles being blamed.

Publication: The Times

Date: 20 October 2017

Unique Monthly Visits:

2,874,400

Link:

https://www.thetimes.co.uk/edition/news/air-pollution-diesel-fumes-make-british-air-among-the-most-toxic-in-west-67kbf3lsz

PURE EARTH GAHP TOGORUN

United Kingdom

UK among worst records in Europe for pollution-related deaths, study finds

PA By John von Radowitz

PA Science 20 October 2017

Exposure to man-made chemicals killed more than 50,000 Britons in 2015, giving the UK one of the worst records of pollution death in Europe, a major study has found.

Globally, pollution claimed nine million lives in that one year – one in six of all deaths, said researchers. Air pollution from vehicles and factories was the biggest killer, accounting for 6.5 million deaths on its own.

In the UK, 8.39% of deaths were due to pollution, a higher proportion than in many other European countries including Germany, France, Spain, Italy, Denmark, Sweden and Switzerland.

More than 155,000 people were killed by pollution in the US, but those deaths made up just 5.74% of the country's total.

Publication: Yahoo News

Date: 20 October 2017

Unique Monthly Visits:

1,038,375,000

Link:

https://uk.news.yahoo.com/uk-among-worst-records-europe-064947985.html

PURE EARTH GAHP TOGORUN

United Kingdom

Boots WebMD PARTNERS IN HEALTH

UK pollution linked to 50,000 annual deaths

Font size: A A A

Share this:

By Peter Russell

WebMD UK Health News

Medically Reviewed by Dr Sheena Meredith

20th October 2017 – Pollution contributes to more than 50,000 deaths each year in the UK, a major report has concluded.

The study, in the medical journal The Lancet, says pollution is linked to around 9 million deaths each year worldwide – equivalent to 16% of all deaths.

✓ 8 conditions made worse by pollution outdoors

Major diseases

Heart disease, stroke, lung cancer and obstructive pulmonary disease (COPD) top the list of pollution-aggravated deaths.

International researchers found that pollution related deaths are largely confined to poor and marginalised people. Almost all deaths (92%) occur in low to middle income countries.

The Lancet Commission on Pollution and Health brings together data on how pollution affects health, which parts of the world are affected and how much it costs.

Publication: Web MD

Date: 20 October 2017

Unique Monthly Visits:

2,731,900

Link:

https://www.webmd.boots.com/heart-disease/news/20171020/uk-pollution-50000-annual-deaths

PURE EARTH GAHP TOGORUN

Ireland

Total Top Tier Articles: 1

Total Reach: 3,031,000

PURE EARTH GAHP TOGORUN

Ireland


THE IRISH TIMES

Poor bear the brunt of 9m pollution-linked deaths a year

'Lancet' findings: Most detailed review of pollution impact on global health ever compiled

Pollution is blamed for up to nine million deaths each year worldwide, disproportionately affecting people living in some of the world's poorest countries, according to a global investigation.

Publication: The Irish Times

Date: 19 October 2017

Unique Monthly Visits: 3,031,000

Link: https://www.irishtimes.com/news/health/poor-bear-the-brunt-of-9m-pollution-linked-deaths-a-year-1.3262421

PURE EARTH | GAHP | TOGORUN

France

Total Top Tier Articles: 4

Total Reach: 33,407,500

PURE EARTH | GAHP | TOGORUN

France


Météo Média

Votre météo quand ça compte vraiment

Un décès sur six est causé par une forme de pollution

Publication: Meteo Media

Date: 21 October 2017

Unique Monthly Visits: 1,819,600

Link: https://www.meteomedia.com/nouvelles/articles/une-mort-sur-six-dans-le-monde-est-causee-par-la-pollution/87998

PURE EARTH | GAHP | TOGORUN

France


EUROPE

La pollution responsable d'une mort sur six dans le monde en 2015

Publication: France 24

Date: 20 October 2017

Unique Monthly Visits: 3,122,400

Link: http://www.france24.com/fr/20171020-environnement-pollution-2015-deces-sante-rapport-revue-lancet

PURE EARTH | GAHP | TOGORUN

France

Publication: La Nouvelle Union

Date: 20 October 2017

Unique Monthly Visits:

64,000

Link:

http://www.lanouvelle.net/national/2017/10/20/la-pollution-est-plus-mortelle-que-la-guerre-et-la-famine--selon.html

France

Publication: Le Quotidien

Date: 20 October 2017

Unique Monthly Visits:

11,900

Link:

https://www.lequotidien.com/actualites/la-pollution-plus-mortelle-que-la-guerre-et-la-famine-0e2f35f935d28eb826b403c562c0ed16

France

Publication: France Info

Date: 20 October 2017

Unique Monthly Visits:

8,241,000

Link:

http://www.francetvinfo.fr/sante/environnement-et-sante/etude-the-lancet-sur-la-pollution-la-chimie-a-developpe-des-molecules-qui-ont-un-impact-majeur-sur-la-population_2429467.html

France

Publication: Le Monde

Date: 20 October 2017

Unique Monthly Visits:

18,329,000

Link:

http://www.lemonde.fr/pollution/article/2017/10/20/la-pollution-responsable-de-9-millions-de-morts-dans-le-monde-par-

Denmark

Total Top Tier Articles: 3
Total Reach: 4,228,200

PURE EARTH GAHP TOGORUN

Denmark


Berlingske

Hver sjette dør af forurening

Publication: Berlingske
Date: 20 October 2017

Unique Monthly Visits:
1,300,400
Link:
https://www.b.dk/nationalt/hver-sjette-dor-af-forurening

PURE EARTH GAHP TOGORUN

Denmark


Jyllands-Posten

Briefing

Opsigtsvækkende tal: Forurening dræber hvert år millioner af mennesker

Publication: Jyllands-Posten
Date: 20 October 2017

Unique Monthly Visits:
1,077,800
Link:
https://jyllands-posten.dk/premium/briefing/ECE9941189/opsigtsvaekkende-tal-forurening-draeber-hvert-aar-millioner-af-mennesker

PURE EARTH GAHP TOGORUN

Denmark


POLITIKEN

Forurening dræber hvert år ni millioner mennesker

Publication: Politiken
Date: 20 October 2017

Unique Monthly Visits:
1,850,000
Link:
http://politiken.dk/udland/art6167582/Forurening-dr%C3%A6ber-hvert-%C3%A5r-ni-millioner-mennesker

PURE EARTH GAHP TOGORUN

United States and Canada

Total Top Tier Articles: 4
Total Reach: 161,139,000

U.S.A


BUSTLE

How Many Deaths Does Pollution Cause Worldwide? You Can Help Lower This Staggering Statistic

Publication: Bustle
Date: 20 October 2017

Unique Monthly Visits:
7,832,000
Link:
https://www.bustle.com/p/how-many-deaths-does-pollution-cause-worldwide-you-can-help-lower-this-staggering-statistic-2957599

U.S.A


CBCnews | World

Pollution causing more deaths worldwide than war or smoking: Lancet

At least 9 million premature deaths were caused by diseases from toxic emissions

The Associated Press Posted: Oct 20, 2017 7:51 AM ET | Last Updated: Oct 20, 2017 1:30 PM ET

Publication: CBC News
Date: 20 October 2017

Unique Monthly Visits:
13,115,00
Link:
http://www.cbc.ca/news/world/pollution-worldwide-deaths-1.4363613

U.S.A


Chicago Tribune

Pollution killing more people every year than wars, disasters and hunger, study says

Environmental pollution — from filthy air to contaminated water — is killing more people every year than all war and violence in the world. More than smoking, hunger or natural disasters. More than AIDS, tuberculosis and malaria combined.

Publication: Chicago Tribune
Date: 20 October 2017

Unique Monthly Visits:
7,220,400
Link:
http://www.chicagotribune.com/news/nationworld/science/ct-deadly-pollution-study-20171019-story.html

U.S.A

Publication: CNBC

Date: 20 October 2017

Unique Monthly Visits: 21,715,000

Link: https://www.cnbc.com/2017/10/20/pollution-linked-to-one-in-six-deaths-worldwide-and-threatens-survival-of-human-societies.html

PURE EARTH GAHP TOGORUN

U.S.A

Publication: Fortune

Date: 20 October 2017

Unique Monthly Visits: 7,123,100

Link: http://fortune.com/2017/10/20/global-pollution-deaths-lancet/

PURE EARTH GAHP TOGORUN

U.S.A

Publication: Human Rights Watch

Date: 20 October 2017

Unique Monthly Visits: 1,041,900

Link: https://www.hrw.org/news/2017/10/19/pollution-one-worlds-biggest-killers

PURE EARTH GAHP TOGORUN

U.S.A

Publication: NPR

Date: 19 October 2017

Unique Monthly Visits: 19,924,000

Link: http://www.npr.org/sections/goatsandsoda/2017/10/19/558821792/report-pollution-kills-3-times-more-than-aids-tb-and-malaria-combined

PURE EARTH GAHP TOGORUN

U.S.A

Publication: Philadelphia Inquirer

Date: 20 October 2017

Unique Monthly Visits:

2,860,500

Link:

http://www.philly.com/philly/health/20171020_ap_cfde2ac162ed430e8e228b5316f2541e.html

U.S.A

Publication: SF Gate

Date: 20 October 2017

Unique Monthly Visits:

11,144,000

Link:

http://www.sfgate.com/news/medical/article/Countries-with-the-highest-pollution-deaths-12292922.php

U.S.A

Publication: STAT

Date: 19 October 2017

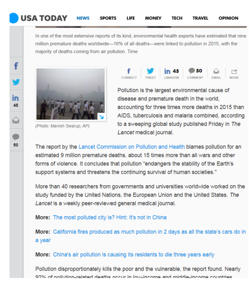
Unique Monthly Visits:

878,100

Link:

https://www.statnews.com/2017/10/19/pollution-toll-health/

U.S.A



Publication: USA Today

Date: 20 October 2017

Unique Monthly Visits:

22,999,000

Link:

https://www.usatoday.com/story/news/2017/10/20/study-global-pollution-worlds-biggest-killer-and-threat-survival-mankind/783321001/

U.S.A

Energy and Environment

Pollution kills 9 million people each year, new study finds

By Brady Dennis October 19

Traffic moves at dusk in New Delhi, home to some of the world's most polluted air. (Manish Swarup/AP)

Publication: The Washington Post

Date: 19 October 2017

Unique Monthly Visits:

56,430,000

Link:

https://www.washingtonpost.com/news/energy-environment/wp/2017/10/19/pollution-kills-9-million-people-each-year-new-study-finds/?utm_term=.ac9451fcc18c

PURE EARTH GAHP TOGORUN

U.S.A

Publication: CNN – Fareed Zakaria

Date: 5 November 2017

Unique Monthly Visits:

1,172,000

Link:

http://edition.cnn.com/shows/fareed-zakaria-gps

PURE EARTH GAHP TOGORUN

Germany

Total Top Tier Articles: 4

Total Reach: 49,342,900

PURE EARTH GAHP TOGORUN

Germany

NEUE STUDIE

Weltweit Millionen Tote durch Umweltverschmutzung

Herzinfarkt, Schlaganfall oder Lungenkrebs: Allein 2015 sind laut einer internationalen Studie neun Millionen Menschen an den Folgen von Umweltschadstoffen gestorben.

Publication: Frankfurter Allgemeine Zeitung

Date: 20 October 2017

Unique Monthly Visits:

7,080,200

Link:

http://www.faz.net/aktuell/gesellschaft/gesundheit/umweltverschmutzung-fordert-millionen-tote-weltweit-15254935.html

PURE EARTH GAHP TOGORUN

Germany

Studie zur Umweltverschmutzung

Giftige Böden, dreckige Luft - Millionen Tote

Stand: 20.10.2017 00:30 Uhr

Jeder sechste Todesfall weltweit ist bedingt durch Verschmutzung von Luft, Wasser oder Boden. Zu dieser Schätzung kommt eine neue Studie. Zwar sind vor allem ärmere Länder betroffen - aber auch in Deutschland lassen sich die Wirkungen nachweisen.

Von Christian Feld und Martin Gent, WDR

Die Gefahr lauert an vielen Orten: In Industriebetrieben sind Arbeiter aggressiven Chemikalien ausgesetzt. Menschen leben jahrelang dicht an mehrspurigen Straßen. Kinder spielen ohne Schuhe auf verseuchtem Boden. Sie alle müssen Umweltverschmutzungen ertragen. Auf deren gesundheitliche, wirtschaftliche und soziale Folgen will die Lancet Commission on Pollution and Health mit ihrer neuen Studie hinweisen. Zwei Jahre lang haben mehr als 40 Experten daran gearbeitet.

Publication: Tagesschau.de

Date: 20 October 2017

Unique Monthly Visits:

7,049,800

Link:

https://www.tagesschau.de/ausland/umweltverschmutzung-todesfaelle-101.html

PURE EARTH · GAHP · TOGORUN

Germany

Millionen Menschen sterben weltweit durch Umweltverschmutzung

Dreckige Luft und unsauberes Wasser führten bei mehr Menschen zum Tod als Aids, Tuberkulose und Malaria zusammengerechnet.

20. Oktober 2017, 4:20 Uhr / Quelle: ZEIT ONLINE, Reuters, dpa, suk / 167 Kommentare

Schüler mit Mundschutz in Indonesien © Wahdi Setiawan/Antara Foto/Reuters

Publication: Zeit

Date: 20 October 2017

Unique Monthly Visits:

8,494,900

Link:

http://www.zeit.de/wissen/umwelt/2017-10/umweltverschmutzung-krankheiten-todesfaelle-studie

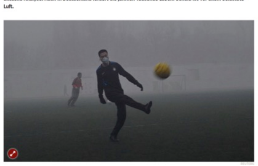
PURE EARTH · GAHP · TOGORUN

Germany

Weltweite Analyse

Umweltverschmutzung verkürzt jedes sechste Leben

Jährlich neun Millionen Todesfälle weltweit hängen mit einer verschmutzten Umwelt zusammen, zeigt eine aktuelle Analyse. Auch in Deutschland fordert sie jährlich Tausende Leben. Schuld ist vor allem belastete Luft.



Publication: Spiegel

Date: 20 October 2017

Unique Monthly Visits:

26,718,000

Link:

http://www.spiegel.de/gesundheit/diagnose/umweltverschmutzung-verkuerzt-jedes-sechste-leben-weltweite-analyse-a-1173711.html

PURE EARTH · GAHP · TOGORUN

Norway

Total Top Tier Articles: 2

Total Reach: 6,779,400

PURE EARTH · GAHP · TOGORUN

Norway

Syklister trosser forurensningen i Beijing. [Foto: Jason Lee, Reuters, NTB scanpix]

Ni millioner døde som følge av forurensing i 2015

Minst ni millioner mennesker døde som følge av forurensning i 2015. Det er tre ganger så mange som aids, tuberkulose og malaria til sammen, ifølge ny rapport.

NTB

Publication: Forskning

Date: 20 October 2017

Unique Monthly Visits:

355,400

Link:

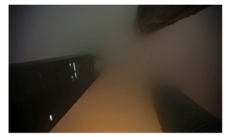
https://forskning.no/helse-miljo-forurensning/2017/10/ni-millioner-dode-som-folge-av-forurensing-i-2015

PURE EARTH BLACKSMITH INSTITUTE

GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION

TOGORUN

Norway



FORURENSNING: Ni millioner mennesker døde for tidlig i 2015 som følge av forurensning. Det hevder en ny forskningsrapport fra The Lancet. Luftforurensning er den største synderen, som her i Shanghai hvor smog fylte gatene en marsdag i 2014. Foto: Carlos Barria / Reuters / NTB Scanpix

Sjokkrapport: Hvert tredje sekund dør noen som følge av forurensning

De fattigste blir rammet hardest av forurensning. En fersk forskningsrapport knytter ni millioner dødsfall til forurensning,

Publication: Dagbladet

Date: 20 October 2017

Unique Monthly Visits:

6,424,000

Link:

https://www.dagbladet.no/nyheter/sjokkrapport-hvert-tredje-sekund-dor-noen-som-folge-av-forurensning/68804327

PURE EARTH BLACKSMITH INSTITUTE

GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION

TOGORUN

Sweden

Total Top Tier Articles: 2

Total Reach: 2,512,000

PURE EARTH BLACKSMITH INSTITUTE

GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION

TOGORUN

Sweden

Föroreningar dödar fler än krig – drabbar tusentals i Sverige

dy Wong/AP

UPPDATERAD 2017-10-20 PUBLICERAD 2017-10-20

Miljöföroreningar dödar fler människor i världen varje år än krig, rökning, hungersnöd eller sjukdomar som aids, malaria och tuberkulos, enligt en ny studie. Även tusentals svenskar dör till följd av föroreningar varje år.

Publication: Dagens Nyheter

Date: 20 October 2017

Unique Monthly Visits:

2,385,400

Link:

https://www.dn.se/nyheter/varlden/fororeningar-dodar-fler-an-krig/

PURE EARTH BLACKSMITH INSTITUTE

GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION

TOGORUN

Sweden


BOHUSLÄNINGEN

Miljöföroreningar dödar miljontals människor i världen varje år. På bilden en tegelfabrik i Indien. Arkivbild. Bild: Channi Anand, AP, TT

Föroreningar dödar fler än krig och sjukdomar

VÄRLDEN Miljöföroreningar dödar fler människor i världen varje år än krig, rökning, hungersnöd eller sjukdomar som aids, malaria och tuberkulos, visar en ny internationell studie.

TT 09:26 - 20 okt, 2017

De flesta av dödsfallen sker i hjärtsjukdomar, stroke och lungcancer. De kopplas till luftföroreningar som orsakas av främst kolkraftproduktion och fordonstrafik, men också markföroreningar på grund av kemisk industri och gruvdrift.

Publication: Bohuslaningen

Date: 20 October 2017

Unique Monthly Visits:

126,800

Link:

http://www.bohuslaningen.se/nyheter/v%C3%A4rlden/f%C3%B6roreningar-d%C3%B6dar-fler-%C3%A4n-krig-och-sjukdomar-1.4750325

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

Italy

Total Top Tier Articles: 3

Total Reach: 20,632,000

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

Italy


Lancet: le morti per smog 15 volte quelle delle guerre

Ambiente. *Le malattie dovute all'inquinamento nel 2015 hanno causato il 16% dei decessi nel mondo. La perdita di benessere derivante dall'inquinamento è stimata sui 4600 miliardi di dollari all'anno: 6,2% della produzione economica mondiale*

Publication: Il Manifesto

Date: 20 October 2017

Unique Monthly Visits:

374,400

Link:

https://ilmanifesto.it/lancet-le-morti-per-smog-15-volte-quelle-delle-guerre/

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

Italy


CRONACA

20 OTTOBRE 2017

Lancet: nel 2015 l'inquinamento ha causato 9 milioni di morti

Publication: Quotidiano

Date: 20 October 2017

Unique Monthly Visits:

1,573,300

Link:

http://www.quotidiano.net/cronaca/video/lancet-nel-2015-l-inquinamento-ha-causato-9-milioni-di-morti-1.3477051

PURE EARTH BLACKSMITH INSTITUTE | GAHP | TOGORUN

Italy

«L'inquinamento? Più letale delle guerre: ogni anno ne muore una persona su sei»

L'inquinamento ambientale sta uccidendo più persone l'anno di tutte le guerre e le violenze in corso nel mondo. Non solo, miete più vittime del fumo, della fame e dei disastri naturali. Ma anche più dell'Aids, della tubercolosi e della malaria combinate insieme. È quanto emerge da uno studio pubblicato sulla rivista scientifica *Lancet*.

Una morte ogni 6 si può ricondurre all'inquinamento. La rivista scientifica The Lancet stima che nel 2015 siano morte circa 9 milioni di persone (il 16% del totale) a causa di qualche forma di smog: aria, acqua, terreni contaminati e molto altro. Il lavoro è frutto di due anni di indagine svolte da organizzazioni internazionali, Ong e 40 ricercatori che nel rapporto sottolineano come l'inquinamento minacci la stessa «sopravvivenza delle società umane».

Publication: Il Mattino

Date: 20 October 2017

Unique Monthly Visits:

1,961,100

Link:

https://www.ilmattino.it/primopiano/cronaca/l_inquinamento_piu_letale_delle_guerre_ogni_anno_ne_muore_una_persona_su_sei-3318255.html

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

Italy

ITALIA

Lancet: nel 2015 l'inquinamento ha causato 9 milioni di morti

20 OTT 2017

Roma, (askanews) - L'inquinamento è stato collegato a 9 milioni di morti in tutto il mondo nel 2015, secondo un report pubblicato da Lancet. La maggior parte dei decessi è avvenuta in Paesi a basso o medio reddito dove l'inquinamento è ritenuto responsabile di un quarto di tutti i decessi.

Publication: Il Sole 24 Ore

Date: 20 October 2017

Unique Monthly Visits:

5,786,200

Link:

http://www.ilsole24ore.com/art/commenti-e-idee/2017-10-20/inquinamento-killer-che-uccide-nove-milioni-persone-mondo—

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

Italy

20 OTTOBRE 2017 00:37

Inquinamento, dati shock: ogni anno 9 milioni di morti

"Lancet" pubblica i dati di un progetto durato due anni. La maggioranza dei decessi avviene nel sud del mondo

(262) LEGGI DOPO COMMENTA

Quasi **9 milioni di morti l'anno**. Sono questi i numeri (relativi al 2015) riferibili all'inquinamento che ci avvelena e che emergono dai risultati di un progetto pubblicati ora sulla rivista "**Lancet**". A fare la parte del leone è l'inquinamento atmosferico (smog, particolato nell'aria ma anche inquinamento da uso domestico di combustibili fossili), responsabile di 6,5 milioni di morti l'anno (in gran parte per malattie cardiovascolari e respiratorie).

Publication: TGCOM24

Date: 20 October 2017

Unique Monthly Visits:

10,937,000

Link:

http://www.tgcom24.mediaset.it/green/inquinamento-dati-shock-ogni-anno-9-milioni-di-morti_3101790-201702a.shtml

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

Spain

Total Top Tier Articles: 2

Total Reach: 33,183,000

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

Spain

1 DE CADA 17 FALLECIMIENTOS

La contaminación provoca 24.000 muertes en un año en España

En el mundo, en 2015 murieron prematuramente nueve millones de personas por esta causa

Barcelona durante un episodio de contaminación, vista desde Collserola (Mané Espinosa)

Comparte en Facebook | Comparte en Twitter | 0

JOSEP CORBELLA, Barcelona
20/10/2017 09:01 | Actualizado a 20/10/2017 13:14

Publication: La Vanguardia

Date: 20 October 2017

Unique Monthly Visits:

12,038,000

Link:

http://www.lavanguardia.com/ciencia/cuerpo-humano/20171020/432192182743/contaminacion-muertes-espana-mundo-lancet.html

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

Spain

SALUD PÚBLICA · Primer estudio de los efectos de todo tipo de contaminación

Una de cada seis muertes es por contaminación

LAURA TARDÓN | Madrid | 20 OCT. 2017 | 00:29

Un niño rodeado de una montaña de residuos tóxicos en Kabwe (Zambia). / LARRY C. PRICE

Publication: El Mundo

Date: 20 October 2017

Unique Monthly Visits:

21,145,000

Link:

http://www.elmundo.es/ciencia-y-salud/salud/2017/10/20/59e8e44bca4741f4148b45f2.html

PURE EARTH BLACKSMITH INSTITUTE | GAHP GLOBAL ALLIANCE ON HEALTH AND POLLUTION | TOGORUN

The *Lancet* Commission on pollution and health

Philip J Landrigan, Richard Fuller, Nereus J R Acosta, Olusoji Adeyi, Robert Arnold, Niladri (Nil) Basu, Abdoulaye Bibi Baldé, Roberto Bertollini, Stephan Bose-O'Reilly, Jo Ivey Boufford, Patrick N Breysse, Thomas Chiles, Chulabhorn Mahidol, Awa M Coll-Seck, Maureen L Cropper, Julius Fobil, Valentin Fuster, Michael Greenstone, Andy Haines, David Hanrahan, David Hunter, Mukesh Khare, Alan Krupnick, Bruce Lanphear, Bindu Lohani, Keith Martin, Karen V Mathiasen, Maureen A McTeer, Christopher J L Murray, Johanita D Ndahimananjara, Frederica Perera, Janez Potočnik, Alexander S Preker, Jairam Ramesh, Johan Rockström, Carlos Salinas, Leona D Samson, Karti Sandilya, Peter D Sly, Kirk R Smith, Achim Steiner, Richard B Stewart, William A Suk, Onno C P van Schayck, Gautam N Yadama, Kandeh Yumkella, Ma Zhong

Executive summary

Pollution is the largest environmental cause of disease and premature death in the world today. Diseases caused by pollution were responsible for an estimated 9 million premature deaths in 2015—16% of all deaths worldwide—three times more deaths than from AIDS, tuberculosis, and malaria combined and 15 times more than from all wars and other forms of violence. In the most severely affected countries, pollution-related disease is responsible for more than one death in four.

Pollution disproportionately kills the poor and the vulnerable. Nearly 92% of pollution-related deaths occur in low-income and middle-income countries and, in countries at every income level, disease caused by pollution is most prevalent among minorities and the marginalised. Children are at high risk of pollution-related disease and even extremely low-dose exposures to pollutants during windows of vulnerability in utero and in early infancy can result in disease, disability, and death in childhood and across their lifespan.

Despite its substantial effects on human health, the economy, and the environment, pollution has been neglected, especially in low-income and middle-income countries, and the health effects of pollution are underestimated in calculations of the global burden of disease. Pollution in low-income and middle-income countries that is caused by industrial emissions, vehicular exhaust, and toxic chemicals has particularly been overlooked in both the international development and the global health agendas. Although more than 70% of the diseases caused by pollution are non-communicable diseases, interventions against pollution are barely mentioned in the Global Action Plan for the Prevention and Control of Non-Communicable Diseases.

Pollution is costly. Pollution-related diseases cause productivity losses that reduce gross domestic product (GDP) in low-income to middle-income countries by up to 2% per year. Pollution-related disease also results in health-care costs that are responsible for 1·7% of annual health spending in high-income countries and for up to 7% of health spending in middle-income countries that are heavily polluted and rapidly developing. Welfare losses due to pollution are estimated to amount to US$4·6 trillion per year: 6·2% of global economic output. The costs attributed to pollution-related disease will probably increase as additional associations between pollution and disease are identified.

Pollution endangers planetary health, destroys ecosystems, and is intimately linked to global climate change. Fuel combustion—fossil fuel combustion in high-income and middle-income countries and burning of biomass in low-income countries—accounts for 85% of airborne particulate pollution and for almost all pollution by oxides of sulphur and nitrogen. Fuel combustion is also a major source of the greenhouse gases and short-lived climate pollutants that drive climate change. Key emitters of carbon dioxide, such as electricity-generating plants, chemical manufacturing facilities, mining operations, deforestation, and petroleum-powered vehicles, are also major sources of pollution. Coal is the world's most polluting fossil fuel, and coal combustion is an important cause of both pollution and climate change.

In many parts of the world, pollution is getting worse. Household air and water pollution, the forms of pollution associated with profound poverty and traditional lifestyles, are slowly declining. However, ambient air pollution, chemical pollution, and soil pollution—the forms of pollution produced by industry, mining, electricity generation, mechanised agriculture, and petroleum-powered vehicles—are all on the rise, with the most marked increases in rapidly developing and industrialising low-income and middle-income countries.

Chemical pollution is a great and growing global problem. The effects of chemical pollution on human health are poorly defined and its contribution to the global burden of disease is almost certainly underestimated. More than 140 000 new chemicals and pesticides have been synthesised since 1950. Of these materials, the 5000 that are produced in greatest volume have become widely dispersed in the environment and are responsible for nearly universal human exposure. Fewer than half of these high-production volume chemicals have undergone any testing for safety or toxicity, and rigorous pre-market evaluation of new chemicals has become mandatory in only the past decade and in only a few high-income countries. The result is that chemicals and pesticides whose effects on human health and the environment were never examined have repeatedly been responsible for episodes of disease, death, and environmental degradation. Historical examples include lead, asbestos, dichlorodiphenyltrichloroethane (DDT), polychlorinated biphenyls (PCBs), and the ozone-destroying chlorofluorocarbons. Newer synthetic chemicals that have entered world markets in the past

Published Online October 19, 2017
http://dx.doi.org/10.1016/S0140-6736(17)32345-0

This online publication has been corrected. The corrected version first appeared at thelancet.com on Nov 7, 2017

See Online/Comment
http://dx.doi.org/10.1016/S0140-6736(17)32588-6 and http://dx.doi.org/10.1016/S0140-6736(17)32545-X

Arnhold Institute for Global Health (Prof P J Landrigan MD), **Mount Sinai Heart** (V Fuster MD), **and Department of Environmental Medicine and Global Health** (Prof A S Preker PhD), **Icahn School of Medicine at Mount Sinai, New York, NY, USA; Pure Earth, New York, NY, USA** (R Fuller BE, D Hanrahan MSc, K Sandilya LLB)**; Office of the President, Manila, Philippines** (N J R Acosta PhD)**; Department of Health, Nutrition, and Population Global Practice** (O Adeyi DrPH), **and Office of the US Executive Director** (K V Mathiasen MALD), **The World Bank, Washington, DC, USA; Department of Chemical and Environmental Engineering, University of Arizona, Tucson, AZ, USA** (R Arnold PhD)**; Faculty of Agricultural and Environmental Sciences, McGill University, Montreal, Canada** (Prof N Basu PhD)**; Ministry of Environment and Sustainable Development, Dakar, Senegal** (A B Baldé MS)**; Scientific Committee on Health, Environmental and Emerging Risks of the European Commission, Luxembourg City, Luxembourg** (R Bertollini MD)**; Office of the Minister of Health, Ministry of Public Health, Doha, Qatar** (R Bertollini)**; Institute and Outpatient Clinic for Occupational, Social and Environmental Medicine, University Hospital of LMU Munich, Munich, Germany**

(S Bose-O'Reilly MD); Department of Public Health, Health Services Research and Health Technology Assessment, University for Health Sciences, Medical Informatics and Technology, Hall in Tirol, Austria (S Bose-O'Reilly); New YorkAcademy of Medicine, New York, NY, USA (J I Bouffourd MD); Department of Environmental Health and Engineering, Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA (P N Breysse PhD); School of Social Work (Prof G N Yadama PhD), and Department of Biology (T Chiles PhD), Boston College, Chestnut Hill, MA, USA; Chulabhorn Research Institute, Bangkok, Thailand (HRH Princess C Mahidol PhD); Ministry of the Health and Social Affairs, Dakar, Senegal (A M Coll-Seck MD); Department of Economics, University of Maryland, College Park, MD, USA (Prof M L Cropper PhD); Resources for the Future, Washington, DC, USA (Prof M L Cropper, A Krupnick PhD); Department of Biological, Environmental and Occupational Health Sciences, School of Public Health, University of Ghana, Accra, Ghana (J Fobil DrPH); Centro Nacional de Investigaciones Cardiovasculares Carlos III, Madrid, Spain (V Fuster); Department of Economics, University of Chicago, Chicago, IL, USA (M Greenstone PhD); Department of Social and Environmental Health Research and Department of Population Health, London School of Hygiene & Tropical Medicine, London, UK (Prof A Haines FMedSci); Nuffield Department of Population Health, University of Oxford, Oxford, UK (Prof D Hunter MBBS); Department of Civil Engineering, Indian Institute of Technology, Delhi, India (Prof M Khare PhD); Faculty of Health Sciences, Simon Fraser University, Burnaby, BC, Canada (B Lanphear MD); Centennial Group, Washington, DC, USA (B Lohani PhD); The Resources Center, Lalitpur, Nepal (B Lohani); Consortium of Universities for Global Health,

2–3 decades and that, like their predecessors, have undergone little pre-market evaluation threaten to repeat this history. They include developmental neurotoxicants, endocrine disruptors, chemical herbicides, novel insecticides, pharmaceutical wastes, and nanomaterials. Evidence for the capacity of these emerging chemical pollutants to cause harm to human health and the environment is beginning to become evident. These emerging chemicals are of great concern, and this concern is heightened by the increasing movement of chemical production to low-income and middle-income countries where public health and environmental protections are often scant. Most future growth in chemical production will occur in these countries. A further dimension of chemical pollution is the global archipelago of contaminated hot-spots: cities and communities, homes and schoolyards polluted by toxic chemicals, radionuclides, and heavy metals released into air, water, and soil by active and abandoned factories, smelters, mines, and hazardous waste sites.

Cities, especially rapidly growing cities in industrialising countries, are severely affected by pollution. Cities contain 55% of the world's population; they account for 85% of global economic activity and they concentrate people, energy consumption, construction activity, industry, and traffic on a historically unprecedented scale.

The good news is that much pollution can be eliminated, and pollution prevention can be highly cost-effective. High-income and some middle-income countries have enacted legislation and issued regulations mandating clean air and clean water, established chemical safety policies, and curbed their most flagrant forms of pollution. Their air and water are now cleaner, the blood lead concentrations of their children have decreased by more than 90%, their rivers no longer catch fire, their worst hazardous waste sites have been remediated, and many of their cities are less polluted and more liveable. Health has improved and people in these countries are living longer. High-income countries have achieved this progress while increasing gross domestic product (GDP) by nearly 250%. The challenge for high-income nations today is to further reduce pollution, decarbonise their economies, and reduce the resources used in achieving prosperity. The claim that pollution control stifles economic growth and that poor countries must pass through a phase of pollution and disease on the road to prosperity has repeatedly been proven to be untrue.

Pollution mitigation and prevention can yield large net gains both for human health and the economy. Thus, air quality improvements in the high-income countries have not only reduced deaths from cardiovascular and respiratory disease but have also yielded substantial economic gains. In the USA, an estimated US$30 in benefits (range, $4–88) has been returned to the economy for every dollar invested in air pollution control since 1970, which is an aggregate benefit of $1·5 trillion against an investment of $65 billion. Similarly, the removal of lead from gasoline has returned an estimated $200 billion (range, $110 billion–300 billion) to the US economy each year since 1980, an aggregate benefit to-date of over $6 trillion through the increased cognitive function and enhanced economic productivity of generations of children exposed since birth to only low amounts of lead.

Pollution control will advance attainment of many of the sustainable development goals (SDGs), the 17 goals established by the United Nations to guide global development in the 21st century. In addition to improving health in countries around the world (SDG 3), pollution control will help to alleviate poverty (SDG 1), improve access to clean water and improve sanitation (SDG 6), promote social justice (SDG 10), build sustainable cities and communities (SDG 11), and protect land and water (SDGs 14 and 15). Pollution control, in turn, will benefit from efforts to slow the pace of climate change (SDG 13) by transitioning to a sustainable, circular economy that relies on non-polluting renewable energy, on efficient industrial processes that produce little waste, and on transport systems that restrict use of private vehicles in cities, enhance public transport, and promote active travel.

Many of the pollution control strategies that have proven cost-effective in high-income and middle-income countries can be exported and adapted by cities and countries at every level of income. These strategies are based in law, policy, regulation, and technology, are science-driven, and focus on the protection of public health. The application of these approaches boosts economies and increases GDP. The strategies include targeted reductions in emissions of pollutants, transitions to non-polluting, renewable sources of energy, the adoption of non-polluting technologies for production and transportation, and the development of efficient, accessible, and affordable public transportation systems. Application of the best of these strategies in carefully planned and well resourced campaigns can enable low-income and middle-income countries to avoid many of the harmful consequences of pollution, leapfrog the worst of the human and ecological disasters that have plagued industrial development in the past, and improve the health and wellbeing of their people. Pollution control provides an extraordinary opportunity to improve the health of the planet. It is a winnable battle.

The aim of this *Lancet* Commission on pollution and health is to raise global awareness of pollution, end neglect of pollution-related disease, and mobilise the resources and the political will needed to effectively confront pollution. To advance this aim, we make six recommendations. Additional recommendations are presented at the end of each Section. The key recommendations are:

(1) Make pollution prevention a high priority nationally and internationally and integrate it into country and city

 www.thelancet.com Published online October 19, 2017 http://dx.doi.org/10.1016/S0140-6736(17)32345-0

planning processes. Pollution can no longer be viewed as an isolated environmental issue, but is a transcendent problem that affects the health and wellbeing of entire societies. Leaders of government at all levels (mayors, governors, and heads of state) need, therefore, to elevate pollution control to a high priority within their agendas; to integrate pollution control into development planning; to actively engage in pollution planning and prioritisation; and to link prevention of pollution with commitments to advance the SDGs, to slow the pace of climate change, and to control non-communicable diseases.

Targets and timetables are essential, and governments at all levels need to establish short-term and long-term targets for pollution control and to support the agencies and regulations needed to attain these goals. Legally mandated regulation is an essential tool, and both the polluter-pays principle and an end to subsidies and tax breaks for polluting industries need to be integral components of pollution control programmes.

(2) Mobilise, increase, and focus the funding and the international technical support dedicated to pollution control. The amount of funding from international agencies, binational donors, and private foundations that is directed to control of pollution, especially pollution from the industrial, transport, chemical, and mining sectors in low-income and middle-income countries is meagre and needs to be substantially increased. The resources directed to pollution management need to be increased within cities and countries as well as internationally. Options for increasing the international development funding directed to pollution include expansion of climate change and non-communicable disease control programmes to include pollution control and development of new funding mechanisms.

In addition to increased funding, international technical support for pollution control is needed in prioritisation and planning of processes to tackle pollution within rapidly industrialising cities and countries; in development of regulatory and enforcement strategies; in building technical capacity; and in direct interventions, in which such actions are urgently needed to save lives or can substantially leverage local action and resources. Financing and technical assistance programmes need to be tracked and measured to assess their cost-effectiveness and to enhance accountability.

(3) Establish systems to monitor pollution and its effects on health. Data collected at the national and local levels are essential for measuring pollution levels, identifying and apportioning appropriate responsibility to each pollution source, evaluating the success of interventions, guiding enforcement, informing civil society and the public, and assessing progress toward goals. The incorporation of new technologies, such as satellite imaging and data mining, into pollution monitoring can increase efficiency, expand geographic range, and lower costs. Open access to these data is essential, and consultation with civil society and the public will ensure accountability and build public awareness. With even limited monitoring programmes, consisting of only one or a few sampling stations, governments and civil society organisations can document pollution, and track progress toward short-term and long-term control targets. Pollution control metrics should be integrated into SDG dashboards and other monitoring platforms so that successes and experiences can be shared.

(4) Build multi-sectoral partnerships for pollution control. Broad-based partnerships across several government agencies and between governments and the private sector can powerfully advance pollution control and accelerate the development of clean energy sources and clean technologies that will ultimately prevent pollution at source. Cross-ministerial collaborations that involve health and environment ministries, but also ministries of finance, energy, agriculture, development, and transport are essential. Collaborations between governments and industry can catalyse innovation, create incentives for cleaner production technologies and cleaner energy production, and incentivise transition to a more sustainable, circular economy. The private sector is in a unique position to provide leadership in the design and development of clean, non-polluting, sustainable technologies for pollution control, and to engage constructively with governments to reward innovation and create incentives.

(5) Integrate pollution mitigation into planning processes for non-communicable diseases. Interventions against pollution need to be a core component of the Global Action Plan for the Prevention and Control of Non-Communicable Diseases.

(6) Research pollution and pollution control. Research is needed to understand and control pollution and to drive change in pollution policy. Pollution-related research should:

- Explore emerging causal links between pollution, disease, and subclinical impairment, for example between ambient air pollution and dysfunction of the central nervous system in children and the elderly;
- Quantify the global burden of disease associated with chemical pollutants of known toxicity such as lead, mercury, chromium, arsenic, asbestos, and benzene;
- Identify and characterise the adverse health outcomes caused by new and emerging chemical pollutants, such as developmental neurotoxicants, endocrine disruptors, novel insecticides, chemical herbicides, and pharmaceutical wastes;
- Identify and map pollution exposures particularly in low-income and middle-income countries;
- Improve estimates of the economic costs of pollution and pollution-related disease; and
- Quantify the health and economic benefits of interventions against pollution and balance these benefits against the costs of interventions.

Washington, DC, USA (K Martin MD); **Faculty of Common Law, University of Ottawa, Ottawa, ON, Canada** (M A McTeer LLM); **Institute for Health Metrics, Seattle, WA, USA** (C J L Murray MD); **Ministry of Environment, Ecology and Forests, Antananarivo, Madagascar** (J D Ndahimananjara MD); **Columbia Center for Children's Environmental Health, Department of Environmental Health Sciences** (F Perera DrPH), **and Department of Health Policy and Management** (Prof A S Preker), **Mailman School of Public Health, Columbia University, New York, NY, USA; UN International Resource Panel, Paris, France** (J Potočnik PhD); **SYSTEMIQ, London, UK** (J Potočnik); **Health Investment & Financing Corporation, New York, NY, USA** (Prof A S Preker); **Parliament of India, New Delhi, India** (J Ramesh MS); **Stockholm Resilience Centre, Stockholm University, Stockholm, Sweden** (J Rockström PhD); **Mexico City, Mexico** (C Salinas PhD); **Department of Biological Engineering and Department of Biology, Center for Environmental Health Sciences, Koch Institute for Integrative Cancer Research, Massachusetts Institute of Technology, Cambridge, MA, USA** (Prof L D Samson PhD); **Children's Health and Environment Program, Child Health Research Centre, University of Queensland, Brisbane, QLD, Australia** (Prof P D Sly DSc); **Environmental Health Sciences Division, School of Public Health, University of California, Berkeley, CA, USA** (K R Smith PhD); **Oxford Martin School, University of Oxford, Oxford, UK** (A Steiner MA); **Guarini Center on Environmental, Energy, and Land Use Law, New York University, New York, NY, USA** (Prof R B Stewart LLB); **Division of Extramural Research and Training, National Institute of Environmental Health Sciences, National Institutes of Health, Research Triangle Park, NC, USA** (W A Suk PhD); **Care and Public Health Research Institute, Maastricht University, Maastricht, the Netherlands**

(Prof C P van Schayck PhD); **United Nations Industrial Development Organization, Vienna, Austria** (K Yumkella PhD)**; and School of Environment and Natural Resources, Renmin University of China, Beijing, China** (Prof M Zhong PhD)

Correspondence to: Prof Philip J Landrigan, Arnhold Institute for Global Health, Icahn School of Medicine at Mount Sinai, New York, NY 10029, USA **philip.landrigan@mssm.edu**

Introduction

Pollution is one of the great existential challenges of the Anthropocene epoch. Like climate change, biodiversity loss, ocean acidification, desertification, and depletion of the world's fresh water supply, pollution endangers the stability of the Earth's support systems and threatens the continuing survival of human societies.[1] Pollution, especially pollution caused by industrial emissions, vehicular exhausts, and toxic chemicals, has increased sharply in the past 500 years, and the largest increases today are seen in low-income and middle-income countries. Yet despite its great and growing magnitude, industrial, vehicular, and chemical pollution in developing countries has been largely overlooked in international development and global health agendas, and programmes for pollution control have received little attention or resources from either international agencies or philanthropic donors. Pollution is now a substantial problem that endangers the health of billions, degrades the Earth's ecosystems, undermines the economic security of nations, and is responsible for an enormous global burden of disease, disability, and premature death.

Pollution is intimately linked to global climate change.[2,3] Fuel combustion—fossil fuel combustion in high-income and middle-income countries, and biomass burning in inefficient cookstoves, open fires, agricultural burns, forest burning,[4,5] and obsolete brick kilns in low-income countries—accounts for 85% of airborne particulate pollution and for almost all pollution by oxides of sulphur and nitrogen. Fuel combustion is the major source of greenhouse gases and short-lived climate pollutants that are the main anthropogenic drivers of global climate change (appendix pp 1–11).[6]

See **Online** for appendix

Pollution is very costly; it is responsible for productivity losses, health-care costs, and costs resulting from damages to ecosystems. But despite the great magnitude of these costs, they are largely invisible and often are not recognised as caused by pollution.[7] The productivity losses of pollution-related diseases are buried in labour statistics. The health-related costs of pollution are hidden in hospital budgets.[8] The result is that the full costs of pollution are not appreciated, are often not counted, and are not available to rebut one-sided, economically based arguments against pollution control.[7,9]

The nature of pollution is changing and, in many places around the world, it is worsening. These changes reflect increased energy consumption, the increased use of new materials and technologies, the rapid industrialisation of low-income and middle-income countries, and the global movement of populations from rural areas into cities. Household air and water pollution, the forms of pollution that were historically associated with profound poverty and traditional lifestyles, are slowly declining. However, ambient air pollution, chemical pollution, and soil pollution, are all increasing.[10,11] Key drivers of these types of pollution are: the uncontrolled growth of cities;[12] rising demands for energy; increasing mining, smelting, and deforestation; the global spread of toxic chemicals; progressively heavier applications of insecticides and herbicides; and an increasing use of petroleum-powered cars, trucks, and buses. Increases in ambient air, soil, and chemical pollution over the past 500 years can be directly attributed to the currently prevalent, linear, take-make-use-dispose economic paradigm—termed by Pope Francis "the throwaway culture"[13]—in which natural resources and human capital are viewed as abundant and expendable, and the consequences of their reckless exploitation are given little heed.[14,15] This economic paradigm focuses single-mindedly on GDP[14] and is ultimately unsustainable: this model fails to link the economic development of human societies to social justice or to maintenance of the Earth's resources.[1,2,15]

Scientific understanding of pollution and its effects on health have greatly advanced.[16,17] New technologies, including satellite imaging,[18] have enhanced the ability to map pollution, measure pollution levels remotely, identify sources of pollution, and track temporal trends.[17] Sophisticated chemical analyses have refined understanding of the composition of pollution and elucidated links between pollution and disease.[19] Large prospective, multi-year epidemiological studies, beginning with the studies by Pope and colleagues[20] in Utah and the Harvard Six-Cities study,[21] have showed that pollution is associated with a much wider range of diseases, particularly non-communicable diseases, than was previously recognised. Pollution is now understood to be an important causative agent of many non-communicable diseases including asthma, cancer, neurodevelopmental disorders, and birth defects in children (appendix p 11); and heart disease, stroke, chronic obstructive pulmonary disease, and cancer in adults.[22–34] In the absence of aggressive intervention, the number of deaths due to ambient air pollution are on track to increase by more than 50% by 2050.[35]

Despite these advances in knowledge, there are still many gaps in information about pollution and its effects on health. These gaps include an absence of information in many countries on pollution levels and the prevalence of pollution-related disease; poor knowledge of the toxic effects of many chemicals in common use, especially newer classes of chemicals;[36,37] incomplete information on the scope of exposures and burden of disease associated with toxic exposures at contaminated sites;[38] and inadequate information on the possible delayed effects of toxic exposures sustained in early life.[39] Also unknown is the exact shape of the dose-response functions used to estimate the relative risk of disease associated with pollution. In the case of fine-particulate air pollution, for example, the shape of the exposure–response association at both very low and very high exposure levels and the assumptions that underlie the integrated exposure–response function[40] used to estimate the relative risks of fine particulate ($PM_{2·5}$) exposure in both the Global Burden of Disease (GBD) study[41,42] and WHO analyses are not precisely known.[23]

The good news is that, despite the great magnitude of pollution and current gaps in knowledge about its effects on human health and the environment, pollution can be prevented. Pollution is not the inevitable consequence of economic development. High-income and some middle-income countries have enacted legislation and issued regulations that build on new scientific knowledge about pollution and its health effects. These laws and regulations are based on the polluter-pays principle; they mandate clean air and clean water and set standards at levels that prevent disease, have established policies for chemical safety, have banned certain hazardous pollutants such as lead, asbestos, and DDT, and have effected clean-up of the worst of the hazardous waste sites.

Many of these proven, cost-effective control strategies are now ready to be exported and adapted for use by cities and countries at every level of income. Their application in carefully planned and well resourced campaigns can enable developing and industrialising countries to avoid many of the harmful consequences of pollution—to leapfrog over the worst of the human and ecological disasters that have plagued industrial development in the past—and to improve human health and wellbeing.

Contrary to the oft-repeated claim that pollution control stifles economic growth, pollution prevention has, in fact, been shown repeatedly to be highly cost-effective. In the USA, for example, concentrations of six common air pollutants have been reduced by about 70% since passage of the Clean Air Act in 1970 and, in the same time period, GDP has increased by nearly 250% (figure 1).[43] Every dollar invested in control of ambient air pollution in the USA not only improves health,[44] but also is estimated to yield US$30 in economic benefits (95% CI $4–88).[45]

Another example of the economic benefits of addressing pollution is seen in the consequences of removing lead from gasoline in the USA. This intervention began in 1975 and, within a decade, had reduced the mean blood concentration of lead in the population by more than 90% (figure 2), almost eliminated childhood lead poisoning, and increased the cognitive capacity of all American children born since 1980 by 2–5 IQ points.[46] This gain in intelligence has increased national economic productivity and will yield an economic benefit of US$200 billion (range $110 billion–300 billion) over the lifetimes of each annual cohort of children born since 1980,[46] an aggregate benefit to-date of over $6 trillion.[47,48]

Yet, despite its harmful effects on human health, the economy, and the environment and, notwithstanding the clear evidence that it can be cost-effectively controlled, pollution (especially industrial, vehicular, and chemical pollution in low-income and middle-income countries) has been largely neglected.[49,50] Work to control the biological contamination of drinking water[51–54] and to curb

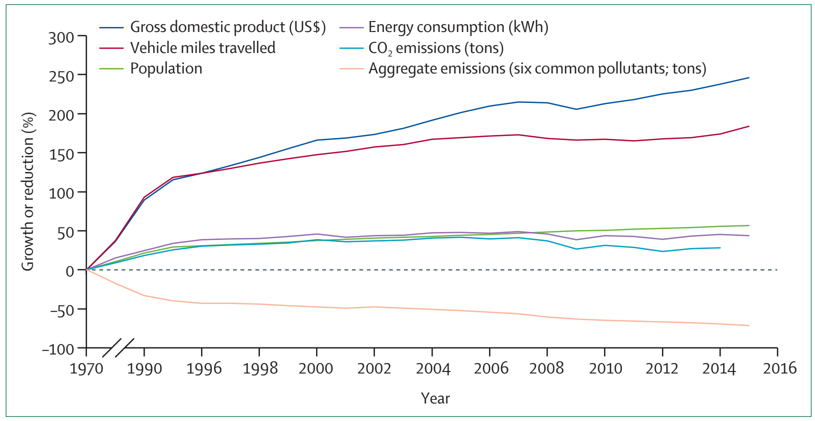


Figure 1: **Pollution, population, and GDP in the USA, 1970–2015**
Figure taken from reference 43, with permission.

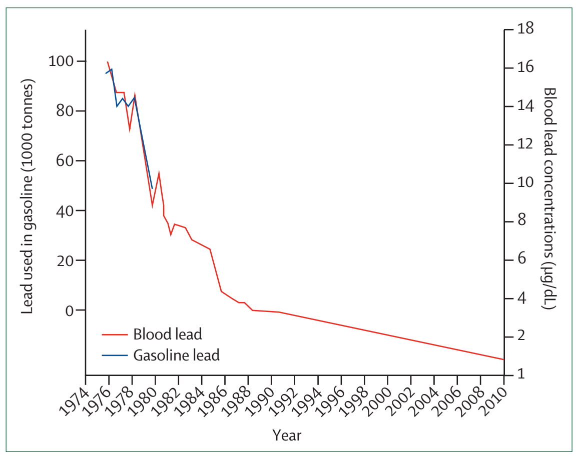


Figure 2: **Correlation between population mean blood concentration of lead and lead use in gasoline in the USA, 1974–91**
Taken from data that is publicly available from the Centers for Disease Control.

household air pollution produced by poorly ventilated cookstoves[55–57] has occurred over many years and those efforts, along with new vaccines, antibiotics, and treatment protocols, have contributed to promising reductions in the morbidity and mortality associated with the traditional forms of pollution.[58–60] However, the burgeoning problems of air, water, and soil pollution produced by modern industry, electricity generation, mining, smelting, petroleum-powered motor vehicles, and chemical and pesticide releases in low-income and middle-income countries have received almost no international attention or resources.[49,50] Budgets for foreign aid from the European Commission, the US Agency for International Development, and most bilateral development agencies, private philanthropists, and major foundations have not included substantive funding for control of industrial, mining and transport-related pollution.[50,61] The national and local resources directed toward the study and control of industrial, chemical, and vehicular pollution and the diseases that they cause within cities and countries are

For the **Global Alliance for Clean Cookstoves** see http://cleancookstoves.org/

For the **US Agency for International Development** see https://explorer.usaid.gov/

often meagre.[62] Lastly, interventions against pollution are barely mentioned in the Global Action Plan for the Prevention and Control of Non-Communicable Diseases,[63] which is a major missed opportunity.

Several factors have contributed to the neglect of pollution. A persistent impediment has been the flawed conventional wisdom that pollution and disease are the unavoidable consequences of economic development, the so-called "environmental Kuznets hypothesis" (panel 1).[64–73] This Commission vigorously challenges that claim as a flawed and obsolete notion formulated decades ago when populations and urban centres were much smaller than they are today, the nature, sources, and health effects of pollution were very different, and cleaner fuels and modern production technologies were not yet available.

Fragmentation of the agendas for environmental health and pollution control is another factor that has contributed to neglect of pollution. In many countries, responsibility for pollution-related disease falls between ministries of health and ministries for the environment, and too often belongs to neither. Air, water, soil, and chemical pollution are each regulated by different agencies and studied by different research groups. The consequence is that the full scale of pollution and its contribution to the global burden of disease are not recognised. The separation of public health from environmental protection has also slowed the growth of research on pollution-related disease, led to the virtual elimination of coursework in environmental health science from the curricula of most medical and nursing schools, and impeded the development of environmental health policy.

For the **World Bank Water and Sanitation Programme** see http://www.wsp.org/

In the international development agenda, neglect of the modern forms of pollution can be traced to the historical origins of overseas development assistance programmes whose goals, when they were launched at the end of World War 2, were to reduce poverty, improve maternal and child health, and combat infectious diseases in an era when much of the world was devastated and more than 50% of countries were classified as low-income.[49,50] At that time, the predominant health problems of the developing world were infectious diseases and maternal and child mortality, and many overseas development programmes have been highly successful and have contributed to the control of these problems.[74] However, these programmes were never intended to address the more modern forms of pollution.

Finally, the opposition of powerful vested interests has been a perennial barrier to control of pollution, especially industrial, vehicular, and chemical pollution. These entrenched interests, which often exert disproportionate influence on government policy, impugn the science linking pollution to disease, manufacture doubt about the effectiveness of interventions, and paralyse governmental efforts to establish standards, impose pollution taxes, and enforce laws and regulations.[75] These interests act both within countries and internationally.

The aim of this *Lancet* Commission on pollution and health is to end the neglect of pollution, especially of the modern forms of pollution, in low-income and middle-income countries, to focus the world's attention onto the silent threat of pollution-related disease, and to mobilise the national and international resources and the political will needed to effectively confront pollution.

To accomplish this aim and to mobilise the resources that will be needed to control pollution around the world, we have reviewed data on the health effects and economic costs of all forms of pollution: pollution of air, water, and soil, pollution in the workplace, and pollution by toxic chemicals (appendix p 15). We have also examined the links between pollution and poverty, injustice, and inequality. Finally, this Commission presents examples of cost-effective, proven strategies that can be adapted by cities and countries at every level of income to control pollution and prevent disease (appendix pp 63–107).

The work of this Commission on pollution and health builds upon work undertaken in the past decade by international organisations and bi-national funders to address the challenges of modern-day pollution, such as the World Bank Water and Sanitation Programme.[76,77] WHO has established a Department of Public Health

Panel 1: The environmental Kuznets curve

The Kuznets curve, developed by economist Simon Kuznets (1901–85), describes the association between economic inequality and per capita income over the course of economic development.[64] This curve illustrates Kuznets' hypothesis that, as a society develops from a primarily agrarian to an urban, industrialised economy, market forces first increase and then, at a so-called "turning point" of per-capita income, decreases the overall degree of economic inequality in the society. These trends are shown as an inverted U-shaped curve.[65]

The Kuznets hypothesis has been extended to environmental economics. Here, it is postulated that pollution and environmental degradation must increase in early stage economic development, that pollution will continue to increase up to a threshold of per-capita income, and that pollution will then decrease as the economy continues to grow. The postulated result is that high income and economic growth eventually lead to environmental improvements. This extension of Kuznets' hypothesis has become entrenched as conventional wisdom in global environmental policy.[66,67]

Despite the great certitude with which the environmental Kuznets hypothesis is sometimes promulgated, empirical and theoretical research finds that the historical evidence in support of this hypothesis is uneven, and that the underlying statistical methods are weak.[70–72] Additional shortcomings are that the environmental Kuznets hypothesis fails to consider the movement of polluting industries from high-income to low-income and middle-income countries,[68] does not consider the health and environmental effects of modern classes of pollutants such as chemical carcinogens, neurotoxicants, and endocrine-disrupting chemicals,[69–73] and does not consider the potential benefits to human health and the environment of newer, non-polluting energy sources.

The conclusions from this analysis are that pollution is not the unavoidable consequence of economic development, and that it is much more important to formulate sound laws, policies, and regulations to control pollution than to wait for an economy to reach a magical tipping point that will solve the problems of environmental degradation and pollution-related disease. The goal of this Commission is to catalyse the formulation of such policies.

and the Environment, which has become a global leader in documenting the effects of environmental threats to children's health.[78,79] The UN Development Programme has taken on many components of the pollution control agenda. The World Bank financially supports several projects to control pollution. The UN Environment Programme also supports several programmes to control chemical pollution, some in partnership with WHO, and supports and oversees international agreements limiting the manufacture, environmental release, and global transport of persistent pollutants,[80] pesticides, hazardous waste, and mercury. The Strategic Approach to International Chemicals Management, housed within the UN Environment Programme, provides a platform for discussion on control of chemical pollution and toxic waste among a broad range of stakeholders (appendix pp 13–14). These global advances in controlling ambient air, chemical, and vehicular pollution are welcome[81] and have produced important gains, such as phasing lead out from gasoline, endorsed by the Partnership for clean fuels and vehicles, incorporating air pollution into the health agenda,[82] establishing programmes to control the addition of lead to paint,[83] and creating a pollution-focused trust fund within the World Bank.

Pollution defined

This Commission defines pollution as unwanted, often dangerous, material that is introduced into the Earth's environment as the result of human activity, that threatens human health, and that harms ecosystems; this definition is based on a definition of pollution developed by the European Union.[84]

To provide a framework for organising scientific knowledge about pollution and its effects on human health and to help focus pollution-related research, this Commission has developed the concept of the pollutome (figure 3). The pollutome is defined as the totality of all forms of pollution that have the potential to harm human health. The pollutome can be viewed as a fully contained (nested) subset of the exposome.[85,86] This model includes pollutant exposures during gestation, infancy, childhood, adolescence, adult life (including occupational exposures), and old age.

Because knowledge about the health effects of pollution varies by pollution type and ranges from the well characterised and quantified to the still emerging, we have divided the pollutome into three zones.

Zone 1 includes well established pollution–disease pairs, for which there are robust estimates of their contributions to the global burden of disease. The associations between ambient air pollution and non-communicable disease are the prime example.[23]

Zone 2 includes the emerging effects of known pollutants, where evidence of causation is building, but associations between exposures and disease are not yet fully characterised and the burden of disease has not yet been quantified. Examples include associations between $PM_{2·5}$ air pollution and diabetes,[24–26] pre-term birth,[27–29] and diseases of the central nervous system, including autism in children,[3,30–32] and dementia in the elderly.[29,33] Soil pollution by heavy metals and toxic chemicals at contaminated industrial and mining sites provides another example of a potentially important, but not yet fully characterised or quantified source of pollution-related disease.[38,87]

Zone 3 includes new and emerging pollutants,[36,37] most of them chemical pollutants whose effects on human health are only beginning to be recognised and are not yet quantified. Several of these chemicals have become widely disseminated in the environment, and many are detectable in the bodies of most persons examined in national surveys, such as the Centers for Disease Control's national biomonitoring programme in the United States. At least some of these chemical pollutants appear to have potential to cause global epidemics of disease, disability, and death. This zone includes developmental neuro-toxicants;[37,88] endocrine disruptors;[89–92] new classes of pesticides such as the neonicotinoids;[93] chemical herbicides such as glyphosate and nano-particles; and pharmaceutical wastes.[94–96] These emerging chemical pollutants are discussed in detail in the appendix of this report (pp 2–11).

The list of diseases attributed to pollution will probably continue to expand as the environmental distributions and health effects of newer chemical pollutants are better defined and new exposure–disease associations are discovered. The health effects of pollution that are currently recognised and quantified could thus be the tip of a much larger iceberg.[88] As more research becomes available, some pollution–disease pairs that are currently placed in zones 2 and 3 of the pollutome could move up to

For the **Strategic Approach to International Chemicals Management** see http://www.saicm.org/

For the **Centers for Disease Control and Prevention national biomonitoring programme** see https://www.cdc.gov/biomonitoring/

For the **Partnership for clean fuels and vehicles** see http://www.unep.org/transport/pcfv/

For the **World Bank pollution management and environmental health programme** see http://www.worldbank.org/en/programs/pollution-management-and-environmental-health-program

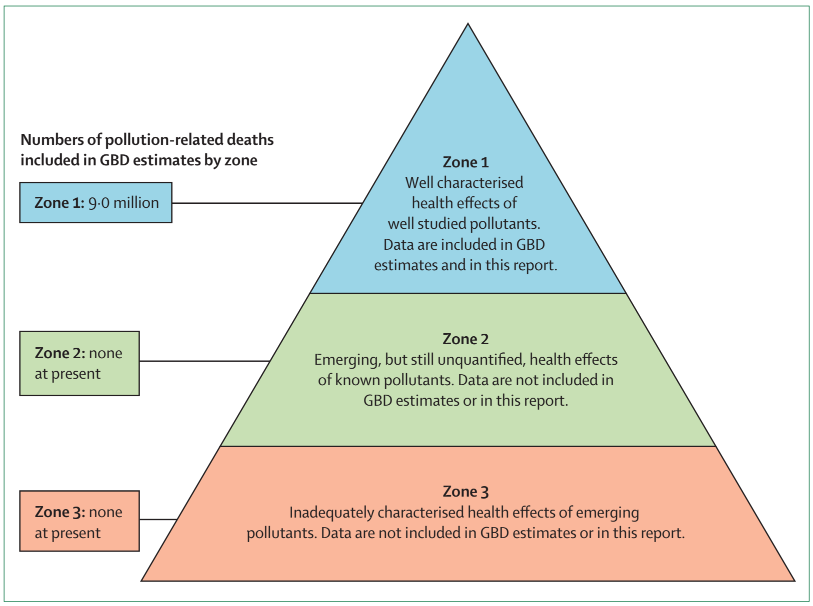


Figure 3: The pollutome

zone 1 and be included in future estimates of the global burden of disease. The numbers of deaths attributable to the forms of pollution included in zones 2 and 3 are unknown.

This Commission's work has been informed by the work of previous *Lancet* Commissions and Series, notably the Commission on Investing in Health,[72] the Commission on the Political Origins of Health Inequity,[73] the Commission on Health and Climate Change,[97] and the Series on Public Health Benefits of Climate Change Mitigation Policies.[98] This Commission's deliberations were guided particularly closely by the findings of The Rockefeller Foundation-*Lancet* Commission on Planetary Health[15] whose 2015 report described how human activity is changing the global environment, increasing risk of disease, and threatening the conditions that, ultimately, sustain all life on Earth.

This Commission was guided further by influential reports from international agencies, among them the 2016 report from WHO,[99] Preventing Disease through Health Environments, the World Bank's Shock Waves report[100] on climate change and global poverty, the World Bank's report,[77] Clean Air and Healthy Lungs, and the United Nations Environment report,[101] Costs of Inaction on the Sound Management of Chemicals.

This report is organised into five Sections. Section 1 synthesises information on the burden of disease attributable to pollution using data from the GBD 2015 Study[41,42] coordinated by the Institute for Health Metrics and Evaluation, and supplemented by data from WHO[99,102] and from Pure Earth.[38] Section 2 examines data on the economic costs of pollution and presents a detailed analysis of the economic losses that result from pollution-related disease. Section 3 examines the links between pollution, disease, and poverty and documents the marked inequities that characterise the global distribution of pollution and pollution-related disease and the disproportionate effects of pollution on children, the poor, the elderly, and other vulnerable populations. Section 4 presents pathways and priorities, case studies, and proven interventions that can be adopted and deployed to control pollution, prevent disease, and advance economic development. Section 5 outlines the Commission's plans for future initiatives.

Sustainable long-term control of pollution will require that societies at every level of income move away from the prevalent resource-intensive, and inherently wasteful, linear take-make-use-dispose economic paradigm, towards a new paradigm rooted in the concept of the circular economy (panel 2).[15,103,104] In a circular economy, pollution is reduced through the creation of durable, long-lasting products, the reduction of waste by large-scale recycling, reuse, and repair, the removal of distorting subsidies, the replacement of hazardous materials with safer alternatives, and strict enforcement of pollution taxes.[105] A circular economy conserves and increases resources, rather than taking and depleting them. This societal transition is essential for promoting smart, sustainable, and inclusive growth that reduces pollution, promotes health, and prevents disease.[104]

Panel 2: Circular economy

A circular economy is an economic model that decouples development from the consumption of non-renewable resources and minimises the generation of pollution and other forms of waste by recycling and reuse.[104] In a fully circular economy, the only new inputs are renewable materials, and all non-renewable materials are recycled. The underlying assumption is that waste is an inherent inefficiency, a loss of materials from the system, and thus a cost.[104] Transition towards a circular economy will reduce pollution-related disease and improve health.

The three core principles of the circular economy are preservation of natural capital by reducing use of non-renewable resources and ecosystem management; optimisation of resource yields by circulating products and materials so that they are shared and their lifecycles extended; and fostering system effectiveness by designing out pollution, greenhouse gas emissions, and toxic materials that damage health.

The steps needed for transition towards a circular economy include large-scale transition to non-polluting sources of energy (wind, solar, and tidal), the production of durable products that require lower quantities of materials and less energy to manufacture than those being produced at present; incentivisation of recycling, re-use, and repair; and replacement of hazardous materials with safer alternatives.[15]

Limitations of the Commission

The Commission's economic analysis does not include information about the costs of environmental damage caused by pollution. The Commission recognises that the ecological damages due to pollution are substantial, but considered analyses of the costs of these damages to fall outside of the scope of our work.

Levels of pollution are changing and pollution caused by industrial, vehicular, and chemical emissions is increasing in many rapidly developing countries, but the Commission's analysis is based on data from the 2015 Global Burden of Disease study, information that is now 2 years old.

Section 1: The burden of disease attributable to pollution

In this Section, we review data for the global burden of disease and death attributable to pollution.[23,38,42,99,106]

Methods

This review of the burden of disease and premature death due to pollution is based on a method for assessing disease burden that was developed in the 1980s by

WHO.[107,108] The core of this approach is the disability-adjusted life-year (DALY) concept, a summary metric of population health that combines information on mortality and disease into a single number to represent the health of a population, thus permitting comparisons of disease burden between countries, between diseases, and over time. The DALY method is at the core of the GBD project, a multinational study initiated by WHO in partnership with the World Bank and the Harvard School of Public Health,[108] and sustained today by WHO[102] and the Institute for Health Metrics and Evaluation.[41,42]

To examine the global burden of disease attributable to pollution risk factors, this Commission has relied principally on the 2015 estimates from the GBD study,[41,42,106] coordinated by the Institute for Health Metrics and Evaluation. We also examine data from the 2012 WHO analysis[99,102,109,110] of the global burden of disease caused by living and working in unhealthy environments.

Following the standard conservative practice of the GBD study[42,106] and WHO,[99] this Commission has restricted its review to combinations of pollution risk factors and disease for which there is convincing or probable evidence of causal association. For this reason, numbers presented are likely to be underestimates of the full burden of disease attributable to the pollutome (figure 3).

In reviewing data on the burden of disease attributable to soil pollution caused by toxic chemicals and heavy metals at contaminated sites, this Commission has relied on information provided by the Blacksmith Institute/Pure Earth Toxic Sites Identification programme.[38] This programme obtains data on pollution caused by chemicals and metals at contaminated sites through field studies that use a protocol adapted from a US Environmental Protection Agency assessment tool.[111] Two particularly common types of contaminated sites are used lead-acid battery recycling sites, where lead is the principal pollutant, and artisanal and small-scale gold mining sites, where the principal pollutant is elemental mercury (which is used to extract gold from ore). We used the methods of Ericson and colleagues[111] to assess the burden of disease associated with lead-acid battery recycling sites, and the methods and data of Steckling and colleagues[112,113] to assess the burden of disease associated with gold mining sites[114–116] These methods are described in detail in the appendix (pp 16–19).

The pollution risk factors examined by the Commission were: (1) air pollution: household air pollution, ambient fine particulate pollution ($PM_{2·5}$), and tropospheric ozone pollution; (2) water pollution: unsafe sanitation, and unsafe water sources; (3) soil, chemical, and heavy metal pollution: lead (including contaminated sites polluted by lead from battery recycling operations), and mercury from gold mining; and (4) occupational pollution: occupational carcinogens, and occupational particulates, gases, and fumes.

In reviewing disease burden in relation to national income, we have relied on the 2015 World Bank income classifications (high, upper middle, lower middle, and low). In reviewing disease burden in relation to geographical region, we have grouped countries using the regional groupings defined by WHO (Africa, eastern Mediterranean, Europe, Americas, southeast Asia, and western Pacific).

To examine temporal trends in the global burden of disease that are attributable to different forms of pollution, we have divided pollution into two broad categories: pollution linked to poverty and pollution linked to industrial development. Pollution linked to poverty includes household air pollution, unsafe water sources, and inadequate sanitation, the forms of pollution associated with profound poverty and traditional lifestyles in low-income and middle-income countries. Pollution linked to industrial development includes pollution produced by industrial emissions, vehicular exhausts, and chemical releases, and includes ambient fine particulate ($PM_{2·5}$) pollution, tropospheric ozone pollution, toxic occupational exposures, and soil pollution caused by heavy metals and toxic chemicals, including lead.

Main findings

The GBD study[42] estimates that pollution-related disease was responsible for 9 million premature deaths in 2015—16% of total global mortality (table 1).[42,99,102] The GBD study also estimates that disease caused by all forms of pollution was responsible for 268 million DALYs—254 million years of life lost and 14 million years lived with disability.[106] This information is available by country and region and is presented in the appendix.

WHO estimates that, in 2012, unhealthy environments were responsible for 12·6 million deaths worldwide—23% of total global mortality—and for 26% of deaths in children younger than 5 years.[99,102,109,110]

The most important finding to be drawn from these two analyses is that both the GBD study and WHO find that pollution is a major cause of disease, disability, and premature death. The GBD study reports that pollution was responsible for an estimated 9·0 million deaths in 2015, whereas the WHO analysis concludes that living in unhealthy environments was responsible for 12·6 million deaths in 2012.

The difference between these two estimates of total mortality attributable to environmental factors mainly reflects differing definitions of environment. This Commission focuses strictly on pollution-related disease, as defined above. By contrast, the WHO definition of environment is broader and encompasses several risk factors that were not included in this Commission's analysis, including road accidents, ultraviolet and ionising radiation, noise, electromagnetic fields, occupational psychosocial risks, built environments, agricultural methods, and man-made climate and ecosystem change. Risk factors that were included

	GBD study best estimate (95% CI)	WHO best estimate (95% CI)
Air (total)	6·5 (5·7–7·3)	6·5 (5·4–7·4)
Household air	2·9 (2·2–3·6)	4·3 (3·7–4·8)
Ambient particulate	4·2 (3·7–4·8)	3·0 (3·7–4·8)
Ambient ozone	0·3 (0·1–0·4)	..
Water (total)	1·8 (1·4–2·2)	0·8 (0·7–1·0)
Unsafe sanitation	0·8 (0·7–0·9)	0·3 (0·1–0·4)
Unsafe source	1·3 (1·0–1·4)	0·5 (0·2–0·7)
Occupational	0·8 (0·8–0·9)	0·4 (0·3–0·4)
Carcinogens	0·5 (0·5–0·5)	0·1 (0·1–0·1)
Particulates	0·4 (0·3–0·4)	0·2 (0·2–0·3)
Soil, heavy metals, and chemicals	0·5 (0·2–0·8)	0·7 (0·2–0·8)
Lead	0·5 (0·2–0·8)	0·7 (0·2–0·8)
Total	9·0	8·4

Note that the totals for air pollution, water pollution, and all pollution are less than the arithmetic sum of the individual risk factors within each of these categories because these have overlapping contributions—eg, household air pollution also contributes to ambient air pollution and vice versa.

***Table 1:* Global estimated deaths (millions) due to pollution risk factors from the Global Burden of Disease study (GBD; 2015)[42] versus WHO data (2012)[99,101]**

in the WHO analysis and not in this Commission account for more than 3 million deaths each year, thus explaining most of the apparent discrepancy between the two estimates (panel 3).[117–120]

Some specific differences are seen between the two sets of estimates (figure 4).[42,99] For example, the GBD study estimates that 4·2 million deaths in 2015 were because of ambient air pollution, whereas WHO attributes 3·7 million deaths in 2012 to this risk factor. The two analyses relied on similar approaches to comparative risk assessment, on the same sources of exposure data, and on the same integrated exposure–response functions[40] but, in 2014, the GBD study made changes to their computational methodology,[42] which appears to account for most of the divergence.

The GBD study estimated that 2·9 million deaths in 2015 were associated with household air pollution, whereas WHO estimated 4·3 million related deaths in 2012. This difference can partly be explained by different approaches in quantifying exposure–outcome associations. The GBD study relied on the integrated exposure–response curve[40] to provide evidence for the effect size of non-communicable diseases, whereas WHO adapted relative risks for certain non-communicable diseases based on epidemiological evidence. Additionally, the GBD study has expanded data sources for personal exposure values for women, men, and children in the past 2 years.

The GBD study estimated that, in 2015, 1·8 million deaths resulted from diseases related to water pollution, whereas WHO estimated 0·84 million related deaths in 2012. This divergence appears largely to reflect differing definitions of access to safe water. The GBD study considers access to safe water at both the water's source and at the point of use, whereas WHO only considers access to an improved water source.

Diseases caused by all forms of pollution were responsible for an estimated 9 million deaths in 2015.[41] Pollution is thus responsible for more deaths than a high-sodium diet (4·1 million), obesity (4·0 million), alcohol (2·3 million), road accidents (1·4 million), or child and maternal malnutrition (1·4 million). Pollution was also responsible for three times as many deaths as AIDS, tuberculosis, and malaria combined (figure 5)[41] and for nearly 15 times as many deaths as war and all forms of violence.[41] Only dietary risk factors (all combined) (12·1 million) and hypertension (10·7 million) caused more deaths than pollution; however, the Commission notes that approximately 2·5% of deaths due to hypertension are attributable to lead.

Pollution and non-communicable diseases

Non-communicable diseases account for most of the total burden of disease due to pollution—approximately 71%.[41] In 2015, all forms of pollution combined were responsible for 21% of all deaths from cardiovascular disease, 26% of deaths due to ischaemic heart disease, 23% of deaths due to stroke, 51% of deaths due to chronic obstructive pulmonary disease, and 43% of deaths due to lung cancer (figure 6).[42]

The relative risks of all non-communicable diseases associated with pollution increase as exposure to pollution increases. An integrated exposure–response function has been developed to describe these associations, and the health effects of air pollution are quantitatively consistent with those of tobacco smoke when their relative risks are plotted against a common metric of exposure to airborne fine particulates.[121]

The sources and nature of pollution change as countries develop and industrialise (figure 7).[10,42] An unsafe water source, unsafe sanitation, and household air pollution are considered to be forms of pollution linked to poverty and the early stages of industrial development. Airborne fine particulate pollution, tropospheric ozone pollution, occupational chemical pollution, and soil pollution by heavy metals and chemicals (including lead) are considered to be forms of pollution linked to industrial development.

Changes to the distribution of pollution-related diseases occur in response to the changes that accompany development.[11] Thus deaths from pneumonia and diarrhoeal diseases—the diseases associated with household air pollution, water pollution, and poor sanitation—are slowly declining worldwide, although they still kill millions of people, particularly children in poor countries. These declines reflect reductions in the forms of pollution associated with traditional lifestyles in low-income and middle-income countries, and the advent of new vaccines such as the pneumococcal vaccine and the rotavirus vaccine;[59] new approaches to paediatric

Panel 3: WHO's programme on pollution and health

WHO has, for several decades, been a leader in conducting crucial evaluations of the health effects of pollution, and these assessments provide the scientific basis for pollution control policies in many countries. WHO is also a global leader in providing guidelines and in coordinating health-focused partnerships for pollution control.

WHO is now further expanding this work through the framework of the Sustainable Development Goals (SDGs). WHO is the custodian agency that monitors progress towards six SDG targets; this monitoring includes tracking several targets measuring the environmental health-related burden of disease within SDG 3. The following are examples of this work:

Ambient air pollution

- WHO has periodically reviewed the international literature on air pollution and developed Global Air Quality Guidelines.[117] These are the primary reference points for air pollution standards worldwide. The latest version was published in 2006,[117] and a committee has been formed to create an updated version in 2018.
- WHO hosts one of the largest databases of ambient air pollution measurements in cities. Currently, the publicly available WHO Global Urban Ambient Air Pollution Database contains air quality measurements from 3000 cities, representing 103 countries. In the past 2 years alone, the database has nearly doubled in size, with more cities now measuring air pollution concentrations and recognising the associated health effects than ever before. This database also provides inputs to the integrated models that use satellite remote-sensing and chemical transport models to estimate ambient air pollution exposure globally, including estimates for regions without any ground-level monitoring (eg, smaller cities and rural areas). The Global Urban Ambient Air Pollution Database also supports monitoring of urban air quality for SDG 11 indicator 11·6: "to reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management".[118]

Household air pollution

- WHO has developed guidelines[119] for indoor air quality regarding household fuel combustion, which clarified the enormous health risks of burning kerosene, coal, and wood in the home, and has provided emission standards for home energy equipment used in cooking, heating, and lighting. This work filled a gap in health guidance for household energy interventions and is increasingly being adopted by development partners investing in improving access to energy in the homes of the poor worldwide.
- WHO has developed several tools and training programmes to build the capacity and understanding of countries and actors working in different sectors to effectively address household energy as a health risk. WHO is currently developing a Clean Household Energy Solution Toolkit (CHEST) to provide the guidance and tools necessary for countries to implement the WHO Guidelines for Indoor Air Quality: Household Fuel Combustion.[119]
- Monitoring access to clean energy in the home is led by WHO in close cooperation with partners performing household surveys (UNICEF, USAID, and the World Bank). The associated indicator, 7·1·2—the "proportion of population with primary reliance on clean fuels and technology"—is part of the Global Tracking Framework of Sustainable Energy for All and is used to show progress towards SDG 7, which follows WHO guidelines criteria.

Climate, pollution, and health

- WHO, the Climate and Clean Air Coalition, and UN Environment Programme have joined forces in the BreatheLife campaign to address the associated crises of air pollution and climate change. The campaign was announced in July, 2016, and launched at Habitat III in Quito, Ecuador.

Urban health

- WHO has established the Urban Health Initiative to reduce deaths and diseases associated with air and climate pollutants in cities, while enhancing health benefits from the policies and measures used to tackle climate pollution.

Water and sanitation

- WHO has produced authoritative guidelines and technical assistance on management of water quality, sanitation, and wastewater, and health for decades. Along with UNICEF, WHO is responsible for tracking the extent of human exposure to poor water, inadequate sanitation, and poor hygiene.

Toxic chemicals

- WHO is the leading international agency for chemical safety through its Intergovernmental Panel on Chemical Safety, which sets guidelines for dozens of commonly used chemicals. The importance of chemicals management is reflected by SDG target 3·9 on reducing deaths and illness from hazardous chemicals, and links to target 12·4 on the sound management of chemicals and wastes. Achievement of sound chemicals management requires a multisector, multistakeholder approach. To advance this work, the 2017 World Health Assembly approved a Chemicals Road Map to enhance the engagement of the health sector in the management of international chemicals.

(Continues on next page)

For the **WHO Global Urban Ambient Air Pollution Database** see www.who.int/phe/health_topics/outdoorair/databases/cities

For the **WHO Chemicals Road Map** see www.who.int/ipcs/saicm/roadmap

(Panel 3 continued from previous page)

Mercury
- WHO is supporting implementation of the Minamata Convention on Mercury and has developed guidance for phasing out mercury-containing instruments in the health sector.[120] Urgent attention by health departments and ministries is needed to address the phase out of import, export, and manufacture of mercury thermometers, sphygmomanometers, and other mercury-containing instruments in health care.

Cancer
- WHO's International Agency for Research on Cancer (IARC) has the responsibility of determining whether chemicals are human carcinogens and conducts a range of research on cancer worldwide. IARC provides evidence-based guidance on cancer control to countries around the world.

For the **Health Effects Institute special report on the state of global air** see https://www.stateofglobalair.org

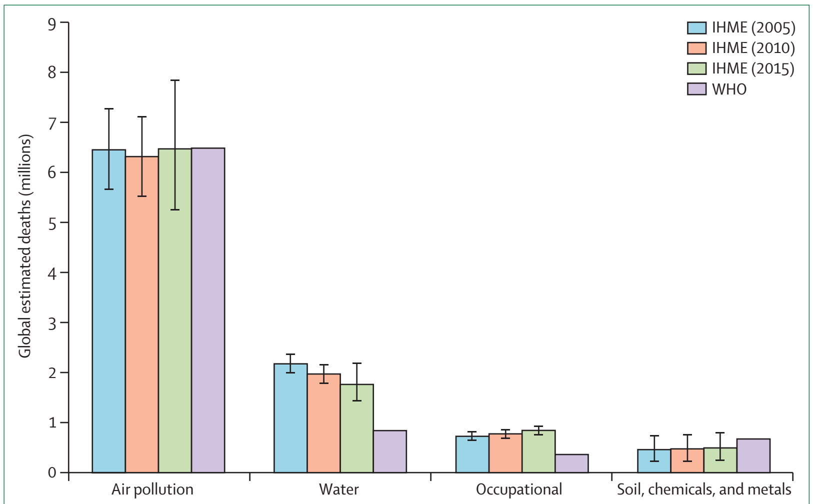


Figure 4: **Global estimated deaths (millions) by pollution risk factor, 2005–15**
Using data from the GBD study[42] and WHO.[99] IHME=Institute for Health Metrics and Evaluation.

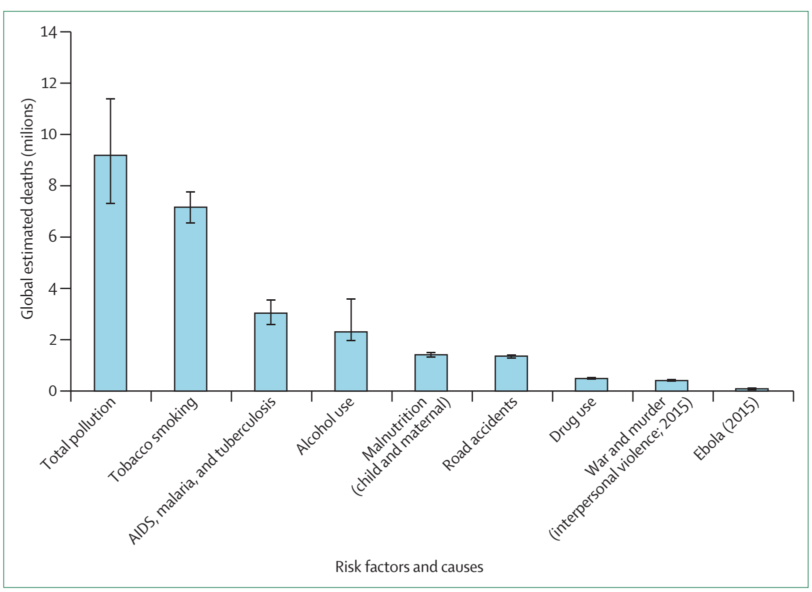


Figure 5: **Global estimated deaths by major risk factor and cause, 2015**
Using data from the GBD Study, 2016.[41]

therapy such as oral rehydration therapy;[60] and improved nutrition of young children and pregnant women.[61]

By contrast, the numbers of deaths caused by ambient air, chemical, and soil pollution—the forms of pollution associated with modern industrial and urban development—are increasing. The number of deaths attributable to $PM_{2·5}$ air pollution is estimated to have risen from 3·5 million (95% CI 3·0 million–4·0 million) in 1990 to 4·2 million (3·7 million–4·8 million) in 2015, a 20% increase. Among the world's 10 most populous countries in 2015, the largest increases in numbers of pollution-related deaths were seen in India and Bangladesh, as reported by the Health Effects Institute. The increase in the absolute number of deaths and DALYs attributable to pollution reflects an increased population size, an ageing population, and increased levels of air pollution in low-income and middle-income countries.[23]

An analysis of future trends in mortality associated with ambient $PM_{2·5}$ air pollution finds that, under a "business as usual scenario", in which it is assumed that no new pollution controls will be put into place, the numbers of deaths due to pollution will rise over the next three decades, with sharpest increases in the cities of south and east Asia.[35,121] These trends are projected to produce a more than 50% increase in mortality related to ambient air pollution, from 4·2 million deaths in 2015 to 6·6 million deaths in 2050 (95% CI 3·4 million–9·3 million).[35,122] These projections are corroborated by an analysis[107] of the health effects of coal combustion in China. Population ageing are major contributors to these projections of growth and absolute increased numbers of deaths from pollution-related disease.

A second analysis[123] examining the potential benefits of reducing $PM_{2·5}$ pollution projects that aggressive controls could avoid 23% of current deaths related to air pollution. However, because of population ageing and consequent increases in age-related mortality from cardiovascular disease, chronic obstructive pulmonary disease, and lung cancer, and also because the exposure–response association between $PM_{2·5}$ pollution and non-communicable diseases is relatively strong at lower levels of exposure but weaker at higher levels, Apte and colleagues[124] note that it will be easier to achieve reductions in mortality in less heavily polluted areas of western

Europe and North America than in heavily polluted regions in Asia.

Geography of pollution

In 2015, the greatest numbers of deaths due to pollution occurred in southeast Asia (3·2 million deaths) and the western Pacific (2·2 million deaths; figure 8).[42] In this definition, southeast Asia includes India and the western Pacific region includes China. The highest population-based estimates of premature death and disease due to pollution are seen in the low-income countries of sub-Saharan Africa.[42]

Pollution and poverty

92% of all pollution-related mortality is seen in low-income and middle-income countries, with the greatest numbers of deaths from pollution-related disease occurring in rapidly developing and industrialising lower-middle-income countries (figure 9).[42] In the most severely affected countries, pollution is responsible for more than one in four deaths.[42] In countries at every level of income, the health effects of pollution are most frequent and severe among the poor and the marginalised. Further discussion of the links between pollution, disease, and poverty is presented in section 3 of this report.

Disease and death due to pollution occur most frequently in the very young and the very old. Deaths due to all forms of pollution show a peak among children younger than 5 years of age, but most pollution-related deaths occur among adults older than 60 years of age (figure 10).[42] By contrast, DALYs resulting from pollution-related disease are highly concentrated among infants and young children, reflecting the many years of life lost with each death and case of disabling disease of a child (figure 11).[42]

Air pollution

Two types of air pollution—household air pollution and ambient air pollution—and two airborne pollutants—fine particulates and ozone—are considered in this Commission.[23] Pollution caused by oxides of nitrogen and by some short-lived climate pollutants is not fully accounted for in this Commission because the burden of disease due to these forms of air pollution is not separately quantified in the GBD study.

Although household and ambient air pollution are considered separately in deriving estimates of disease burden,[42,99] they are both comprised of many of the same pollutants and often co-exist; for example, in low-income and middle-income countries, household cooking contributes to ambient particulate air pollution.[55,56] Accordingly, the total numbers of deaths attributed to air pollution in the GBD study and in the WHO estimates are less than the arithmetic sum of the number of deaths attributed to each form of pollution alone.[35,99,125]

Air pollution disperses globally. Airborne pollutants travel across national boundaries, continents, and oceans.[126–128] An analysis[129] of emissions from Chinese export manufacturers found that, on days with strong westerly winds (winds blowing from China across the Pacific), 12–24% of sulphate concentrations, 2–5% of ozone, 4–6% of carbon monoxide, and up to 11% of black carbon pollution detected in the western USA were of Chinese origin.

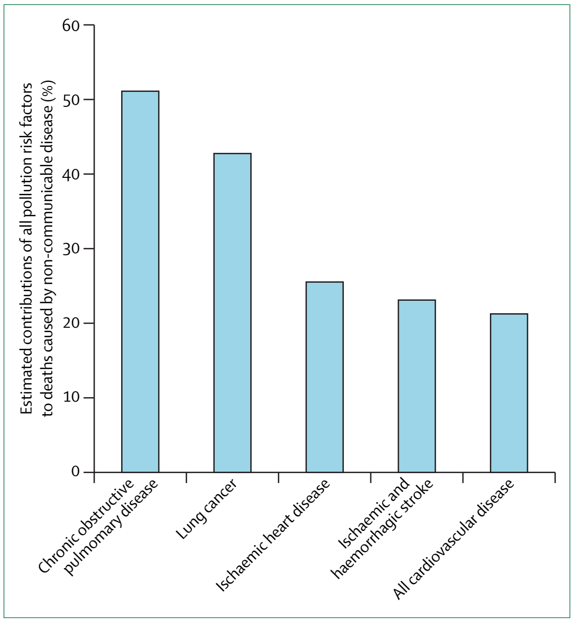


Figure 6: **Estimated contributions of all pollution risk factors to deaths caused by non-communicable diseases, 2015**
GBD Study, 2016.[42]

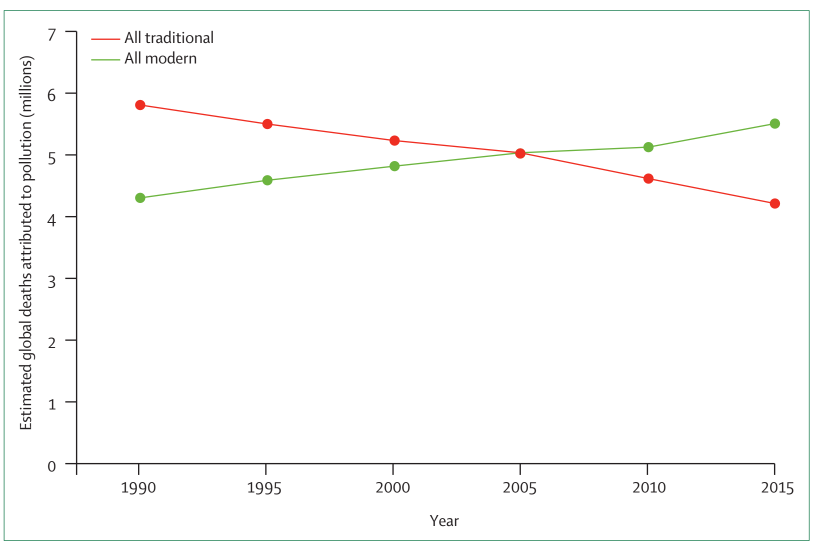


Figure 7: **Estimated global deaths (millions) by pollution category, 1990–2015**
GBD Study, 2016.[42] All modern=modern forms of pollution, comprising ambient air, chemical, occupational, and soil pollution. All traditional=traditional forms of pollution, comprising household air and water pollution.

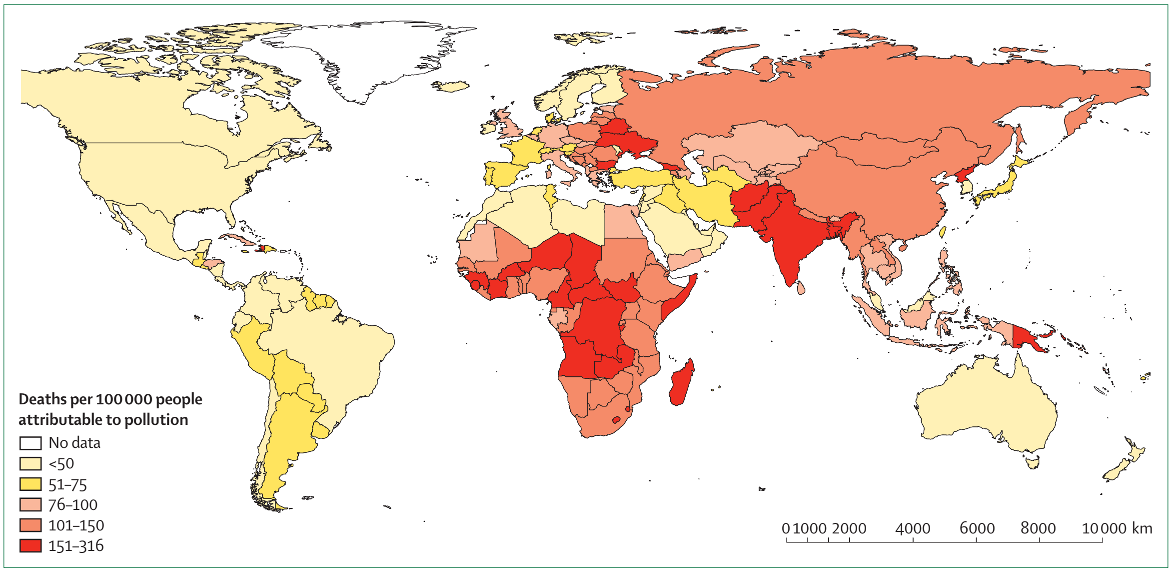


Figure 8: **Number of deaths per 100 000 people that are attributable to all forms of pollution, 2015**
GBD Study, 2016.[42]

Air pollution and disease

$PM_{2·5}$ is the best studied form of air pollution and is linked to a wide range of diseases in several organ systems.[23,130] The strongest causal associations are seen between $PM_{2·5}$ pollution and cardiovascular and pulmonary disease. Specific causal associations have been established between $PM_{2·5}$ pollution and myocardial infarction,[131–137] hypertension,[138] congestive heart failure, arrhythmias,[139] and cardiovascular mortality.[24,140–143] Causal associations have also been established between $PM_{2·5}$ pollution and chronic obstructive pulmonary disease and lung cancer.[42] The International Agency for Research on Cancer has reported that airborne particulate matter and ambient air pollution are proven group 1 human carcinogens.[34,40,144]

Fine particulate air pollution is associated with several risk factors for cardiovascular disease, including: hypertension,[138] increased serum lipid concentrations,[145] accelerated progression of atherosclerosis,[146–148] increased prevalence of cardiac arrhythmias,[139] increased numbers of visits to emergency departments for cardiac conditions,[132,133] increased risk of acute myocardial infarction,[131] and increased mortality from cardiovascular disease[142] and stroke.[149]

Clinical and experimental studies suggest that fine airborne particles increase risk of cardiovascular disease by inducing atherosclerosis, increasing oxidative stress, increasing insulin resistance, promoting endothelial dysfunction, and enhancing propensity to coagulation.[145,147,148,150]

Emerging evidence suggests that additional causal associations may exist between $PM_{2·5}$ pollution and several highly prevalent non-communicable diseases. These include diabetes,[25] decreased cognitive function, attention-deficit or hyperactivity disorder and autism in children,[30,31,151,152] and neurodegenerative disease, including dementia, in adults.[28,29,33] $PM_{2·5}$ pollution may also be linked to increased occurrence of premature birth and low birthweight.[27,153–159] Some studies have reported an association between ambient air pollution and increased risk of sudden infant death syndrome.[160] These associations are not yet firmly established, and the burden of disease associated with them has not yet been quantified, and they are therefore included in zone 2 of the pollutome (figure 3).

Water pollution

This Commission considers two types of water pollution: unsafe water source and inadequate sanitation.[51] Many areas in low-income and middle-income countries lack

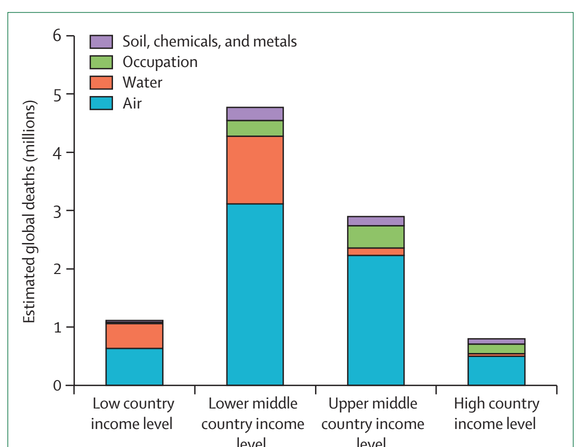


Figure 9: **Estimated deaths by pollution risk factor and country income level, 2015**
GBD Study, 2016.[42]

acceptable water supplies and many people, particularly in rural areas in poor countries, have inadequate sanitation.[52] Prevention technologies and systems exist, but poverty, lack of knowledge, and other priorities constrain the adoption of improvements.[161]

The problems of water supply and health are intensified where industrial pollutants contaminate water systems because treatments that control infectious agents are not effective in removing many toxic chemicals from drinking water. Improved analytical techniques have allowed identification of hundreds of industrial chemicals, pharmaceuticals, and pesticides in water systems. Some of the worst biological and chemical pollution of drinking water is seen in rapidly urbanising and industrialising lower-middle-income countries, where local waterways and groundwater are heavily polluted and serious health conditions are widely reported, but no alternative water sources exist.[53]

The principal diseases linked to water pollution are acute and chronic gastrointestinal diseases, most importantly diarrhoeal diseases (70% of deaths attributed to water pollution), typhoid fever (8%), paratyphoid fever (20%), and lower respiratory tract infections (2%).[42] These estimates include diseases associated with an unsafe water source, inadequate sanitation, and inadequate hand-washing. Polluted water and inadequate sanitation are linked, additionally, to a range of parasitic infections. These diseases affect more than 1 billion people, predominantly in low-income and middle-income countries.[41]

Water pollution also has effects on planetary health that extend beyond its effects on human health.[15] Pollution of rivers, lakes, and the oceans from agriculture, manufacturing, and the extractive industries can have catastrophic effects on freshwater and marine ecosystems that result in the collapse of fisheries and the diminished livelihood of indigenous populations and others who rely upon fish as a major food source.[162,163]

Most of the deaths caused by unsafe sanitation and unsafe water sources occur in children younger than 5 years of age. Increased numbers of deaths from waterborne pollution-related disease are also seen in adults older than 60 years of age.

Burden of disease due to water pollution

The GBD study[42] estimates that, in 2015, 1·8 million deaths were attributable to water pollution, including unsafe water sources, unsafe sanitation, and inadequate handwashing. Of this total, 0·8 million deaths were estimated to be caused by unsafe sanitation and 1·3 million to unsafe water sources. The total burden of disease attributable to water pollution is less than the sum of the diseases attributable to each of its components because of overlaps between unsafe water source, unsafe sanitation, and inadequate handwashing. WHO data indicate that 0·28 million deaths were attributable to unsafe sanitation in 2012 and that unsafe water sources were responsible for 0·5 million deaths.[99] As in the case of air pollution, the total number of deaths attributed to all forms of water pollution combined is less than the arithmetic sum of the deaths due to the individual types of water pollution because the various types of water pollution often co-exist and overlap with each other.

Trends in disease from water pollution

Targeted interventions to provide modern water and sanitation infrastructure began in the developing world as early as the 1950s, in the early days of international development assistance programmes. The Millennium

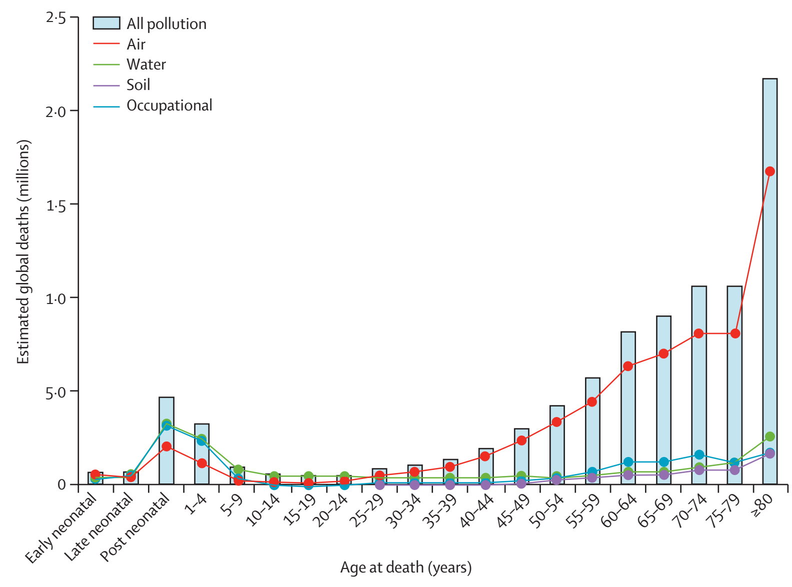


Figure 10: **Estimated global deaths by pollution risk factor and age at death, 2015**
GBD Study, 2016.[42]

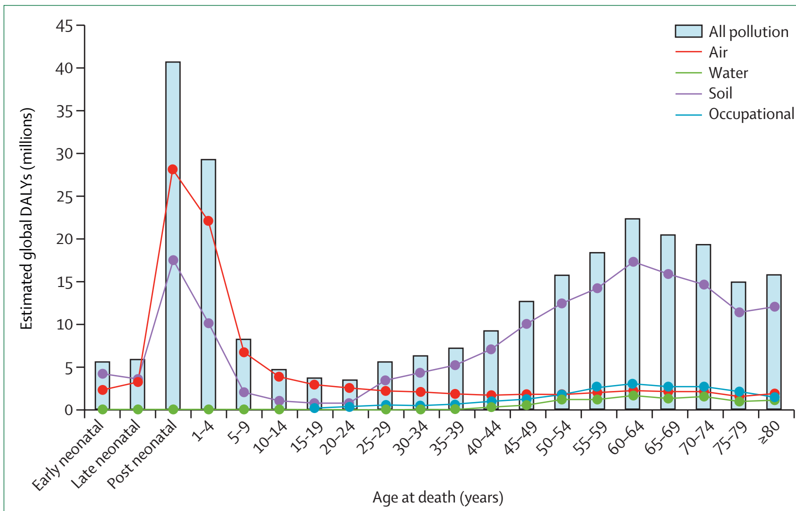


Figure 11: **Estimated global DALYs by pollution risk factor and age at death, 2015**
GBD Study, 2016.[42] DALYs=disability-adjusted life-years.

Development Goals (MDGs) accelerated this work, and MDG Target 7C called on the global community "by 2015, to halve the proportion of the population without sustainable access to safe drinking water and basic sanitation". To track interventions against water pollution and waterborne disease, WHO and UNICEF established the Joint Monitoring Programme for Water Supply and Sanitation.[54]

Substantial progress has been made in reducing water pollution and waterborne disease. Between 1990 and 2015, 2·6 billion people gained access to improved drinking water sources, 2·1 billion people gained access to improved sanitation, and the MDG Target 7C was met 5 years ahead of schedule. In this time, the number of children dying from diarrhoeal diseases decreased by almost 60%, from approximately 1·5 million deaths in 1990 to slightly greater than 0·6 million deaths in 2012. However, despite this progress, 2·4 billion people are still using unimproved sanitation facilities, including 946 million people who still practise open defecation.

For **WHO data on numbers of water pollution-related mortalities** see http://www.who.int/healthinfo/mortality_data/en/

Geography of water pollution and disease

Population-based estimates of the number of deaths from water pollution are highest in sub-Saharan Africa (figure 12).[42] Large numbers of deaths are seen also in some southeast Asian countries. In the past two decades, China has greatly reduced mortality from waterborne infectious disease.[42]

Importantly, these data do not reflect deaths from chemical pollution of water, because data for levels of chemical contamination of drinking water are not available for most low-income and middle-income countries. Disease due to chemical contamination of drinking water is included in zone 2 of the pollutome (figure 3).

Soil, heavy metal, and chemical pollution

Comprehensive assessments of the health effects of most forms of soil, heavy metal, and chemical pollution have not yet been published. Lead is an exception, and has been studied extensively. Newer research on a few contaminated sites is beginning to report data for disease burden at these sites; at present, these estimates are limited to DALYs and do not include deaths.

Lead

People have used lead for centuries but, until the modern era, it was largely an occupational poison.[164] In the 19th and 20th centuries, lead moved beyond the workplace into air, water, and soil in countries around the world as a consequence of sharp increases in lead production that accompanied the Industrial Revolution. In the early 20th century, lead was incorporated, for the first time, into mass-market consumer products such as lead-based paint and gasoline. Global contamination of air, water, and soil resulted. Global production of lead has more than doubled since the 1970s and continues to rise. Increasing global manufacture of batteries for products ranging from mobile phones to cars, is the main driver of this increase.[165] 82% of deaths due to lead occur in low-income and middle-income countries.

In adults, chronic exposure to lead is an established risk factor for hypertension, renal failure, cardiovascular

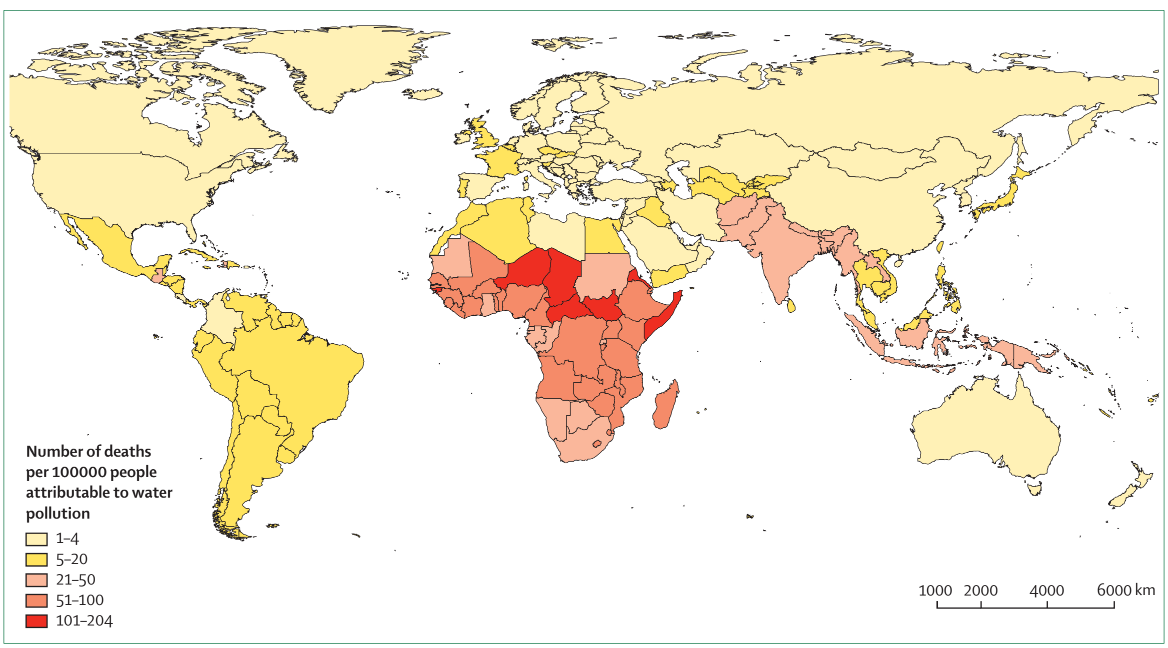


Figure 12: **Number of deaths per 100 000 people due to water pollution, 2015**
GBD Study, 2016.[42]

disease, and stroke, especially among workers exposed in their occupations. Large-scale epidemiological studies[26] based on a national probability sample have confirmed that the causal association between lead, hypertension, and mortality from cardiovascular disease is evident even at very low blood lead concentrations.

Neurodevelopmental toxicity is the most important consequence of lead toxicity in children.[166] The neurobehavioural sequelae of paediatric lead exposure include cognitive impairment,[167–170] shortening of attention span with increased risk for attention deficit or hyperactivity disorder,[171] and increased risk for antisocial and criminal behaviours.[172,173] These effects can persist across the entire lifespan and result in decreased school performance, increased risk of drug abuse and incarceration, and decreased economic productivity. Lead causes neurobehavioural damage in children at even the very lowest blood concentrations. WHO states that "there is no known level of lead exposure that is considered safe" (panel 4).[30,32,37,88,91,173–177]

Trends in lead exposure

Despite continuing increases in global lead production, bans on the use of lead in petrol, paint, plumbing, and solder have produced substantial reductions in lead exposure and disease burden. Lead has now been removed from gasoline in more than 175 countries.

Despite these advances, several sources of occupational and community exposure to lead persist.[38,178,179] Lead-glazed pottery is a notable source of exposure in several countries.[169,180] Infants in the womb can be exposed to lead via transplacental transfer, and nursing infants can be exposed to lead in breastmilk.[181] Children are at risk of exposure to lead-based paint in older housing[182,183] and to lead that leaches into drinking water from lead pipes and solder.[184] Informal (so-called "backyard") recycling of used lead-acid batteries is a widespread source of lead exposure for both workers and communities.[185]

Estimates from the GBD study[42] indicate that lead was responsible for 0·5 million premature deaths and for 9·3 million DALYs in 2015. This estimate is based entirely on adult deaths (15 years and older). Half of these deaths occurred in people aged 70 years and older. These estimates do not reflect exposures to lead at contaminated sites.[186] Although lead has caused child mortality in episodes of acute poisoning at heavily contaminated sites in low-income and middle-income countries,[187] it is not a major contributor to child mortality globally.

Cardiovascular diseases, including hypertension, coronary artery disease, stroke, cardiac arrhythmias, and peripheral arterial disease, account for the overwhelming majority of deaths attributable to lead in adults.[26,188] These associations are evident at blood lead concentrations as low as 5 μg/dL.[188,189] The GBD study[42] estimates that lead exposure accounts for 2·5% of the global burden of ischaemic heart disease. Lead is also estimated to account for 12·4% of the global burden of idiopathic intellectual disability (panel 4). The GBD analysis indicates that deaths in 2015 that were attributable to lead are as follows: cardiovascular disease (465 000 deaths), ischaemic heart disease (240 000), cerebrovascular disease (155 000), ischaemic stroke (68 000), haemorrhagic stroke (87 000), hypertensive heart disease (47 000), and chronic kidney disease (28 000).[42]

WHO estimates that, in 2012, lead was responsible for 13·9 million DALYs[109] and that childhood lead exposure is responsible for mild to moderate mental retardation of 0·6 million children annually.[190]

Panel 4: Pollution and neurodevelopment

Foetuses, infants, and children are particularly sensitive to neurotoxic pollutants, even at very low levels of exposure, because of the vulnerability of early-stage development of the human brain.[91,174–176] Toxic exposure during so-called windows of vulnerability in early life can cause lasting damage to brain function. Lead poisoning in childhood has, for example, been linked to reduced cognitive function and also to juvenile delinquency, violent crime in adulthood, and lifelong reduction in economic productivity.[37] Neurotoxic pollutants are also linked to autism,[152] attention deficit and hyperactivity disorder,[89,177] and conduct disorders.[173]

Exposure to neurotoxic pollutants is widespread as a result of fossil fuel combustion, industrial and agricultural production, and the extensive use of toxic chemicals in consumer products.[30] Routine biomonitoring studies have detected many dozens of toxic pollutants in the bodies of children and pregnant women.[175]

Pollutants known to be toxic to the developing brain (in addition to lead) include mercury, combustion by-products such as polycyclic aromatic hydrocarbons and fine particulate matter, organophosphate pesticides, brominated flame retardants, phthalates, and polychlorinated biphenyls.[88] Many more commonly used chemicals, whose developmental neurotoxicity has not yet been discovered could be causing undetected damage to children today.

The social and economic costs of early life exposure to neurodevelopmental toxicants are great. Large economic and social gains can be realised through prevention of these disorders.[32]

Pollution at contaminated sites

Polluted soil at contaminated sites threatens the environment and human health in communities worldwide. Most contaminated sites are relatively small, but the aggregate number of people affected globally by the many hundreds of thousands of extant sites is large.[191] Polluted sites are most commonly contaminated by informal, small-scale, unregulated local industry or artisanal activity.[191–193] Sites can be contaminated by current industrial and mining activity, or they can be abandoned, legacy sites that were contaminated by previous operations.[194]

The contaminants at polluted sites that pose the greatest threats to health are environmentally persistent substances such as metals, persistent organic pollutants (including persistent pesticides), and radionuclides. The metals most commonly encountered at polluted sites include mercury, lead, chromium, and cadmium.

Panel 5: **Superfund legislation**

Legislation to control contaminated waste sites was enacted in the USA in the aftermath of a series of environmental and public health disasters.[199] The major trigger occurred at the Love Canal (Niagara County, NY, USA), an unused channel between Lake Erie and Lake Ontario into which the Hooker Chemical Company had dumped toxic wastes from the 1940s until the 1960s. When it was full, the canal was covered with a clay seal, and homes and a school were built on top of this clay. However, the waste did not stay underground. The canal filled with water and, by 1976, heavy rain regularly caused toxic sludge to bubble up into the basements of the overlying homes and into nearby streams. By the time this site was recognised as a hazardous waste site, Love Canal contained an estimated 21 000 tonnes of discarded chemicals. Within a few years, a second major waste site was discovered near Louisville, KY. Known as the Valley of the Drums, the site contained thousands of steel drums full of chemical wastes that had accumulated over several decades.

These events made it clear to policy makers and the public that hazardous waste was an environmental and public health emergency. In response, the US Congress passed the Comprehensive Environmental Response Compensation and Liability Act on Dec 11, 1980. The law became known as the Superfund Act because it authorised the creation of a large fund that, from 1980 to 1995 was supported by a tax on the chemical manufacturing and petroleum industries, the two major producers of toxic chemical wastes. Many of the new hazardous waste sites subsequently being discovered were the result of actions by polluters who no longer existed. The tax was based on the polluter-pays principle and was intended to provide resources to remediate abandoned sites. In 1995, the US Congress allowed the tax on the chemical and petroleum industries to expire. Since that time, remediation of hazardous waste sites in the USA has been supported through general tax revenues.

	Artisanal small-scale gold mining		Used lead-acid batteries		Total median DALYs (range)
	Population exposed	Median DALYs	Population exposed	Median DALYs	
Africa	10·90	1·91	4·11	0·32	2·23 (0·97–3·49)
Eastern Mediterranean	0·30	0·05	1·54	0·10	0·15 (0·04–0·27)
Europe	2·35	0·43	1·45	0·07	0·19 (0·09–0·28)
Americas	0·37	0·07	5·53	0·22	0·50 (0·24–0·76)
Southeast Asia	0·37	0·07	3·73	0·13	0·29 (0·08–0·50)
Western Pacific	0·19	0·35	3·73	0·13	0·48 (0·20–0·76)
Total	16·70	2·96	16·80	0·87	3·83 (1·61–6·06)

DALYs=disability-adjusted life-years.

Table 2: **Estimated exposed populations (millions) and DALYs attributable to artisanal and small-scale gold mining and used lead-acid battery recycling by region, 2016**[112,113,203]

Human exposure to contaminated soil at toxic sites can result from ingestion, inhalation, or dermal absorption.[195] Ingestion is the most common pathway. Children are at greatest risk of exposure because they play close to the ground and because of their common oral exploratory behaviour.[196–198]

In high-income countries, substantial progress has been made in identifying and remediating contaminated industrial sites and, thus, in reducing exposures and associated disease. In the USA, the Superfund programme (panel 5),[199] a national programme for site remediation, has been funded by the US Federal Government since 1980[199,200] and additionally by state governments. In Europe, similar programmes have been created and, since 2004, they have been subsumed under the Environmental Liability Directive of the European Commission, which establishes a framework to prevent damage and remediate hazardous sites based on the polluter-pays principle.[201]

Burden of disease due to soil pollution by metals and chemicals at toxic sites

Based on data from the Blacksmith Institute/Pure Earth Toxic Sites Identification programme, we estimate that about 61 million people in the 49 countries surveyed to-date are exposed to heavy metals and toxic chemicals at contaminated sites. Because this estimate reflects exposures at only a fraction of the total number of contaminated sites worldwide, further investigation will be required before the full magnitude of exposures at such sites and their contribution to the global burden of disease can be estimated.[202]

Two types of contaminated sites that have begun to be studied in detail are used lead-acid battery recycling sites and artisanal and small-scale gold mining sites (table 2).[112,113,203] Lead poisoning from informal battery recycling is seen in low-income countries in all regions of the world.[187,204–206] Artisanal and small-scale gold mining takes place worldwide, but is most highly concentrated in Africa.[207] Details on methods for these analyses can be found in the appendix (pp 17–18).

We estimate that between 6 million and 16 million people are exposed to dangerous concentrations of lead each year at used lead-acid battery recycling sites.[185,203] These exposures result in the loss of an estimated 0·87 million DALYs annually.[203] We also estimate that between 14 million and 19 million artisanal and small-scale gold miners are at risk of occupational exposure to elemental mercury.[112] These exposures result in an estimated 2·9 million DALYs lost annually to elemental mercury poisoning.[112]

Occupational pollutants

Recognition of the health consequences of toxic occupational exposures dates to 200 BC,[164] and many of the diseases caused by occupational exposures were well known by the 1700s.[208,209] The major epidemics of industrial disease that ravaged workers' health in the 19th and 20th centuries are, however, of relatively recent origin. Such diseases include coal workers' pneumoconiosis,[210] silicosis,[164] bladder cancer in dye workers[211] leukaemia and lymphoma in workers exposed to benzene,[212] and asbestosis, lung cancer, mesothelioma, and other malignancies in workers exposed to asbestos.[213] These conditions can be traced to the rapid, initially largely uncontrolled, industrialisation and reckless exploitation of natural resources that characterised the Industrial Revolution in western Europe, North America, Japan, and Australia.

In high-income countries, the worst occupational exposures have now been controlled by legislation and regulation, backed by strong enforcement, and rates of occupational disease are down.[164,214] Substantial progress has been made in controlling exposures to occupational carcinogens. Central to this success has been the work of WHO's International Agency for Research on Cancer, which has produced independent and objective analyses of the carcinogenicity of hundreds of chemicals. These analyses guide cancer control programmes in countries around the world

By contrast, occupational exposures to toxic pollutants have become highly prevalent in the past 50 years in low-income and middle-income countries.[42] The worst of these exposures tend to occur in informal, small-scale, locally owned establishments where child labour is also a frequent problem.[176]

Burden of disease due to toxic occupational pollutants

Occupational pollutants cause a wide range of diseases.[164,215–217] The GBD study[42] considers the burden of disease attributable to two types of occupational pollutants. These are occupational carcinogens—asbestos, polycyclic aromatic hydrocarbons, silica, sulphuric acid, trichloroethylene, arsenic, benzene, beryllium, cadmium, chromium, diesel exhaust, second-hand smoke, formaldehyde, and nickel—and occupational particulates, gases, and fumes.

The GBD study[42] estimates that, in 2015, toxic occupational risk factors (not including occupational injuries or ergonomic factors) were responsible for 0·88 million deaths globally and for 18·6 million DALYs. Carcinogens were responsible for 0·49 million (55%) of the deaths from occupational exposures to toxicants and for 9·8 million DALYs. Asbestos was responsible for nearly 40% (0·18 million) of all deaths caused by occupational carcinogens. Exposures to particulates, gases, and fumes in the workplace were responsible for an estimated 0·36 million deaths and for 8·8 million DALYs.

WHO data indicate that, in 2012, occupational pollutants were responsible for 0·36 million deaths.[110] Occupational respiratory carcinogens (arsenic, asbestos, beryllium, cadmium, chromium, diesel exhaust, nickel, silica) were responsible for 0·1 million of these deaths; occupational leukaemogens (benzene, ethylene oxide, ionising radiation) for 3000 deaths; occupational particulates, dusts, fumes, and gases for 0·23 million deaths; and acute occupational poisonings for 27 000 deaths. WHO estimates that, in 2012, occupational exposures were responsible for 13·6 million DALYs.[109]

Age distribution of deaths linked to toxic occupational pollutants

Most deaths attributable to occupational pollutants and, especially, to occupational carcinogens occur in people aged 50 years and older (figure 13).[42] This pattern reflects the long latency of most occupational cancers.[213]

Pollution sources not currently quantified

Many hundreds of new synthetic chemicals have entered world markets in recent decades, come into widespread use, and are now beginning to be recognised as potential threats to health. These chemicals have become extensively disseminated in the environment, are detectable in the bodies of almost all people examined in national surveys, and have the potential to cause global epidemics of disease, disability, and death. Most chemicals have undergone little or no assessment of their safety or potential hazards to human health.

For **IARC monographs on the evaluation of cancer risks to humans** see http://monographs.iarc.fr/

Because the effects of these new chemicals on human health are only beginning to be recognised and their contributions to the global burden of disease are not yet quantified, they are currently placed within zone 3 of the pollutome (figure 3). Such emerging chemical pollutants are described below.

Developmental neurotoxicants

Evidence is strong that widely used chemicals and pesticides have been responsible for injury to the brains of millions of children and have resulted in a global pandemic of neurodevelopmental toxicity.[37,88] The manifestations of exposure to these chemicals during early development include loss of cognition, shortening of attention span, impairment of executive function, behavioural disorders, increased prevalence of attention deficit and hyperactivity disorder, learning disabilities, dyslexia, and autism.[37]

Prospective epidemiological birth cohort studies have been a powerful instrument for detecting associations between prenatal exposures to developmental neurotoxicants and disease.[218] Examples of pollution-related diseases in children that have been identified through prospective studies are: cognitive impairment, with decreased IQ in children exposed prenatally to

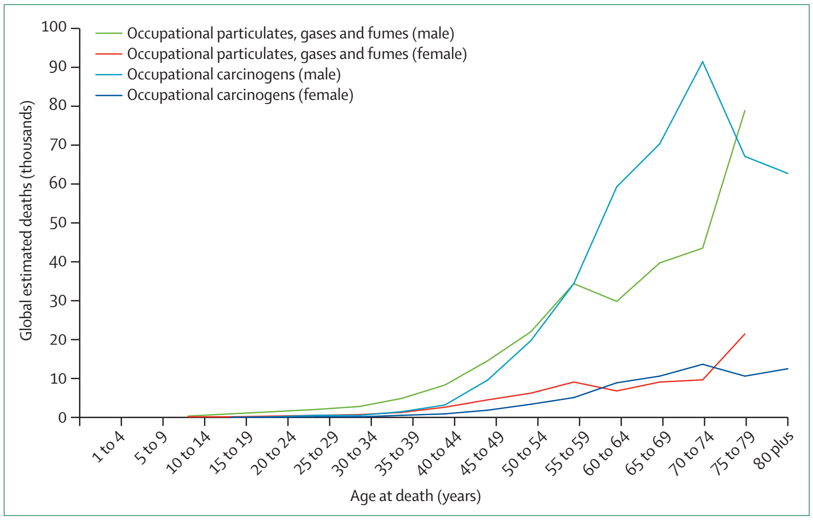


***Figure 13:* Global estimated deaths due to occupational carcinogenic and particulate exposures by age at death and gender, 2015**
GBD Study, 2016.[42]

PCBs;[219] reduced IQ and shortening of attention span in children exposed prenatally to methyl mercury;[37] microcephaly at birth, anatomical and functional delays in brain development, and autistic behaviours in children exposed prenatally to the organophosphate pesticide, chlorpyrifos;[220,221] autistic behaviours in children exposed prenatally to phthalates;[89] cognitive impairment, shortened attention span, and disruptive behaviour in children exposed prenatally to brominated flame retardants;[177] and neurodevelopmental delays in children exposed prenatally to polycyclic aromatic hydrocarbons.[32,175]

An important unanswered question is whether there are additional chemicals in use today whose ability to cause silent injury to the developing human brain has not yet been discovered.[88,222,223]

Endocrine disruptors

Endocrine disruptors are chemical pollutants that mimic, block, or alter the actions of normal hormones.[78,90–92] They include phthalates, bisphenol A, perchlorate, several pesticides, such as the orthophosphates, brominated flame retardants, and dioxins. Many endocrine disruptors are also developmental neurotoxicants. These chemicals are manufactured in volumes of millions of kilograms per year and are used widely in consumer products such as soaps, shampoos, perfumes, plastics, and food containers. Exposures in utero to even extremely low doses of endocrine-disrupting chemicals during early development can lead to permanent impairments in organ function and increased risk of disease. Prenatal exposures have been linked to autistic behaviours in children[224] and to anomalies of the reproductive organs in baby boys.[225]

Pesticides

More than 20 000 commercial pesticide products, including insecticides, herbicides, fungicides, and rodenticides are available on world markets. More than 1·1 billion pounds of these products are used in the USA each year and an estimated 5·2 billion pounds globally.[226] Some of the heaviest applications occur in low-income and middle-income countries where use and exposure data are scant. Experience with three categories of pesticides—the organophosphate insecticides, the neonicotinoid insecticides, and the synthetic herbicide glyphosate—illustrate the challenges posed by these new and inadequately tested pesticide chemicals.

The organophosphate insecticides are a large and widely used class of pesticides. Members of this class of chemicals are powerful developmental neurotoxicants, and prenatal exposures are associated with persistent deleterious effects on children's cognitive and behavioural function and with long-term, potentially irreversible, changes to brain structure that are evident on MRI.[220] Toxicological studies of rodents exposed perinatally to organophosphates produce parallel findings.[227]

The neonicotinoids are a novel class of neurotoxic pesticides that were developed in the 1980s and whose use has risen substantially in the past decade. The neonicotinoid imidacloprid is now the most widely used insecticide in the world.[228] In the USA, agricultural use of neonicotinoids was nearly 4 million kg in 2014.[229]

Neonicotinoids target nicotinic acetylcholine receptors in the insect nervous system.[230] They are water-soluble and can persist for years in soils, dust, wetlands, and groundwater and are detected in commonly consumed foods. Substantial evidence indicates that neonicotinoids can have negative effects on the behaviour and health of bees and other pollinators at environmentally relevant concentrations.[231,232] These chemicals are a suspected cause of bee colony collapse disorder. Despite their extensive use and known neurotoxicity to insects, very little information is available on the possible human health effects of the neonicotinoids.[228]

Chemical herbicides account for nearly 40% of global pesticide use and applications are increasing.[226] A major use is in production of genetically modified food crops engineered to be resistant to glyphosate (Roundup), the world's most widely used herbicide. Glyphosate-resistant, so-called "Roundup Ready" crops, now account for more than 90% of all corn and soybeans planted in the USA, and their use is growing globally. Glyphosate is widely detected in air and water in agricultural areas, and glyphosate residues are detected in commonly consumed foods.

Epidemiological studies of agricultural workers who were exposed occupationally to glyphosate and other herbicides have found evidence for increased occurrence of non-Hodgkin lymphoma in these people. Toxicological studies of experimental animals exposed to glyphosate show strong evidence of dose-related carcinogenicity at several anatomical sites, including renal tubule carcinoma and haemangiosarcoma. On the basis of these findings, the International Agency for Research on Cancer has determined that glyphosate is a "probable human carcinogen";[233] this finding is contested by glyphosate's manufacturer.

Thousands of tonnes of pharmaceutical waste are released into the environment each year, especially in high-income and middle-income countries, and measurable concentrations of several pharmaceuticals are detected in urban wastewater.[95,96]

The sources of pharmaceutical waste pollution include discharges from pharmaceutical manufacturing plants, hospitals, agriculture, and aquaculture. Anti-inflammatory agents, antibiotics, oestrogens, anti-epileptics, caffeine, and cancer chemotherapy agents are among the compounds most commonly detected. In some locations, concentrations of the anti-inflammatory drug diclofenac have been reported to exceed predicted no-effect levels.[234,235] Concern is increasing that these compounds could damage freshwater and salt water marine species through a range of toxicological mechanisms, including endocrine disruption.

Further information on these emerging chemical pollutants is presented in the appendix (pp 2–11).

Research recommendations

To increase knowledge of pollution and its effects in human health, this Commission recommends that research be undertaken to: (1) define and quantify the burden of neurodevelopmental disease in children and the burden of neurodegenerative disease in adults attributable to $PM_{2.5}$ air pollution (zone 2 of the pollutome); (2) define and quantify the burden of diabetes attributable to $PM_{2.5}$ air pollution (zone 2 of the pollutome); (3) define and quantify the burden of preterm birth and low birth weight attributable to $PM_{2.5}$ air pollution (zone 2 of the pollutome); (4) better quantify the burden of disease caused by chemical pollutants of known toxicity at contaminated sites, such as lead, mercury, chromium, arsenic, asbestos, and benzene (zone 2 of the pollutome); and (5) discover and quantify health effects associated with new and emerging chemical pollutants, such as developmental neurotoxicants, endocrine disruptors, novel classes of insecticides, chemical herbicides, and pharmaceutical wastes (zone 3 of the pollutome).

Section 2: The economic costs of pollution and pollution-related disease

Premature death and disease due to pollution impose great costs on national budgets and health-care spending, especially in rapidly industrialising low-income and middle-income countries. Diseases caused and exacerbated by pollution result in medical expenditures and in pain and suffering. Pollution-related disease can reduce labour force participation, labour market productivity, and economic output. In children, pollution-related disease can cause failure in school and perpetuate intergenerational poverty. Early life exposures to neurotoxic pollutants such as lead and mercury can impair cognition, diminish the ability to concentrate, and disrupt behaviour, thus reducing lifetime earnings. The costs of disease and premature death caused by pollution, especially the more modern forms of pollution, are rising rapidly.[236]

The costs of pollution-related disease are often overlooked and undercounted because they are associated with non-communicable diseases of long latency that extend over many years, are spread across large populations, and are not captured by standard economic indicators.[7–9,237] These costs are much more difficult to calculate than the costs of pollution control, which are usually tangible and concrete.[238] Although the costs of pollution-related disease can have large effects on the budgets of health ministries and increase spending in health systems, they are typically buried in general health expenditures and hospital budgets, hidden in productivity reports, do not affect the budgets of environment ministries, and are not attributed to pollution.[9]

The costs of pollution-related disease include: (1) direct medical expenditures, including hospital, physician, and medication costs, long-term rehabilitation or home care, and non-clinical services such as management, support services, and health insurance costs; (2) indirect health-related expenditures, such as time lost from school or work, costs of special education, and the cost of investments in the health system (including health infrastructure, research and development, and medical training); (3) diminished economic productivity in persons whose brains, lungs, and other organ systems are permanently damaged by pollution; and (4) losses in output resulting from premature death.

Pollution-related disease is responsible also for intangible costs, such as those of poor health in people made ill by pollution, disruption of family stability when a person of working age becomes disabled or dies prematurely as a result of pollution, and the loss in years of life to the person themselves.

A method to estimate the tangible costs of pollution-related disease was developed in the early 1980s by an expert committee convened by the Institute of Medicine.[239] The core of this method is calculation of the so-called "fractional contribution" of pollution to causation of a particular disease.[41] This environmentally attributable fraction is defined as ''the percentage of a particular disease category that would be eliminated if pollution was reduced to the lowest feasible levels.''[240] This fractional contribution is then multiplied by the number of cases of pollution-related disease in a population and by the average cost per case to calculate the total costs of pollution-related disease.

The cost of a case of illness is often measured by the medical expenses incurred when a person is ill (the direct costs of illness) and by the loss in productivity when a person dies prematurely or is disabled (the indirect cost of illness).[241] This method has been used to estimate the costs of pollution-related disease in children[242–244] and of occupational disease in workers,[245] has enabled quantification of the effects of pollution-related disease on GDP, and has provided a means to calculate costs that are typically externalised and not captured by standard accounting methods, and thus were previously hidden.[7] Information derived from this so-called full-cost accounting method has proven to be a powerful lever for shaping public policy and is an effective antidote to one-sided arguments for not taking or delaying action against pollution that are based solely on the costs of pollution control.[7,9]

The cost of illness approach to calculating costs of pollution-related disease works reasonably well in countries with strong public health data systems and robust information about the costs of disease. However, it is less applicable in countries without those resources. Therefore, the GBD study and WHO estimates of the burden of disease due to pollution are based primarily on data for premature deaths and do not adequately reflect the full burden of pollution-related disease because, in many countries, researchers are not able to capture information about pollution-related morbidity. In countries where data are available relating pollution to morbidity and to the costs of disease, these costs are often substantial. Such studies suggest that the morbidity costs resulting from pollution-related disease might conservatively increase mortality costs by 10–70%,[236,246,247] and some individual country studies suggest that the increment might be even greater: 25% for Colombia,[247] 22–78% for China,[248] and 78% for Nicaragua.[249]

A second shortcoming in using the cost of illness approach to estimate the health costs of pollution is that it can never capture the intangible losses caused by pollution-related disease, even when comprehensive data are available. For example, this method can neither measure the family disruption that follows the premature death of a mother or a father nor can it quantify the grief that follows the death of a child. Those losses are separate and qualitatively different from losses in income generated or in goods produced.[14] Similarly, a method that is based solely on the effect of pollution on GDP cannot fully describe the negative effects of pollution on societal health, on diminished visibility in national parks, on ecosystem services, or the benefits of pollution control in enhancing national welfare.[72]

To overcome these shortcomings in the cost of illness approach, economists have devised a second strategy to assess disease costs: the so-called "willingness-to-pay" method. This metric is a measure of how much people are willing to pay to reduce the risk of premature death.[250–252] This approach captures individuals' preferences for avoiding increases in risk of death by analysing their behaviour in risky situations (the revealed preference approach) or in hypothetical choice situations involving changes in their risk of death (the stated preference approach).

To aggregate data from willingness to pay (WTP) studies, economists have developed the Value of a Statistical Life (VSL) concept. The VSL is defined as the total of what many people would pay for small reductions in the probability of dying over the coming year that, together, add up to saving one life. For example, if each of 10 000 people were willing to pay US$100 over the coming year to reduce their risk of dying by 1 in 10 000, one statistical life would be saved and the VSL would equal $100×10 000, or $1 000 000.

Multiplying the number of lives lost to pollution by the VSL provides an estimate of the health costs associated with pollution. Multiplying the number of lives that pollution control would save by the VSL provides an estimate of the benefits of pollution control.

Although the VSL method has the disadvantage of relying on estimates of what people say they will pay to reduce mortality risks, it overcomes many of the limitations that hinder efforts to estimate pollution-related disease costs; for instance, by expanding estimates from those made solely in terms of productivity losses and effects on GDP. The VSL method has been used by governments in high-income countries and in Colombia, Malaysia, Mexico, and Peru, amongst others, to estimate the benefits of reducing pollution.[246]

Methods

This Commission uses both approaches in the current analysis. Economic losses from pollution-related disease are therefore measured in terms of lost productivity and health-care costs, and the costs of pollution-related disease are also presented using estimates derived from WTP studies. Costs associated with air, water, and lead pollution are included in this analysis, but costs associated with soil pollution are not yet available and are not included. To calculate the VSL in countries where no original studies are available, we have extrapolated estimates from other countries, taking differences in income levels into account.[246,253] This method is described in the appendix (pp 25–28).

The economic benefits that result from the control of pollution and prevention of pollution-related disease are the same as the costs that result from pollution-related disease. Losses in economic productivity are a key component of the costs of pollution-related disease. When pollution-related disease results in the death of children or adults of working age, the economic output that those people would have produced is lost forever. The productivity losses associated with premature mortality are measured by calculating the output that an individual would have produced over his or her working life, summing these losses to the present.

Pollution-related disease also reduces the productivity of ill people while they are working. Hanna and Oliva[254] estimated that the closing of a heavily polluting refinery in Mexico City, Mexico, increased the hours worked by people living near the refinery by 3·5%. Zivin and Neidell[255] found that a 10 ppb reduction in ground-level ozone increased the productivity of farm workers in California, USA, by 5·5%. Chang and colleagues[256] report that each 10 μg/m³ increase in outdoor $PM_{2·5}$ concentrations reduced the productivity of factory workers by 6% in northern California, USA. Similarly, water pollution has also been shown to reduce adult productivity. An estimated 35 million people in Bangladesh are exposed to concentrations of arsenic in groundwater that exceed 50 μg/L and 57 million people are exposed to concentrations above the WHO standard of 10 μg/L. Carson and colleagues,[257] who performed this study, estimate that reducing arsenic concentrations to the WHO standard would increase annual hours worked by the average household in their sample by 6·5%.

A method to measure lost output is to calculate its effects on a worker's contribution to GDP. Table 3 shows reductions in GDP that result from pollution-related deaths as a percentage of a country's GDP. Losses are reported by World Bank income group and pollutant category (lead exposure, ambient air pollution, household air pollution, unsafe water, and unsafe sanitation. Because the magnitude of productivity losses is sensitive to the interest rate used to discount losses to the present (discount rate), this Commission gives results using two different discount rates (1·5% and 3%). For country-level data see appendix (pp 43–47).

Because pollution-related disease is most common in heavily polluted, low-income countries, productivity losses due to pollution-related disease are disproportionately high in these countries. Thus, in low-income countries, productivity losses due to pollution-related disease represent between 1·3% and 1·9% of GDP. By contrast, in lower middle-income countries, these losses amount to between 0·6% and 0·8% of GDP. In low-income countries, the largest productivity losses due to pollution-related disease result from lack of access to safe water and sanitation, followed by exposures to air pollution. Household air pollution alone causes losses of between 0·49% and 0·68% of GDP in low-income countries.

In upper middle-income and high-income countries, most economic losses attributable to pollution-related disease are due to ambient air pollution. These losses comprise a smaller fraction of GDP than in low-income and lower middle-income countries because there is generally less pollution in these countries and prevalence of pollution-related disease is lower. An additional factor that reduces the estimated costs of pollution-related disease in high-income countries is that more than 82% of deaths due to air pollution in these countries occur in people age 65 years and older. This reduces the calculated costs because the international definition of working age is 15–64 years of age and, hence, the economic contribution of premature death in people older than 65 years is not counted. In upper middle-income and high-income countries, estimated economic losses due to pollution-related disease in 2015 were more than US$53 billion.

Additional economic costs of coal combustion not included in this analysis are costs related to disease and premature death in coal miners due to injuries and coal workers' pneumoconiosis; costs of lung cancer in coke oven workers; ecological and community costs of mountain top removal and strip mining; losses in property values near mines and along railroad rights-of-way; loss of timber resources; and crop losses due to water contamination.[9]

	Ambient air pollution and household air pollution	Unsafe water and unsafe sanitation*	Lead exposure	Total
High income	0·044% (0·048%)	0·0028% (0·0033%)	0·0027% (0·0029%)	0·050% (0·054%)
Upper-middle income	0·13% (0·15%)	0·019% (0·027%)	0·0054% (0·0059%)	0·15% (0·18%)
Lower-middle income	0·32% (0·40%)	0·28% (0·40%)	0·012% (0·013%)	0·61% (0·82%)
Low income	0·62% (0·86%)	0·70% (1·03%)	0·012% (0·013%)	1·33% (1·90%)
World	0·092% (0·11%)	0·033% (0·047%)	0·0042% (0·0046%)	0·13% (0·16%)

Results without parentheses discount future output at the rate of growth in per capita GDP plus 3%. Results in parentheses discount future output at the rate of growth in per capita GDP plus 1·5%. For the calculations see appendix (pp 25–26). *Includes, but is not limited to, no hand washing with soap.

Table 3: **Productivity losses as a percentage of gross domestic product (GDP) by pollutant and World Bank income group**

Pollution benefit-cost analyses

Benefit-cost analyses of water and sanitation improvements and improved cookstoves must account for the health benefits of these interventions, the time savings for households who no longer need to collect water or firewood, and the benefits associated with improved childhood health, such as greater educational achievement.

The health benefits associated with a project to improve water quality (eg, home disinfection of drinking water) exceed the reduced mortality risk and lost productivity measured in this chapter, and also include reductions in morbidity due to diarrhoea, especially among children, and associated reductions in malnutrition.

Two studies that combine results from the medical literature to estimate the global benefits of various water and sanitation interventions suggest benefit-cost ratios greater than 1 for many interventions on the basis of health benefits and time savings. The average benefit-cost ratio for deep borehole wells with hand pumps is 4·64, whereas household water treatment with bio-sand filters yields an average benefit-cost ratio of 2·48.[258,259] A cost–benefit analysis finds that improved water supplies, according to the WHO definition, yield a return of US$2 for every dollar invested.

Despite general acceptance that well targeted water and sanitation interventions have positive benefit-cost ratios,[260,261] the scale of these benefits can be questioned, given the number of uncertainties that are usually involved.[262,263] Site-specific analysis and examination of the range of probable benefit-cost ratios can provide useful input to the process of making policy and project decisions.[264]

Neurotoxic pollutants can reduce productivity by impairing children's cognitive development. It is well documented that exposures to lead and other metals (eg, mercury and arsenic) reduce cognitive function, as measured by loss of IQ.[168] Loss of cognitive function directly affects success at school and labour force participation and indirectly affects lifetime earnings. In the USA, millions of children were exposed to excessive concentrations of lead as the result of the widespread use of leaded gasoline from the 1920s until about 1980. At peak use in the 1970s, annual consumption of tetraethyl lead in gasoline was nearly 100 000 tonnes.

It has been estimated that the resulting epidemic of subclinical lead poisoning could have reduced the number of children with truly superior intelligence (IQ scores higher than 130 points) by more than 50% and, concurrently, caused a more than 50% increase in the number of children with IQ scores less than 70 (figure 14).[265] Children with reduced cognitive function

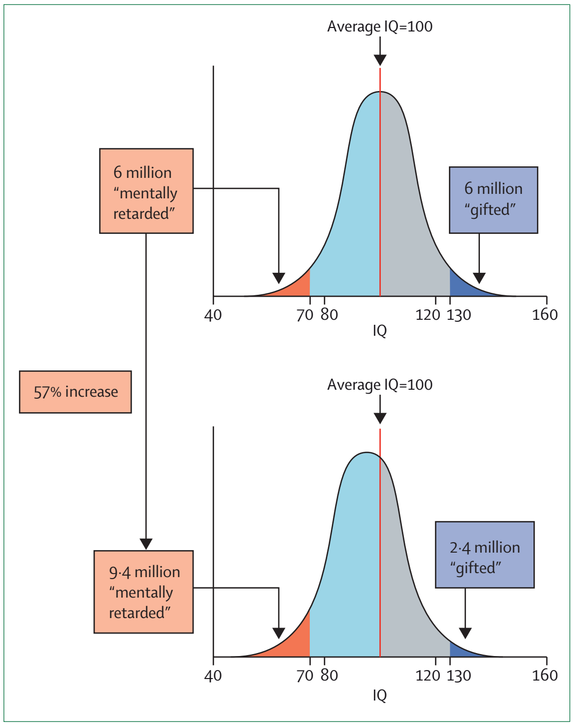


Figure 14: **Model of intelligence losses associated with a mean 5-point drop in IQ of a population of 100 million**
Figure taken from reference 265, with permission.

due to lead did poorly in school, required special education and other remedial programmes, and could not contribute fully to society when they became adults.

Grosse and colleagues[46] found that each IQ point lost to neurotoxic pollution results in a decrease in mean lifetime earnings of 1·76%. Salkever and colleagues[266] who extended this analysis to include the effects of IQ on schooling, found that a decrease in IQ of one percentage point lowers mean lifetime earnings by 2·38%. Studies from the 2000s using data from the USA[267,268] support earlier findings but suggest a detrimental effect on earnings of 1·1% per IQ point.[269] The link between lead exposure and reduced IQ[46,168] suggests that, in the USA, a 1 μg/dL increase in blood lead concentration decreases mean lifetime earnings by about 0·5%. A 2015 study in Chile[270] that followed up children who were exposed to lead at contaminated sites suggests much greater effects. A 2016 analysis by Muennig[271] argues that the economic losses that result from early-life exposure to lead include not only the costs resulting from cognitive impairment but also costs that result from the subsequent increased use of the social welfare services by these lead-exposed children, and their increased likelihood of incarceration.

Pollution-related disease has substantial effects on health-care expenditure. To quantify these costs, it is necessary to know the number of cases of each category of pollution-related disease in a population and the average health-care expenditure per case (appendix pp 29–31). These data are available for some high-income countries[272] but not for low-income and middle-income countries, except for Sri Lanka.[273]

Respiratory disease, cardiovascular disease, stroke, and cancer account for the largest proportion of the DALYs from pollution-related disease. Air pollution is responsible for half of the DALYs associated with lower respiratory tract infections and chronic obstructive pulmonary disease worldwide, and for a quarter of the DALYs resulting from ischaemic heart disease and stroke.[42,106] Globally, 24% of the DALYs associated with cancers of the trachea, bronchus, and lungs are attributed to air pollution. The proportions of DALYs linked to each of these non-communicable diseases are higher in low-income and middle-income countries than in high-income countries (table 4).[41,42] For country-level calculations see the appendix (pp 57–62).

Based on information from seven high-income countries, it can be estimated that air pollution, which accounts for 2·4% of all DALYs in these countries (panel 6),[42] accounts for 3·5% of their total health expenditure; in 2013, this amounted to US$100 billion. In Sri Lanka, a rapidly industrialising lower middle-income country where the burden of pollution-related disease is proportionately much larger than in high-income countries, air pollution accounts for 6·5% of all DALYs. Estimated expenditures on disease due to air pollution in Sri Lanka account for 7·4% of all health-care expenditures.

	Lower respiratory infections	Tracheal, bronchial, and lung cancer	Ischaemic heart disease	Ischaemic stroke	Haemorrhagic stroke	Chronic obstructive pulmonary disease	Cataracts
High income	12%	8%	13%	9%	11%	16%	1%
Upper-middle income	34%	30%	24%	20%	24%	41%	14%
Lower-middle income	57%	38%	35%	28%	31%	52%	25%
Low income	64%	48%	43%	36%	22%	51%	35%
Global	53%	24%	28%	37%	27%	44%	19%

Calculations based on data from the GBD 2015 Mortality and Causes of Death Collaborators (2016)[41] and the GBD 2015 Risk Factors Collaborators (2016).[42]

Table 4: **Percentage of disability-adjusted life-years attributable to air pollution (household air pollution plus ambient air pollution) by disease and country income group**

 www.thelancet.com **Published online October 19, 2017 http://dx.doi.org/10.1016/S0140-6736(17)32345-0**

Globally, unsafe water and sanitation, including poor hand hygiene, are associated with 96% of DALYs due to diarrhoeal disease and with 95% of the DALYs linked to typhoid fever. In low-income countries, these percentages are even higher (97% for both diseases). Health-care expenditures on pollution-induced diarrhoea and typhoid are difficult to quantify due to inadequate data. However, the costs of treating these diseases, especially for children, represent only a small proportion of the health costs to society from these diseases[274,275] and the impoverishing effect of these diseases can be as great, if not greater, than the direct cost of illness. For example, in children who survive diarrhoea, effects on nutritional status and school attendance are likely to far outweigh the costs of treatment. Repeated bouts of diarrhoea interfere with the body's ability to absorb nutrients and, in countries where many children are malnourished, compound the effects of poor nutrition.[276] The negative effects of poor nutrition on labour force productivity[277] and the effects of diarrhoea and other childhood diseases on school attendance are well studied.[278] All of these effects are magnified in settings where poor households forego medical treatment but still suffer substantial impoverishment from the loss of household income or long-term disability, where the foregone treatment is a low-cost intervention that could have restored full labour market participation.

We define welfare losses from pollution-related disease as equal to household WTP to reduce pollution. When the VSL method is used to estimate the global costs of premature deaths attributable to pollution, the total in 2015 was more than US$4·6 trillion, or 6·2% of world GDP (table 5).[42]

This estimate of WTP to reduce pollution greatly exceeds the estimated costs of pollution-related disease that are derived from productivity losses alone for two reasons. Firstly, what people will pay to reduce their risk of death is much greater than the present value of lost output. When a person dies at age 35 years, the present value of productivity losses is about 20 times per capita GDP; in low-income countries, the ratio of the VSL to per capita GDP is between 40:1 and 50:1. Secondly, the VSL is applied to all premature deaths, not only those of adults at working age. Because 75% of deaths associated with lead pollution, 64% of deaths associated with ambient air pollution, 33% of deaths associated with unsafe water and sanitation, and 56% of the deaths associated with household air pollution occur at age 65 years or older, these deaths are excluded from economic calculations based on productivity losses. The VSL approach values these deaths by what people are willing to pay to avoid them. By contrast, the method based on productivity losses presented in table 3 assigns no value to deaths that occur at age 65 years or older.

Although pollution damages are highest, in absolute terms, in high-income countries, they are highest as a proportion of income in low and middle-income countries. Table 5 shows the damages associated with each pollutant category, measured in 2015 US dollars at market exchange rates and as a percent of gross national income (which represents the sum of incomes earned by all residents of a country), and summarised by World Bank income category. The method used to calculate these damages is identical to that used in the Institute for Health Metrics and Evaluation-World Bank study;[279] however, this Commission presents all figures converted to 2015 US dollars at market exchange rates rather than using purchasing power parity dollars. Because the ability to pay to reduce mortality risks increases with income, it is highest for high-income countries. The value of avoided mortality as a percent of income is, however, much higher as a proportion of income for low-income and middle-income countries—between 8·3% and 9·4% of gross national income, reflecting the fact that most pollution deaths occur in these countries.

Ambient and household air pollution together constitute the largest category of welfare damages for all groups of countries. In high-income and upper middle-income countries, the damages associated with ambient air pollution outweigh the damages associated with household air pollution—ie, eliminating all deaths due to ambient air pollution would yield higher benefits than eliminating all deaths due to household air pollution. The reverse is true in lower middle-income and low-income countries. The damages from unsafe water and sanitation remain substantial, constituting 39% of damages in low-income and 27% of damages in lower middle-income countries.

Panel 6: Summary of Commission's estimates of the health costs of pollution-related disease

- In high-income countries, health-care spending on diseases caused by air pollution alone amounted to 3·5% of total health expenditures in 2013.
- In Sri Lanka, the only low-income or middle-income country for which data are available, health-care spending on diseases due to air pollution accounted for an estimated 7·4% of health-care spending in 2013.
- The costs of lost productivity from pollution-related disease are estimated to be between 1·3% and 1·9% of gross domestic product (GDP) in low-income countries, and between 0·6% and 0·8% of GDP in low-middle income countries.
- In high-income and upper-middle-income countries, the cost of lost productivity associated with pollution-related disease is estimated to have exceeded US$53 billion in 2015.
- When the willingness-to-pay method is used to estimate the amount that people would be willing to pay to avoid premature death due to pollution-related disease, the total is estimated to be more than US$4.6 trillion, which is 6·2% of global economic output.

	Ambient air pollution and household air pollution	Unsafe water and unsafe sanitation*	Lead exposure	Total
High income	US$1691 (3·52%)	US$159 (0·33%)	US$303 (0·63%)	US$2153 (4·48%)
Upper-middle income	US$1691 (8·37%)	US$89 (0·44%)	US$118 (0·59%)	US$1898 (9·40%)
Lower-middle income	US$367 (6·38%)	US$143 (2·49%)	US$28 (0·49%)	US$538 (9·36%)
Low income	US$18 (4·83%)	US$12 (3·30%)	US$0·740 (0·20%)	US$31 (8·33%)
Total	US$3767 (5·06%)	US$404 (0·54%)	US$451 (0·61%)	US$4622 (6·21%)

For the calculations see appendix (pp 27–28). *Includes, but is not limited to, no hand washing with soap.

Table 5: **Welfare damages (in billion US$) and as percentage of gross national income by pollutant and World Bank country income group (2015)**[42]

The welfare losses presented in table 5 (for country-level calculations, see appendix pp 48–52) can also be used to estimate WTP for policies to control pollution. Table 6 shows estimates of the amount a person exposed to pollution would be willing to pay to reduce the risk of death from exposure to each pollutant source to zero, converted to 2015 US dollars at market exchange rates.[42] For country-level WTP calculations, see the appendix (pp 53–56). This WTP estimate is the product of the VSL and the mortality risk associated with the pollutant, which is also shown. The WTP values indicate what a person would be willing to pay to reduce their risk of death due to pollution, assuming that they understood the risk. Some of these numbers might appear low—for example, the WTP per person for an improved water source in low income countries is US$15 per person; however, this would almost be sufficient to cover the capital costs of installing a borehole well (approximately $20 per person).[280] Moreover, measures to control pollution yield benefits beyond reductions in mortality risk, such as convenience and comfort, in addition to health benefits. Reducing outdoor air pollution and smoke from burning solid fuels provides aesthetic and ecosystems benefits, and the health benefits of clean air.

Although high, these numbers almost certainly underestimate the full economic burden of pollution-related disease because of inadequate data in many countries on pollution and disease prevalence, poor knowledge of the toxic effects of many chemicals in widespread use,[36,37] and lack of information on the possible effects later in life of toxic exposures sustained in early life. An issue that contributes to this underestimate is that calculations of productivity losses due to pollution understate the total value of output lost due to premature mortality because deaths of persons over age 64 are not counted in these calculations. It should also be noted that the economic approach for calculating productivity effects reflects only losses in output that are captured in GDP, and thus does not capture productivity losses in domestic work (child care, cleaning, and cooking) or in the informal sector.[281] Finally, GDP does not measure societal wellbeing.[14,282]

The estimates presented here also do not capture the health savings that have been projected to result from the reductions in air pollution that will arise from strategies to slow the pace of global climate change.[2] The evidence for health benefits of climate mitigation was reviewed in the *Lancet* Commission on Health and Climate Change.[97] The annual marginal benefits of avoided mortality from reductions in air pollution that will result from greenhouse gas mitigation strategies are estimated to range from US$50–380 per ton of CO_2 abated, and are projected to exceed marginal abatement costs in both 2030 and 2050.

Research recommendations

We make several recommendations related to research on the economic costs of pollution. Research is needed to improve estimates of the morbidity costs of pollution. This requires measuring the morbidity associated with pollution, which is more difficult than estimating mortality. This improvement also requires valuing morbidity endpoints, which are more diverse than mortality.

Additionally, work is needed to improve estimates of the non-health benefits of reducing pollution. For traditional pollution problems, these estimates should include the value of time savings associated with water and sanitation interventions and improved cookstoves and the education benefits associated with reduced illness in children. For ambient air pollution, estimates should include the aesthetic value and the ecosystem benefits of cleaner air.

Section 3: Pollution-related disease, poverty, and the SDGs

The former Secretary General of the United Nations, Kofi Annan, has declared that "the biggest enemy of health in the developing world is poverty."[283] Pollution, poverty, poor health, and social injustice are deeply intertwined. Pollution and pollution-related disease most affect the world's poor and powerless.[284] Pollution's victims are often the vulnerable and the voiceless. To understand the links between pollution, poverty, and pollution-related disease, it is necessary to elucidate the complex and multidimensional nature of poverty.[285] Poverty is not simply a lack of money. Poverty results also in reduced access to education, health care, nutrition, and sanitation and impedes participation in legal and political processes, when such processes exist, and in civil society. When

www.thelancet.com **Published online October 19, 2017 http://dx.doi.org/10.1016/S0140-6736(17)32345-0**

	Ambient air pollution	Household air pollution	Unsafe water sources	Unsafe sanitation	Lead exposure
High income	US$1472 (4·0)	US$98 (0·7)	US$11 (0·1)	US$1 (0·007)	US$264 (0·7)
Upper-middle income	US$523 (6·8)	US$214 (2·9)	US$13 (0·2)	US$5 (0·1)	US$47 (0·6)
Lower-middle income	US$85 (6·9)	US$66 (5·7)	US$39 (3·1)	US$23 (1·9)	US$10 (0·7)
Low income	US$13 (4·1)	US$23 (7·4)	US$15 (4·8)	US$11 (3·6)	US$1 (0·4)
Average	US$459 (6·2)	US$123 (4·6)	US$25 (2·0)	US$14 (1·3)	US$64 (0·7)

Numbers in parentheses are number of deaths associated with the pollutant per 10 000 people associated with the pollutant. For the calculations see appendix (pp 27–28).

***Table 6:* "Willingness to pay" per person (in US$, 2015) to reduce risk of death associated with pollution, by World Bank country income group and pollution type**[42]

families lack access to food, clothing, and shelter, they do not have the resources to support even a minimum level of health.

This Section of the Commission report presents data documenting that pollution and pollution-related disease are concentrated among the poor and contribute to the intergenerational perpetuation of poverty. Pollution-related disease can result in lost income and increased health-care costs, thus imposing disproportionately great economic burdens on poor families and communities.[286] In children, early-life exposure to neurotoxic pollutants can impair cognitive function and diminish the ability to concentrate, further contributing to school failure and reducing lifetime earnings. In example, a long-term follow-up study[144] of children exposed to lead reported that an elevated blood lead concentration at age 11 years was associated with lower cognitive function and reduced socioeconomic status at age 38 years, with diminished IQ, and downward social mobility. Moreover, poverty can worsen health, for example, by forcing people to live in environments that make them ill, without decent shelter, clean water, or adequate sanitation.[287] When people live near polluting factories or downstream from hazardous waste sites, or when poor women have no alternative but to cook with traditional stoves in close quarters, or when children are forced to pick by hand through electronic waste to recover precious metals to sustain themselves and their families,[288] poverty can exacerbate poor health.

Without political influence and with little power in most countries to control or prevent pollution, the poor have limited ability to determine the fate of their communities. Their dependence for survival on tight social networks further restricts their mobility and opportunities. The result of these interconnected forces is that poverty is a trap that often spans generations. The poor have disproportionately heavy exposures to pollution and disproportionately high amounts of disease, disability, and premature death.[289,290] A major challenge to enlightened heads of government is to balance economic development that lifts people and communities out of poverty against pollution control and the prevention of pollution-related disease.

Pollution threatens fundamental human rights: the rights to life, to health, and to wellbeing.[291] It jeopardises the rights of the child, the right to safe work, and the protection of the most vulnerable.[292] Pollution and pollution-related disease are often reflections of environmental injustice. Many countries recognise the right to a healthy environment as a basic human right linked to the right to life and other fundamental human rights.[293,294] The right to a healthy environment also includes the right to safe food and water and adequate housing.[293,294]

Recognition of the right to a healthy environment requires that all members of a society have unfettered access to information about sources and patterns of pollution; that they have the power to participate in environmental planning and decision making; and that there is an environmental regulatory agency and an independent judiciary that protect the environment from polluters, and the poor against pollution.[295]

Pollution and pollution-related disease are often reflections of environmental injustice. Robert Bullard, widely regarded as the father of the environmental justice movement,[296] defines a core principle of environmental justice as "all people and communities are entitled to equal protection of environmental and public health laws and regulations."[297] Bullard stresses that environmental justice is a far-reaching concept that involves much more than equal enforcement of laws and regulations. In Bullard's view, environmental justice is a basic human and civil right and requires meaningful and timely involvement of people and communities in decisions that affect their environment and wellbeing. In 1991 Bullard and his colleagues, at the first National People of Color Environmental Leadership Summit adopted 17 Principles of Environmental Justice.[298] These principles were developed as a guide for organising, networking, and relating to government and non-government organisations.

Environmental injustice is the inequitable exposure of poor, minority, and disenfranchised populations to toxic chemicals, contaminated air and water, unsafe workplaces and other forms of pollution, and the consequent disproportionate burden among these populations of pollution-related disease, often in violation of their human rights. Environmental injustice has been characterised as a form of structural violence.[299] In many instances, environmental injustice is linked to so-called "structural racism".[300]

Panel 7: India's judicial system for pollution

During the UN Conference on Environment and Development in 1992, India committed to providing judicial and administrative remedies for the victims of environmental damage. To fulfil this commitment, India became the third country in the world to start a National Green Tribunal, a judicial body exclusively established to judge environmental cases. The National Green Tribunal was formed on Oct 18, 2010. The focus of this body is on the effective and expeditious resolution of cases relating to environmental protection and conservation of forests and other natural resources. The National Green Tribunal is mandated to make final judgments on applications and appeals within 6 months of their filing. The National Green Tribunal is comprised of judges, who are supported by environmental experts to provide informed guidance on environmental issues, to validate the Tribunal's legal judgments.

Cases such as the Vedanta Bauxite Smelter in Orissa, the Thermal Power Plants in Andhra Pradesh, and the Jaitpur Nuclear Power Plant in Maharashtra have seen controversy and protests. The involvement of the National Green Tribunal has resulted in amicable solutions to these cases, ensuring the people of the affected regions a safe and liveable environment. Before establishment of the National Green Tribunal there were numerous cases in which large industries were confronted by local people fighting for the environment.

Global spread of extractive industries: oil and gas production, mining, and smelting

Social and economic factors that have contributed to the global spread of environmental injustice and the inequitable exposure of poor and marginalised populations to pollution and disease include globalisation, which has caused the movement of hazardous industries such as chemical manufacture, steel making, pesticide production, and shipbreaking from higher income countries to low-income and middle-income countries. This movement has entailed low wages, little or no environmental and occupational regulation, and weak public health infrastructure. The consequences of these occupational and environmental conditions are disease and injury in underprotected workers, diseases caused by toxic chemicals in residents of communities near polluting facilities, and industrial explosions. Examples include the chemical explosion in Bhopal, India where a pesticide production factory that had been trans-shipped from the USA detonated and killed and injured thousands or workers and local residents; the global trade in asbestos that results in shipment of 2 million tons of asbestos annually to the world's poorest countries, where it will produce epidemics of lung cancer, mesothelioma, and other malignancies;[214] and the global trade in banned and restricted pesticides.

Transboundary transfers of hazardous and toxic wastes, such as electronic wastes and chemical wastes, from high-income to low-income and middle-income countries are a further cause of the global spread of environmental injustice. The global spread of artisanal and small-scale gold mining and the concomitant spread of occupational and community-wide exposure to elemental mercury and methylmercury are another example.[112,113] The expansion of gold mining is driven by large increases in the global price of gold, which encourage poor people to leave agriculture and other traditional occupations. Although small-scale mining is relatively profitable for the miners, it is highly exploitative in that the majority of the profits accrue with brokers and retailers, and the burdens of disease and environmental degradation fall almost entirely upon mining communities. Regional conflicts and wars, frequently driven by a desire for natural resources (namely oil, minerals, and timber) further aggravate these problems.

Environmental injustice exists in countries at all levels of income and development and in all regions of the world,[284,301–303] as can be seen in the following examples and case studies.

Combating environmental injustice

To advance environmental justice and reduce the inequitable exposure of the poor and the marginalised, countries must develop legal mechanisms that provide recourse for environmental injustice. India's green court, for example, provides citizens with access to an independent judiciary that has the power to redress pollution injustices. Such a system, when connected with openly shared data on toxic exposures and health can serve as a powerful mechanism to address environmental injustice (panel 7).

Environmental injustice in North America is well documented. Recurrent racial and ethnic disparities have been documented in North America in exposures to various forms of pollution. A study of the ambient air pollution in New York City have documented that almost all diesel bus depots, places where buses idle their engines for hours while emitting pollutants, are in minority, mostly disadvantaged neighbourhoods. Disproportionately increased prevalence of asthma and other respiratory diseases have been documented among children in these communities.[304] In the so-called "Cancer Alley" region of Louisiana, an 85 mile stretch along the Mississippi River where 125 companies manufacture a quarter of all petrochemical products made in North America, the US Commission on Civil Rights determined that the African-American community was economically disadvantaged and disproportionately affected by pollution from hazardous facilities.[305] Another case study[306] of environmental injustice in the USA relates to the exploitative uranium mining operations on Native American (Navajo) lands. Mining operations there depleted and contaminated the scarce water supply and produced high prevalence of lung cancer in Navajo underground miners, who suffered intense occupational exposures to radon.[306] A final example involves the disproportionate exposures of Hispanic farm workers to acutely toxic organophosphate pesticides, such as parathion. Several cases of acute pesticide poisoning have resulted. Many of these workers are undocumented immigrants and, hence, afraid to protest environmental injustice and pollution.[307]

In Canada, environmental injustice occurs in the traditional lands of First Nations (indigenous peoples). First Nations are battling the Alberta Oil Sands Project in northern Alberta[308] and exposure to Canada's worst air pollution hotspot in Ontario's so-called "Chemical Valley", where 40% of the country's chemical manufacturing is located.[309]

Environmental injustice issues are also prevalent in Europe.[310] In central and eastern Europe, some minority Roma people and refugee and displaced communities from Kosovo have faced environmental injustice. In Kosovo, camps for displaced Roma were located in an area polluted by toxic tailings from a lead mine. In Durres, Albania, refugees from Kosovo were housed in a disused chemical plant that had previously produced sodium dichromate and lindane, compounds classified by the International Agency for Research on Cancer as class 1 (proven) human carcinogens.[311]

In Asia, the sustained economic growth that has enabled substantial reduction in poverty has simultaneously increased toxic pollution and environmental inequity.[312] In China, a highly publicised example involved a paraxylene chemical factory in the city of Dalian, where residents feared that typhoons could breach chemical storage tanks and flood lower socioeconomic areas of the city with toxic material.[313]

In India, a well studied example of environmental injustice is the disproportionate siting of mineral and metals extraction facilities in the Adivasi belt of central and northeast India where 70 million Adivasis—tribal people—live in extreme poverty and are disproportionately exposed to air, water, and soil pollution produced by these facilities.[313] In a landmark case linking the mining industry in the Adivasi belt to environmental injustice,[314] the Indian Supreme Court observed that the fundamental rights of citizens, guaranteed by the Constitution, included "the right of enjoyment of pollution-free water and air for full enjoyment of life".

In Africa, extraction of natural resources is a major driver of environmental injustice and pollution. In Zambia, the lead and zinc mines at Kabwe are among the world's most polluted places. Although these mines are no longer active, the residue left behind after decades of extraction by overseas-based companies have contaminated soil and the local water supply. Children in Kabwe have blood lead concentrations that are 5–10 times higher than the threshold concentration recommended by the US Centers for Disease Control and Prevention.[315] Mineral extraction has also been associated with environmental injustice in post-apartheid South Africa, where large-scale gold mining has resulted in epidemic silicosis among miners, many of them economic migrants from the poor countries of southern Africa surrounding South Africa.[313] Gold mining was also the cause of the 2010 tragedy in Zamfara State, Nigeria, in which 163 people in deeply impoverished communities, including 111 children, died of acute lead poisoning.[316] Similar events have been recorded in relation to gold mining in Ghana.

In Latin America, environmental inequality is evident in a series of clashes between extractive industries, particularly the mining industry but also oil and gas production, and indigenous communities. Examples include the Tia Maria copper project in Peru, operated by Mexico's Southern Copper Corporation, the world's second largest copper mining company, and the USA-based Newmont Mining Company's US$4·8 billion Conga gold-copper project, Peru's biggest mining investment. Protests against the inequitable placement of these enormous projects on lands belonging to native peoples and the resulting disproportionate burdens of pollution, environmental degradation, and disease are reshaping basic paradigms of resource-based development. These struggles have forced contemporary legal systems, including legal systems in the high-income home countries of mining conglomerates, to accommodate indigenous world views and to correct, rather than perpetuate the unjust effects of economic growth upon the poor.[313,317]

With the worldwide spread of toxic chemicals and modern-day pollution, interest has grown in investigating, documenting, and mapping environmental injustice. Information produced through these efforts, especially information documenting patterns of pollution at the local level, can provide powerful leverage to disproportionately exposed communities who are struggling to reduce their exposure and their inequitable burden of pollution-related disease.

In Europe, the Environmental Justice Atlas, a global online database, now lists information on about 2000 sites around the world where pollution and environmental injustice are documented or suspected. Linked to this database is Environmental Justice, Organisations, Liabilities and Trade, a global research project supported by the European Commission that is compiling The Map of Environmental Justice, an atlas of maps documenting the distribution of pollution and environmental injustice around the world.[318]

For the **Environmental Justice Atlas** see https://ejatlas.org/

Pure Earth, a New York-based environmental non-profit organisation has developed a Toxic Sites Inventory Program that includes information on about 3500 polluted sites—active and abandoned mines, smelters, factories, and hazardous waste dumps—a number that is still growing.[38] This database focuses on contaminated sites in low-income and middle-income countries and has served as a resource to the work of this Commission.

In the USA, the Environmental Protection Agency has developed an open-access mapping tool, EJSCREEN, that is available on the EPA website and makes data on environmental injustice publicly available. This tool overlays 12 environmental factors, including information on levels of airborne particulate matter, lead paint, and proximity to water discharges with six demographic factors, including income level and percentage of the population classified as minority. The resulting maps

For **EJSCREEN** see https://www.epa.gov/ejscreen enable people to check their neighbourhoods and to directly examine the intersection of pollution with poverty.

The global distribution of pollution and pollution-related disease illustrates the connections between pollution, poverty, and environmental injustice. 92% of pollution-related deaths occur in low-income and middle-income countries (figure 8). In countries at every level of income, the health effects of pollution are most frequent and severe among the poor and the marginalised. By far, the largest share of pollution-related diseases is the outcome of urban and household air pollution. However, water pollution and toxic occupational exposures are also crucial contributors to mortality and morbidity.

Air pollution, poverty, and environmental injustice

In 2015, more than 99% of deaths due to household air pollution and approximately 89% of deaths due to ambient air pollution occurred in low-income and middle-income countries.[319,320] Several cities in India and China record average annual concentrations of $PM_{2·5}$ pollution of greater than 100 μg/m³, and more than 50% of global deaths due to ambient air pollution in 2015 occurred in India and China.

Ambient air pollution in rapidly expanding mega-cities such as New Delhi and Beijing attracts the greatest public attention; however, WHO documents that the problem of ambient air pollution is widespread in low-income and middle-income countries and finds that 98% of urban areas in developing countries with populations of more than 100 000 people fail to meet the WHO global air quality guideline for $PM_{2·5}$ pollution of 10 μg/m³ of ambient air annually.

Household air pollution offers an even starker example of the strong links between pollution and poverty.[57] Deaths due to household air pollution are highly concentrated in the world's poorest countries.[57] An estimated 3 billion people in low-income and middle-income countries, mostly in rural communities, use solid fuels (firewood, biomass, or charcoal) and traditional stoves for heating and cooking.[57] In sub-Saharan Africa, for example, firewood is the main source of fuel, as it is in many parts of south Asia. The use of biomass fuels is closely linked to gender inequality. Without access to the cleaner fuels and cookstoves available to many urban households, rural women in these regions and their children are disproportionately exposed to toxic fumes from smoky open fires. As they cook food for the family or study by the light of the stove, these women and children court sickness and premature death in a way their urban counterparts do not.

For the **Basel convention** see http://www.basel.int/

Water pollution, poverty, and environmental injustice

Poor water and inadequate sanitation and hygiene are also highly concentrated in the world's poorest countries. An estimated 2·5 billion people lack access to a basic toilet; 1 billion people defecate in the open; and 748 million people lack clean drinking water.[321] Poor people living in rural areas, indigenous peoples, people with disabilities, and other marginalised groups are especially likely to lack these basic services.

A sharp gender gap is evident in the health and social effects of water pollution and inadequate sanitation. Girls are particularly severely affected by inadequate access to safe water because the task of collecting water falls disproportionately on them and because lack of water introduces a problem with menstrual hygiene. The many hours that girls in poor communities must spend fetching water increase the risk that they will miss school and, thus, remain trapped in their communities by lack of education. If a school does not provide safe, private toilets, monthly periods can also force girls to miss class or to leave school altogether.[322]

Of all deaths due to toxic occupational exposures, 92% occur in low-income and middle-income countries. This distribution reflects the fact that high-income countries have largely solved their worst problems of occupational exposure and reflects the international migration of polluting industries from high-income countries to poor countries.[323,324]

As a consequence of globalisation and production outsourcing, pollution and pollution-related disease have become planetary problems.[325,326] Dumping hazardous materials produced in high-income countries in poorer countries is a clear intersection between global pollution and environmental injustice. This dumping includes shipment of pesticides, industrial waste, and toxic chemicals that are no longer permitted in North America or the European Union to poor countries. For example, in 2006, 500 tons of toxic waste were transported from Amsterdam in the vessel Probo Koala and dumped in sites around Abidjan, Côte d'Ivoire. The toxic gas produced by the release of these chemicals resulted in 17 deaths and in more than 100 000 cases of respiratory and gastrointestinal disease.[327,328] A second example has been documented at a large electronic waste site at Agbogbloshie in Accra, Ghana.[329] This site contains thousands of broken computers and other electronic components shipped from European countries in containers labelled "secondhand goods"; the European Union allows export of genuinely reusable electronic goods, but the material shipped to Agbobloshie is usually broken beyond repair and hardly reusable.[326] Electronic waste dumpsites in poor neighbourhoods can be found worldwide, especially in the Asia-Pacific region. It is estimated that the global electronic waste market will quadruple in the next decade, from US$9·8 billion in 2012 to $41·4 billion in 2019.[330]

International action to address the global problem of dumping led to development of the 1989 Basel Convention on the Transboundary Movement of Hazardous Wastes and to conventions on persistent organic pollutants,[80] pesticides, mercury, hazardous waste, and chemicals. The European Union also joined the cause and has issued directives to limit international

www.thelancet.com **Published online October 19, 2017 http://dx.doi.org/10.1016/S0140-6736(17)32345-0**

dumping that include restrictions on hazardous substances and on waste electrical and electronic equipment, both promulgated in 2002. Although these conventions and directives are limited by weak enforcement and by structural impediments, such as the requirement in the Rotterdam Convention for complete unanimity amongst all participating countries before a pollutant can be proscribed, they have, nonetheless, helped to slow the global movement of toxic substances and reduce toxic pollution.

Pollution, poverty, and the UN's SDGs

The SDGs were adopted by the United Nations in September 2015 to guide the international development agenda until 2030. The SDGs are intended to advance human dignity in countries around the world.[331] It is of note that the predecessor to the SDGs, the Millennium Development Goals that guided global action until 2015, made no mention of pollution at all. By contrast, SDGs focus on the issue to an extraordinary extent, as noted in the introduction, and as befits an issue so integral to the fight against poverty. The main provision is, appropriately, in SDG 3 on good health and wellbeing, where SDG 3·9 commits the world community, by 2030, to "substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water, and soil pollution and contamination".[332] The other pollution-specific goal is SDG 6 on water and sanitation, in which SDG 6·3 calls, by 2030, to "improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally".

However, the SDGs do not leave the issue there. Given the close linkages between poverty and exposure to toxic pollution and the need to reduce, if not eliminate, both, the SDGs seem to recognise that some actions to achieve the broader goals, such as SDG 1 (end poverty) and SDG 2 (end hunger), could, if unchecked, result in exacerbation of pollution exposures. Hence, pollution control must be central to agricultural and industrial development, if development of these is to be truly sustainable. To this end, the SDGs make repeated references to preventing and reducing pollution. These include SDG 2·4 (improving soil quality), SDG 7 (clean energy), SDG 9·4 (clean technologies and industrial processes), SDG 11 (sustainable cities and communities), SDG 12 (responsible consumption and production), and SDGs 14–15 (water and land conservation). Achievement of these SDGs will also positively affect environmental justice and fulfil SDG 10 (reduced inequalities). Importantly, measures to reduce greenhouse gas emissions and short-lived climate pollutants, such as black carbon, will help achieve SDG 13 (climate action).

The SDGs are explicitly about sustainable development but, for development to be sustainable, it must both combat poverty and ensure equity. In 1987, the Report of the World Commission on Environment and Development on "our common future" stated that sustainable development must assure the poor that they receive a fair share of the resources required to sustain their economic growth.[333] With the growing recognition that pollution not only exacerbates poverty but leads to environmental injustice, sustainability of development is now also increasingly linked to equity. As observed in the Human development report 2011 by the United Nations Development Programme,[334] sustainability and equity might not always be mutually reinforcing (although they can sometimes be), and the most feasible alternative solutions might require explicit and careful consideration of the trade-offs involved. Such an approach to pollution control will not only yield positive synergies between sustainability and equity but also ensure that the SDGs regarding poverty, pollution, and environmental justice are comprehensively met.

For the **Rotterdam convention** see http://www.pic.int/

The Regional Action Plan for Intergovernmental Cooperation on Air Pollution for Latin America and the Caribbean, prepared by UN Environment Programme in the context of the Latin America and the Caribbean Forum of Ministers of Environment is an example of a high-level plan that sets out common directions for national governments to work together on broad issues.[335] This Action Plan promotes collaboration towards the creation and adoption of national and local policies and programmes to reduce emissions of key pollutants and to achieve improvements in urban air quality in the region. The Action Plan covers broad supportive activities such as technical assistance, policy cooperation, methods, research, and awareness raising and monitoring. The Regional Action Plan will support and encourage the national and local administrations to develop and implement practical local plans to reduce the effects of air pollution.

Research recommendations

To reduce the inequitable exposure of the poor and the marginalised to pollution, this Commission recommends two key strategies. First, we recommend funding of research to document and map the disproportionate effects of pollution upon the poor, women, and girls be adopted as a priority by international health agencies. Additionally, a special focus should be placed on overseas development assistance to protect indigenous peoples and their communities from pollution and its harmful effects.

Section 4: Effective interventions against pollution: priorities, solutions, and benefits

A key message of this Commission report is that, with leadership, resources, and a clearly articulated, data-driven strategy, much of the world's pollution can be controlled and pollution-related disease prevented. Strategies to curb pollution have been developed, field-tested, and proven cost-effective. These strategies were developed initially in high-income countries and are now moving into

For the **Minamata convention** see http://www.mercuryconvention.org/

middle-income countries. They are based on law and regulation, rely heavily upon technology, are subjected to continuous evaluation, are backed by strong enforcement, and incorporate the polluter-pays principle. These programmes are held accountable to targets and timetables. These successful, effective strategies for pollution control can be used as models and adapted to local circumstances in cities and countries at every level of income. Their application can enable developing cities and countries to leapfrog over the worst of the human and ecological disasters that have plagued economic development in the past.

A second key message is that control and prevention of pollution provide several benefits, both short-term and long-term, for societies at every level of income. The direct benefits of pollution mitigation include improvements in air and water quality and improvements in health. The health benefits include reductions in disease incidence and prevalence, improvements in children's health, reductions in the numbers of premature deaths, increasing longevity, and substantial enhancements in quality of life. Indirect benefits include enhancing gender equity, alleviating poverty, increasing tourism, improving education, and enhancing political stability. Pollution control makes cities more liveable and attractive, benefits ecosystems, improves the economy and, when coupled with efforts to transition to clean fuels and to control emissions of greenhouse gases, pollution control can help to slow the pace of global climate change and accelerate the transition to a cleaner, more sustainable, circular economy.[81,336,337]

These many benefits of pollution control underscore the reality that pollution is much more than merely an environmental challenge; pollution is a profound and pervasive threat that affects many aspects of human health and wellbeing.

Pollution control today builds on the successes of the past. The industrially developed countries were the first to control pollution, and many of their control strategies were adopted in the aftermath of environmental and public health disasters caused by pollution. Thus, in mid-19th century London, UK, putrid contamination of the River Thames and recurrent epidemics of cholera led to regulation of public drinking water sources[338] and to the construction of large conduits for the removal of human waste and industrial pollution that now form the Thames Embankment.[339] Episodes of severe air pollution with substantial loss of life, such as the Great Fog of London in 1952,[340] and the Donora, Pennsylvania episode in the USA led to the passage of clean air legislation. Occupational and mining disasters catalysed the development of worker health and safety legislation. The discovery of contaminated toxic sites in the USA at Love Canal in New York and the Valley of the Drums in Kentucky led to legislation mandating clean-up of hazardous waste sites—the Superfund legislation.[175] An epidemic of congenital methylmercury poisoning in Minamata, Japan[341] led to global action to protect human health and the environment against mercury and culminated in adoption of the Minamata Convention.[198]

In response to the rapid, poorly controlled growth of cities and the global spread of industrial production and chemically intensive agriculture, low-income and middle-income countries have become increasingly engaged in pollution control. Targeted interventions to control water pollution, improve sanitation, and reduce waterborne diseases were among the earliest efforts to control pollution in low-income and middle-income countries, and began as early as the 1950s. Bangladesh has long been in the forefront of this work,[342,343] China has made extraordinary progress in control of water pollution and prevention of waterborne infectious disease (panel 8),[344–354]

Panel 8: China's recent experience

In its 13th Five-Year Plan, for 2016, the Government of China acknowledged the dangers posed by pollution[344] and set specific targets for environmental improvement and restriction of resource use.

Air pollution

- China adopted The Air Pollution Prevention and Control Law in 1987. This law and its subsequent revisions have resulted in an 10% national decline in particulate matter less than 2·5 μm ($PM_{2·5}$) between 2014 and 2016, despite extremely high particulate concentrations in certain cities such as Beijing.[345] A 2016 amendment to the law explicitly mentioned, for the first time, the connection between environmental protection and public health.[346]
- China has increased its reliance on non-fossil energy sources (predominantly renewables and nuclear) from 9·4% of total energy use in 2010 to 12·0% in 2015, surpassing the 12th Five-Year Plan target of 11·4% by 2015. The most recent Five-Year Plan[347] aims to increase non-fossil energy use to at least 15% by 2020, and to at least 20% by 2030.
- China has implemented a vast network of stations to monitor air quality in more than 400 cities. The capacity to track emissions has been central to developing policy and implementing data-driven regulatory frameworks.[348]

Water pollution

- China's most recent water pollution legislation, the Water Ten Plan, was adopted in April, 2015.[349] This plan sets metrics and targets for ten major polluting industries. Among key targets to be met by 2020 are: more than 70% of water in seven key rivers shall reach Grade III or above; more than 93% of urban drinking water sources shall reach Grade III or above; reduce groundwater extraction and control groundwater pollution; and use of groundwater falling under the "very bad" category shall decrease to around 15%.
- The Ministry of Environmental Protection estimates that the Water Ten Plan will boost GDP by ¥5·7 trillion (US$91 billion), with a ¥1·9 trillion benefit to the affected industries.[350]

Soil pollution

- The 13th Five-Year Plan calls for the establishment of laws to monitor, prevent, and remediate soil pollution. The goal is to make 90% of polluted arable land safe for agricultural use by 2020, increasing to 95% by 2030.[351] The Ministry of Environmental Protection estimates that the actions of the 13th Five-Year Plan could add ¥2·7 trillion ($411 billion) to the nation's GDP and create around 2 million jobs.[352]
- The Five-Year Plan also details a nationwide soil quality monitoring programme.[353,354]

and Peru has embarked on a programme to improve mine drainage.[355]

Air pollution control programmes are developing in cities in several low-income and middle-income countries, including Mexico City,[356] Ulaanbaatar,[357] and New Delhi.[358] China is embarking on a national effort to reduce air pollution that includes a plan to dramatically increase reliance on non-polluting, renewable energy sources, and is on track to nearly triple its solar capacity between 2015 and 2020, adding 15 to 20 GW of solar capacity per year.[123,359–361]

Most countries now have programmes in place to address some aspects of pollution, and almost all have established frameworks for regulatory control of industry, although staffing, resources, and enforcement capacity are variable.[362] This Section of the Commission report enumerates the benefits of pollution control, describes key elements of successful pollution control strategies and the responsibilities of stakeholders, and it concludes with recommendations.

The benefits of pollution control

Examples of pollution control and its benefits are presented in this section, panels 9 and 10,[119,131,363–367] and in the appendix (pp 63–107).

One benefit afforded by pollution control is reduction of household air pollution by providing liquefied petroleum gas and bio-gas and by providing affordable electricity that is produced by non-polluting, renewable energy sources to replace wood chips, coal, charcoal, and cow dung as cooking fuels. These interventions not only reduce exposures to airborne particulates, thereby improving health, but they also produce short-term and long-term economic returns to local communities because households (especially women) are able to spend less time collecting wood, or processing dung for cooking, and thus have more time to devote to economically productive activities (for women) or education (for girls).[368]

A second benefit is improvements in sanitation that are achieved by providing clean water and toilets. These interventions not only reduce prevalence of waterborne disease but they also allow more children, especially girls, to attend school.[369] These improvements benefit tourism and help lift the economy in developing countries, since a reputation for clean beaches, an unpolluted environment, biodiversity, and safe food and water can help to lure discerning tourists and increase their spending.[370]

Another benefit is seen in shifting the energy sector from coal-fired power plants to cleaner gas-fired plants, and, better yet, to low-polluting renewable energy sources such as wind, tidal, geothermal, and solar. These interventions not only reduce pollution and improve the cardiorespiratory health of entire populations, but they will also sharply reduce greenhouse gas emissions, and increase the efficiency of electricity generation.[371]

Additional benefits are produced by controlling urban air pollution by upgrading public transportation, encouraging active transport (walking and cycling), reducing sulphur content of motor fuels, promoting use of low-emission and zero-emission vehicles (while concurrently cleaning the energy supply), and restricting car and trucks from city centres. These interventions not only improve air quality, but will also reduce childhood asthma, reduce incidence of cardiovascular disease, stroke, and diabetes in adults, and enhance the quality of urban life.[372,373]

Another benefit in controlling pollution is that remediation of highly contaminated sites in densely

Panel 9: Partial successes in reducing air pollution from cookstoves

China's National Improved Stove Programme

- China's National Improved Stove Programme (1982–92) has distributed 180 million improved cookstoves to people in rural areas of China, in conjunction with provincial programmes. This programme is among the world's largest and most successful national programmes for improved stoves.[363] The initiative aimed primarily to increase efficiency and thus reduce the use of biomass fuel. Middle-income households were targeted in this programme, and households were expected to purchase the stoves themselves.[364] All improved cookstoves had chimneys, and some had blowers for more efficient combustion.
- With regard to the primary objective of achieving better fuel efficiency, China's programme lowered household air pollution levels, but, unfortunately, this reduction was not sufficient to meet China's indoor air quality standards and substantial exposures remained. A fundamental problem was that the stove designs did not reduce emissions, but focused on fuel efficiency and, at best, moved the smoke outside, where it still caused exposures. Nevertheless, the programme showed that large-scale effects could be achieved by a well organised and well supported effort that was coordinated nationally, but with substantial local participation. Additionally, an epidemiological study of household stove improvement that was undertaken in a cohort of 21 232 Chinese farmers followed from 1976 to–1992 showed that stove improvement was associated with a greater than 30% reduction in incidence of lung cancer.[365]

Indian National Programme on Improved Chulha

- A second national programme at a similar scale to the Chinese programme, the Indian National Programme on Improved Chulha stoves, which operated from about 1984 to2001, was reported to have had little effect on fuel efficiency nationally, and even less in reducing long-term exposure to smoke.[366]

Gyapa Stoves Project, Accra, Ghana

- An African example of a successful cookstove intervention was the Gyapa Stoves Project in Accra, Ghana. In 2000, 95% of Ghanaian households used solid fuels to power stoves.[367] This was a much higher percentage than the estimated 73·4% for the rest of northwest Africa. Many homes in Ghana were poorly ventilated and the burning of solid fuels, such as savannah wood, was inefficient and contributed to deforestation and ecosystem imbalance. To address this problem, EnterpriseWorks/VITA, Shell Foundation, and USAID partnered in 2002 to implement a programme to replace traditional coal-pots with improved stoves called the Gyapa Stove. The Gyapa stove requires 50–60% less fuel than traditional stoves and produces less smoke. This project was unusual in that it aimed to create a sustainable business model that helped the local economy by creating jobs to manufacture the stoves. In 2008, 68 000 stoves were sold in Accra and Kumasi. Air quality was found to have improved by 40–45%.

Panel 10: Cleaner fuels and indoor air

In the past 2 years, major advances have made clean fuels more available in several countries. Examples of programmes to introduce cleaner fuels are the following:

The Indian liquefied petroleum gas programme

- In 2016, India set a goal of providing access to liquefied petroleum gas to 50 million additional poor families in 3 years through a large programme that was operated through the national oil companies. In 2016, more than 10 million households have already been targeted through the national Give it Up campaign, in which middle class families voluntarily give up their liquefied petroleum gas subsidy to a family who are below the poverty line, and corporate responsibility funds are earmarked for the upfront costs.

Ecuador's electric induction stove programme

- In Ecuador, the national government has developed a major programme to change every traditional cookstove in the country to an electric induction stove. Electric induction stoves are 50% more efficient and faster than gas or normal electric cooking, and have other advantages, including improved safety. This transition is possible because Ecuador has nearly universal electrification, much of it derived from hydroelectric projects. Other countries, including Paraguay and Bhutan, also have hydropower potential, and both are currently undertaking preparatory studies.
- Ultimately, it is clear that any household use of solid fuel has negative effects on health and that the eventual goal should be the elimination of solid fuel and its replacement with cleaner sources of energy. In the interim, in areas and countries where elimination of solid fuel is not immediately possible, transition to the cleanest biomass stoves should be strongly encouraged.[119] Millions of lives can be extended every year among the poorest populations in the world by such a transition, but the challenges are still great.
- Progress in implementing clean energy is tracked by the International Energy Agency at both the national and sectoral levels, which has shown some advances in the generation of cleaner energy nationally, but inadequate progress in meeting transportation goals. The International Energy Agency concludes that "strong actions linked to stated targets need to be pushed forward to achieve the clean energy potential".

populated areas will reduce the prevalence of poisoning by toxic chemicals and heavy metals, will enhance land values, and encourage urban redevelopment. Brownfield remediation projects have been successful in covering the expense of clean-up by the private sector.[200]

Reductions of exposures to lead from pottery (panel 11)[374–376] and paint will reduce childhood lead poisoning and thus enhance the intelligence, creativity,[169] and economic productivity of entire societies.[46]

A final benefit of pollution control results from bans on the production and use of asbestos, which will reduce asbestosis, lung cancer, and malignant mesothelioma and will therefore produce substantial gains in economic productivity by preventing serious illness and premature death and will also result in reductions to health-care costs. In conclusion, well designed and executed pollution control strategies will advance attainment of many of the UN's SDGs.[16]

Essential components of pollution control programmes

Planning processes that prioritise interventions against pollution, link pollution control to protection of public health, and integrate pollution control into development strategies are the first step to dealing with pollution. Defining and prioritising interventions enables a focus on cost-effectiveness and creates roadmaps for comprehensive solutions.

The key societal underpinnings for successful pollution control at any level of development include courageous and visionary leadership by heads of government—mayors, governors, and heads of state—along with an engaged, informed, and empowered civil society. It is also important that there be a shared societal commitment to protecting human health and advancing social justice and a carefully designed, evidence-driven package of pollution control policies.

Effective plans to control pollution require support from many sectors of society and, therefore, must involve collaborations among many agencies and organisations within and outside governments, and nationally and internationally. These stakeholders must be fully integrated into a city's or a country's development agenda. If they are to be successful, these efforts must include not only ministries of health and environment, but also ministries of finance, energy, industry, agriculture, and transport. Pollution control policy cannot exist in isolation.

Successful strategies rely on a mix of primary prevention approaches that eliminate pollution at source, coupled with downstream pollution control technologies, such as filters and stack scrubbers, that remove pollutants from the waste stream after they have already been formed. Examples of highly transformative strategies for pollution control that are based on primary prevention include shifting the mix of energy sources in a city or country away from polluting fuels toward non-polluting, renewable fuels;[377] use of safer feedstocks in industrial production, such as feedstocks produced by the burgeoning technologies of green chemistry, which eliminate use of hazardous feedstuffs and production of materials that can cause injury to human health and the environment;[378] incentivising the adoption of clean production technologies; and enhancing access to efficient, affordable public transportation.[379] Primary prevention can also be achieved by banning highly hazardous and carcinogenic materials such as asbestos, benzene, PCBs, and DDT, as has been successfully achieved in many countries. Primary prevention of pollution based on the elimination of pollution at source is inherently more effective than downstream control technologies, such as stack scrubbers or water filters that reduce the amount and toxicity of pollutant emissions after they have already been formed. Primary prevention of pollution at source is also essential for accelerating transition to a more sustainable, circular economy.

Further elaboration of these themes and case studies on pollution control are presented in the appendix (pp 63–82). The key elements of all successful pollution control plans are discussed in the following sections.

Establish ambitious but attainable targets and timetables for pollution control

Targets and timetables are essential for programmes to control pollution; these provide benchmarks and metrics for assessing progress towards pollution control. This Commission recommends establishing specific numerical targets and deadlines for pollution control and prevention of pollution-related disease in every city and country, along with incentives for meeting deadlines and penalties for failing to meet them.

Pollution control targets must be appropriate for each country's level of income and development and guided by the WHO pollution control targets. These targets will be most effective when they are focused on pollution sources that are established to be priorities and must be integrated into commitments to meet the SDGs and to reduce greenhouse gas emissions.

Prioritise interventions

It is crucial that pollution control programmes establish and adhere to a robust, systematic, and transparent system for prioritising pollution control that is based on assessment of health effects, environmental damages, and cost-effectiveness of control of various pollution sources. A robust system for assigning priority will avoid the pitfall of prioritising interventions on the basis of political expediency[380,381] or because they happen to be an item in the evening news.

Quick, highly visible successes are extremely important in gaining public support for a pollution control programme. It is therefore essential that intervention plans identify pollution sources whose early control will result in quick wins. Rapid, measurable improvements in public health, especially in the health of children, are powerful levers for building public and political support.

Key steps in ranking pollution sources in terms of their health effects, a key process of an effective health and pollution action plan, are as follows: (1) examine the frequency and severity of disease attributed to various types of pollution using data from national sources and data from the GBD study, and use this information to prioritise interventions against pollution; (2) for each type of pollution apportion the relative contributions of different exposure sources; (3) evaluate the efficacy of new programmes that have potential to reduce health effects from each pollution source, review existing programmes for efficacy and reach, and identify performance gaps and legal, regulatory, and enforcement gaps; (4) identify potential interventions (new and expanded) for those exposures for which there are dramatic effects on health outcomes and measurable indirect benefits, and evaluate these interventions for cost-effectiveness; (5) focus not only on high-visibility sources of pollution, but also on pollution sources that historically have received less attention, such as household air pollution, contaminated sites, lead (including lead in pottery glazes, lead in paint, and lead from other sources that might be specific to a specific culture), and occupational risks, including asbestos; (6) review the benefits of interventions against pollution and health improvement, considering the roles of gender equity, alleviation of poverty, slowing of the pace of climate change, increased tourism, economic growth, improved education, and political factors (panel 12);[382–387] (7) bring all relevant agencies into the prioritisation process, including senior representatives of ministries of health, environment, industry, development, finance, transportation, energy, planning, and legislative branches, and civil society, if possible; and (8) begin implementation with those programme areas where past experience will be a strong return on investment, as measured by benefit to public health and the possibility for early victories: examples include removing lead from paint or pottery, cleaning up highly visible toxic hotspots, banning asbestos, or publishing a ranked list of the most important pollution sources in a city or country, involving the media in advertising early successes.

Panel 11: Mexico's challenge: combating lead pollution

Pottery is produced in more than 10 000 artisanal, mostly small scale, workshops across Mexico. Most workshops use inexpensive, low temperature kilns that are not capable of firmly binding lead glaze to the clay. Lead is therefore released from the glaze into food. Lead has been used for centuries to glaze pottery in Mexico, and pottery is a pervasive source of population exposure to lead.[374–376] Beginning in the 1990s, the Mexican Government determined that prevention of lead poisoning must be a national public health priority and launched a multipronged approach strategy that included interventions against the use of lead in pottery.

The following are key elements of the control strategy:

- Undertake a comprehensive survey of artisanal workshops, to identify those using lead-based glazes
- Track producers and distributors of lead-based glaze and distributors and producers of lead-free glaze to understand the routes to market
- Notify producers and intermediaries that Mexican federal standards impose an absolute prohibition on the use of lead-based glazes in ceramics used for preparing or serving food
- Engage with producers of lead-free glaze to assist them in improving their product to better match the appearance of lead-glazed ceramics and to facilitate distribution
- Create market incentives for use of lead-free ceramics
- Strengthen enforcement of the federal lead glaze standard through improved monitoring and targeted inspections
- Launch a broad communications campaign to educate pottery makers and the public about the dangers of lead-glazed pottery and to advertise the high quality and enhanced safety of lead-free glazes

Establish robust systems for environmental monitoring and public health tracking

High quality metrics that monitor pollution and track progress towards national and local pollution prevention and disease control goals are essential to the success of any health and pollution action plan. Early establishment of public health and environment monitoring systems should therefore be a priority. Evidence-driven updates at

***Panel 12:* Cost-effective policies to improve access to safe water and sanitation**

Disinfection kits for home drinking water and ceramic filters are low-cost technologies for purifying drinking water in rural households without access to safe water. Latrines are a cost-effective solution to open defecation. Chlorination of home drinking water costs between US$50 and $125 per lifeyear saved; ceramic filters cost between $125 and $325.[382]

A seemingly attractive solution to improving access to safe drinking water and improving sanitation would be for donors to distribute chlorination kits, filters, and latrines free of charge. Empirical studies have shown, however, that this approach is ineffective and wastes resources because not all households will use disinfection kits for home drinking water, even when they are provided free of charge. A better solution would be to charge for the technology and subsidise the purchase. Studies suggest that people who pay something for a product are more likely to use it.[383] Another effective approach is to distribute vouchers to households that can be redeemed when a kit is purchased.[384] Requiring households to redeem the voucher separates the households that are likely to use the kit from those that are not.

Lowering the price of ceramic drinking water filters and latrines, which have a large upfront cost, can substantially increase their uptake.[385,386] However, subsidies can be expensive. Microfinancing schemes that spread the cost of water filters or latrines over time have been effective in increasing uptake at a lower cost to funders than total subsidies.[387] This approach allows a larger number of households to be covered for a given expenditure of funds and has the added benefit of gaining household and community ownership of the improvement. Composting toilets might have some advantages in some circumstances, for example where there is no sewage system.

regular intervals are crucial. We encourage governments to consider creation of a central data coordination system that acts as a focus and point of reference for all data on pollution—household, ambient, and occupational. This system should provide validated information and synthesised reports to the public and could be a basic source of raw data for regulators, researchers, and policy makers.

The economic costs of pollution include not only productivity and health costs, but also costs resulting from destruction of ecosystems and loss of key species such as pollinators and fish stocks that convey great benefits to human beings and are crucial to sustaining life on earth. Like the economic losses that result from pollution-related disease, the costs of environmental degradation are mostly invisible. These costs are not captured by standard economic indicators and are buried within the uncounted, unpaid costs of modern industrial and agricultural production.

For the **Health Effects Institute** http://www.wsp.org/

The Economics of Ecosystems and Biodiversity is a global initiative sponsored by the UN Environment Programme that addresses the challenge of quantifying the economic losses that result from environmental degradation. This initiative applies a structured approach to valuation of ecological losses, explores the visible and invisible costs and benefits that flow from ecosystems into the economy, and evaluates how these flows might change under different policy interventions. The initiative examines the potential consequences of policy reforms that realign incentives and fiscal policy in both negative (ie, polluter-pays) and positive (ie, beneficiary-pays) ways. These scenarios can be analysed and juxtaposed against a scenario in which no changes are made, to identify more sustainable pathways.[388–390]

Monitoring air pollution typically involves a combination of ground-level monitoring and atmospheric dispersion modelling to determine air pollution concentrations and their distribution.[391,392] Low-cost air pollution monitors to measure levels of pollutants on the ground represent an important advance.[393] The use of satellite-based remote sensing to estimate levels of air pollution is gaining increased attention, although the coverage and interpretation of satellite data is still being refined.[394]

The importance of accurate epidemiological data for the prevention and control of disease has been recognised since the work of pioneers such as William Farr,[338] who documented patterns of disease and death during the great cholera epidemic in Britain of 1848–49. National and international programmes for the systematic collection, consolidation, evaluation, and rapid dissemination of data on morbidity and mortality have become a core component of the global public health infrastructure.[395,396]

There are still many gaps in knowledge, especially in poor countries with insufficient resources for systematic data collection.[397] Therefore, only a third of the world's population and only 5% of Africa has usable information on causes of death. China and India have both been redeveloping their verbal autopsy registration systems, in which cause of death is based on data provided by field-trained personnel, and these data systems are improving.[398] Limitations in the quality of public health data reduce the accuracy of global estimates of the burden of disease related to pollution.

Accountability

Accountability is of paramount importance, and programmes for pollution control and prevention must be continuously assessed and held accountable to targets and deadlines using both process metrics (the number of regulations established, monitors installed, or tests performed) and outcome measures (reductions in levels of pollution in air and water, or improvements in health status). Monitoring data and data on progress toward achieving targets and timetables must be made publicly accessible to citizens and civil society.[399–401]

Carefully selected metrics provide an essential foundation to monitoring and accountability. The Health Effects Institute has developed a taxonomy of metrics that can be used to track the progress of pollution control programmes. Regarding air pollution programmes, a summary of metrics suggested by The Health Effects Institute include regulatory metrics, emissions metrics, and pollutant metrics.[399]

Establish a sound chemicals management programme

A high proportion of the 140 000 chemicals and pesticides in commerce have never been adequately tested for safety or toxicity.[36] Information on potential toxicity is publicly available for only about half of the commercial chemicals with high production volume that are in widest use, and information on developmental or reproductive toxicity is available for fewer than 20% of these widely used chemicals.[402] Because of the failure to test chemicals for toxicity, populations around the world today are exposed to hundreds of untested chemicals and recurrent episodes of disease and environmental degradation have resulted.[36]

To address the problem of population exposure to untested chemicals of unknown hazard, high-income countries are beginning to develop chemicals management programmes.[403,404] Mandatory testing of chemicals for safety and potential toxicity, coupled with the imposition of controls or bans on the manufacture and use of toxic chemicals are the two linchpins of these policies.[36] High-income countries have the resources to establish their own chemical testing programmes such as those supported by the European Chemical Agency and the US National Toxicology programme. Low-income and middle-income countries must rely on results from those testing agencies and on findings on chemical safety and toxicity promulgated by international bodies of high repute that are independent of the chemical manufacturing industry such as WHO's International Programme on Chemical Safety,[109] the International Agency for Research on Cancer, UN Environment Programme,[101] and the Ramazzini Institute.

Establish and enforce environmental laws and regulations and base regulation on the polluter-pays principle

A strong body of law[405] and clear, transparent, impartially enforced regulations are crucial components of policy packages for pollution control in all countries.

Experience in the USA documents the importance of law and regulation in reducing pollution. Through national regulations established under the US Clean Air Act, the USA has reduced concentrations of six common air pollutants by 75% since 1970 while increasing GDP by nearly 250% (figure 1).[43] Every dollar invested in control of ambient air pollution in the USA is estimated to yield US$30 in benefits (95% CI $4–88).[45]

The State of California has also deployed a suite of laws and policies to control air pollution that, in some instances, are even stronger than US federal regulations.[406] California's policies to reduce traffic-related air pollution include low-emission vehicle standards, a low-sulphur gasoline standard, diesel emissions standards, and financial incentives for replacement and retrofit of high-polluting vehicles. Additional policies that have been very successful include requirements for cleaner diesel fuels in marine vessels and railroad locomotives, and requirements for cleaner diesel fuels for stationary diesel engines and agricultural equipment. Policies to reduce emissions from stationary pollution sources include legally mandated reductions in emissions of oxides of nitrogen and sulphur, mandatory reviews of emissions from new sources, and source-specific emissions standards. Application of these standards has resulted in reductions in levels of major air pollutants by more than 70% in California, produced measurable improvements in children's respiratory health,[44] and has accomplished these goals in a time when the GDP has risen sharply, thus documenting, yet again, that control of pollution does not stifle economic development or societal advancement.[43]

Application of the polluter-pays principle is an important component of environmental regulation. The imposition of legally mandated requirements that polluters pay for their pollution and its clean-up create a powerful incentive to adopt new, more efficient production technologies that will reduce pollution. Application of the polluter-pays principle forces polluting industries to acknowledge and account for the previously externalised costs of pollution. Lastly, application of the polluter-pays principle can generate revenues that help to support the costs of pollution control programmes.

For the **European Chemical Agency** see https://echa.europa.eu/information-on-chemicals

As a corollary to imposing the polluter-pays principle, it is important that governments also end subsidies to polluting industries such as coal, oil, gas, and chemical production. When polluting industries are granted subsidies by governments, these governments and the taxpayers who support them are indirectly paying to be polluted.

For the **Ramazzini Institute** see http://www.ramazzini.org/en/

A competent, independent, non-corrupt judiciary provides an essential back-up to environmental laws and regulation.[407] An independent judiciary is needed to ensure the fair and impartial application of regulatory standards and to protect people, especially indigenous people and their lands, from the damaging effects of polluting industrial activities. For further discussion on existing national and international chemical control legislation and agreements, see the appendix (pp 13–14).

Engage with the private sector

This Commission emphasises that multiple stakeholders should be involved in controlling pollution and preventing pollution-related disease, including top government leaders, but also key civil servants, business, academia, and civil society. Carefully listening to the views of the most important and influential stakeholders (both formal and informal) can help to ensure that all the parties who can advance (or derail) programmes are taken into account.[77]

Enlightened business leaders can be powerful advocates for pollution control and disease prevention. The creation of incentives by governments for non-polluting industries can be powerful catalysts for innovative action, as seen by the rapid development of solar power systems and the organic food industry.

Support city-level initiatives to encourage active transport: reward walking and cycling, increase access to and affordability of public transport, and minimise use of motorised transport

Cities now house more than half of the world's population, a fraction that is growing rapidly, are responsible for 75% of greenhouse gas emissions, and account for 85% of global economic activity.[408,409] Cities, especially rapidly growing cities in low-income and middle-income countries, have some of the world's highest concentrations of ambient air and chemical pollution and the highest prevalence of disease caused by these forms of pollution.

Important initiatives are now underway in cities around the world to reduce emissions of both pollutants and greenhouse gases, and to make cities more resilient and sustainable. Several organisations at the local, national, and global levels have contributed to this progress and they include the Regional Plan Association in New York, the World Bank's Eco2Cities initiative, and the UN Department of Economic and Social Affairs urbanisation planning programmes.

Mayors have been powerful actors in efforts to control pollution and pollution-related disease, and visionary mayors have resurrected formerly blighted cities and turned them into places of extraordinary beauty and high livability.[410] This Commission commends initiatives to launch urban design and planning initiatives that reimagine cities through building green spaces, parks, and walkways, encouraging active transport (such as walking and cycling), and increasing access to and affordability of public transport. Such programmes are discussed in detail in the 2016 *Lancet* Series on City Planning and Population Health.[411,412]

Willingness to confront vested interests

Planning and prioritisation processes regarding health and pollution do not always proceed smoothly. The analyses regarding trade-offs between economic development and pollution are nuanced and vary substantially from industry to industry and country to country. In general, when public health externalities are included in the assessment, even primary industries like heavy manufacturing and mining achieve better long-term macroeconomic performance when strong controls for pollution management are in place.[413,414] However, these analyses can be complex and often contentious. Projections of growth rates and of the burden of pollution-related disease should look at sliding ranges of benefit, since low-polluting industries might provide substantial net benefits to a community. Heads of government who successfully confront vested interests, bring agencies together, reduce environmental injustice, control pollution, and prevent pollution-related disease can reap great praise, build a legacy, help the world achieve the SDGs, and earn an honoured place in history.

The next section of this Commission report outlines the contributions that various stakeholders— government, civil society, and health professionals—can make to pollution control.

Responsibilities of governments and major foundations

National, state or provincial, and city governments are powerful actors in efforts to control pollution and prevent pollution-related disease. Governments in countries at all levels of income have made remarkable victories against pollution.

Leadership by the head of government—the President, Prime Minister, Governor or Mayor—is of the utmost importance. Heads of government are uniquely well positioned to educate the public and the media about the importance of preventing pollution-related disease and can create a vision for a country or a city without pollution. These heads of government also have the power to bring together several agencies within their governments—health, environment, finance, transport, industry, energy, and development—to make pollution control a priority.

Heads of government also have great power to address the so-called "political economy" of pollution.[415] Much pollution, especially industrial pollution, is produced by vested interests that profit by externalising the costs of production and discharging unwanted wastes into the environment. These individuals and organisations will typically resist efforts to control pollution. Heads of government have unique power to overcome this resistance and to negotiate just settlements that reduce pollution and achieve social justice. Experience in countries at all levels of income shows that pollution control can be accomplished in the face of powerful opposition, but that the task is seldom easy and requires committed leadership and broad partnerships across civil society.

Responsibilities of international agencies

International development organisations, including UN agencies, multilateral development banks, bilateral funding agencies, private foundations, and non-governmental organisations, have important responsibilities in pollution control and prevention of pollution-related disease that complement and extend the role of governments. These agencies should elevate pollution prevention within the agendas of international development and global health and substantially increase the resources they devote to pollution, establishing it as a priority in funding mechanisms.

These agencies should build on existing global data platforms to develop a central platform to monitor and coordinate information on all forms of pollution globally, and should consider convening a bi-annual conference on pollution.

International agencies should also provide resources to reduce pollution-related disease in low-income and middle-income countries by:

(1) encouraging the development of action plans regarding health and pollution, both nationally and

regionally, and of specific pollution control projects that set time targets; (2) building data tracking systems to collect information on pollution and disease; (3) supporting direct interventions against pollution where such actions are urgently needed to save lives; (4) supporting interventions against pollution when international action can leverage local action and resources; (5) building professional and technical capacity within governments; (6) strengthening the capacity of universities in low-income and middle-income countries to research environmental health science and to train future health and environmental professionals; and (7) supporting research programmes in environmental health science in partnership with international academic institutions, including clinical and epidemiological studies to learn more about the undiscovered links between pollution and non-communicable disease.

This Commission also calls on international foundations and private donors to come together with governments around the world to establish dedicated international development funding specifically dedicated to the control of industrial, vehicular, mining, and chemical pollution. Such funding will be most effective in curbing pollution when its award is contingent upon host countries' implementation of the polluter-pays principle and ending financial subsidies and tax breaks for polluting industries.

Several design options for dedicated pollution control funding could be considered. The first is a new standalone fund analogous to GAVI (the Vaccine Alliance) or the Global Fund to Fight AIDS, Tuberculosis and Malaria, in which private philanthropists and foundations provide start-up monies that are then periodically replenished by governments. Another option is a large trust fund that is hosted and managed by an existing global institution, such as a multilateral development bank or a foundation. Alternatively, a virtual fund with contributions based on explicit agreements could be used. Finally, expansion of existing funding instruments for international development assistance could be used, including funds specifically designated for pollution control.

Responsibilities of citizens and civil society

Citizens and civil society organisations in countries and cities around the world have important responsibilities in the prevention of pollution, and non-governmental organisations have an important role in many countries in holding governments and companies accountable for pollution control and prevention of pollution-related disease. Civil society organisations can contribute to pollution control by acting as watchdogs, by serving as representatives of the public interest, and by advocating for specific policies, regulations, and practices (panel 13).[350] Civil society groups, especially those that are well funded and science-based, are a powerful force to represent poisoned populations. These organisations can highlight omissions in policy and advocate for change.[416] The best of these organisations provide solid policy support to government action and take a long-term, broad view of issues in their actions and recommendations.[417]

> ***Panel 13:* Case study: the power of civil society in controlling urban air pollution**
>
> National and city governments have key roles in solving pollution problems. But governments cannot act alone. The political will to create, implement, and sustain successful pollution control policies over the long term requires the involvement of citizens and civil society from many sectors. For example, in the winter of 2010–11, hourly air quality data from Beijing began, for the first time, to be publicly released by both the Chinese Government and the United States Embassy. Soon thereafter, so-called "airpocalypses" during winter were documented, and Beijing's air quality data began to be discussed extensively in local and international media. This unprecedented access to real-time air quality data spurred software developers to build apps, pushing the data out to millions. Through apps, social media, and general media outlets, the citizens of Beijing began, for the first time, to feel the air pollution problem in new, immediately accessible, and data-driven ways.
>
> Since that time, China has invested in several programmes to mitigate air pollution. An expanded network of air quality monitors has been installed in Beijing and across the country. Stricter regulatory policies have been implemented. New emergency action plans for high-pollution days have been developed and promulgated. Simultaneously, public interest in pollution has not waned. In 2015, a popular television journalist, Chai Jing, made an independent documentary "Under the Dome" that discussed the effects of air pollution on health, which went viral across the country and then the world. The number of research publications on air pollution in Beijing have exponentially increased.
>
> It is difficult to pinpoint the exact contributions of the policy, activism, technology, research, and media communities to the successful pollution control effort in Beijing and their effects on each other, but clearly their combined efforts are beginning to make a positive difference. Since 2014, government sources in Beijing have reported year-to-year decreases in annual average $PM_{2·5}$ concentrations, and these findings are consistent with data for decreasing concentrations of $PM_{2·5}$, as calculated from the monitor on the United States Embassy.[350]
>
> Although Beijing and China still have a long way to go to clean their air, this case study documents the power of community involvement in pollution control and the crucial importance of data.

Responsibilities of health professionals

Physicians, nurses, and other health professionals have important responsibilities in helping societies to confront the challenges of pollution and pollution-related disease as they have educated societies around the world about the dangers of nuclear war and global climate change.

Health professionals can begin by controlling pollution and reducing carbon emissions from hospitals and health-care facilities and by reducing pollution and carbon-intensive energy sources in their own lives. Health professionals can support local, regional, and national planning efforts and emphasise the links between pollution and health, develop new transdisciplinary educational curricula that build knowledge of environmental health science and about the health effects of pollution, and support research in exposure science, environmental science, health policy research and health economics.

Partnerships between government, civil society, and the health professions have proven powerfully effective in past struggles to control pollution. For example, in the ultimately successful effort to remove lead from gasoline, which was fiercely resisted for many years by the lead industry, partnerships were built between government agencies, health professionals, and civil society organisations.

Interventions against pollution

Table 7 gives a brief overview of interventions, effective policy solutions, and institutional needs by pollution type. Strategies to improve water and sanitation and to reduce indoor air pollution typically take the form of subsidies, especially in low-income countries, whereas policies to reduce pollution from stationary and mobile sources usually rely on regulation, often in the form of standards. Many of these strategies are policy-based and enforcement-based,[418] not requiring large governmental investments.

Section 5: Conclusion—the way forward

Pollution is the largest environmental cause of disease and premature death in the world today. Pollution poses a massive challenge to planetary health[15] and deserves the concentrated attention of national and international leaders, civil society, health professionals, and people around the world. Yet, despite its far-reaching effects on health, the economy and the environment, pollution—especially the rapidly growing threat of industrial, vehicular, and chemical pollution in low-income and middle-income countries—has been neglected in the international assistance and the global health agendas. Strategies for control of industrial, chemical, and automotive pollution in developing countries have been deeply underfunded.[49,50]

The goal of this Commission is to raise global awareness of the importance of pollution, to end neglect of pollution-related disease, and to mobilise the resources and the political will that are needed to effectively confront pollution.

To achieve this aim and advance progress toward the elimination of pollution, members of this Commission

	Ambient air (outdoor) pollution	Household air pollution	Water pollution and sanitation	Contaminated soil and water
Short-term interventions	Identify sources of key pollutants to enable targeted interventions; target control of stationary sources and install dust management systems; establish monitoring systems; mandate improved fuel quality and engine standards; and design and implement effective enforcement systems	Review current interventions—eg, cleaner fuels and cookstoves—and determine the most scalable strategies; targeted education campaigns; expand support for successful current systems	Expand campaigns for handwashing and improved sanitation; review and expand successful small-scale facilities; develop planning for river basin-wide construction of sanitation facilities; initiate construction of expanded sanitation facilities	Create inventories of polluted sites; test solutions with low-cost pilots for highly toxic sites; clean-up of high-impact sites; provide technical assistance and training
Medium-term interventions	Establish requirements for cleaner vehicles, including testing stations (controls on diesel vehicles, catalytic converters, converting to gas); provide incentives for use of electric and hybrid vehicles; upgrade public transport fleets	Expand access to clean fuels and cleaner cookstoves; upgrade heating and other solid fuel systems	Expand individual household connections for water and sewers	Establish disposal facilities; expand remediation projects; develop remediation industry; support brownfields pilot projects
Long-term interventions	Expand or upgrade public transit; facilitate active commuting by constructing walkways and cycle paths; create mechanisms to discourage vehicle use	Full (possibly universal) access to clean fuels	Upgrade existing drainage and sewage treatment	Establish regional and national toxic sites remediation programmes
Policy and institutions	Undertake source apportionment to identify the most important sources of pollution; establish and prioritise control targets and timetables; establish a high-level intersectoral Steering Committee; involve the public and civil society organisations	Define the target population; identify the responsible government agency with a mandate for health improvement; formulate a practical strategy for upgrading or switching fuels; define financial incentives	Define the target population; calculate the level of service required to achieve goals; community involvement strategy; establish a financial strategy	Establish policy and targets; generate specific policies for small and medium-sized enterprises, artisanal and small-scale gold mining, and other sectors; provide a clear mandate to the responsible government agency; define local powers and responsibilities; define and enable structures of financial support
Building capacity	Achieve adequate monitoring and testing of major air pollutants and emission sources; develop understanding of source contributions; use vehicle testing stations	Establish monitoring mechanisms;identify, review, and support local distributors and providers	Contracts or agreements with utilities providers; and strengthen community-level partnerships	Establish regulations and standards; approve technical support providers—eg, laboratories, testing firms—; expand regulation of active polluters; impose the so-called polluter pays principle; end government subsidies for polluting industries
Common gaps and structural issues	Expansion to less well resourced secondary cities	Reduction or elimination of use of solid fuels for heating	Financial sustainability in an era of increasing water shortage	Requirement of special measures at large-scale sites, such as polluted rivers

Table 7: **Short-term, mid-term, and long- term interventions against pollution and the infrastructure and actions required to support them**

and contributors to this report have initiated a series of activities within different sectors and countries that will extend beyond the life of this Commission and are intended to prevent pollution and save lives. At a global level, several authors of this Commission are in early stages of designing a Global Pollution Observatory, to be housed within the Global Alliance for Health and Pollution. This new observatory will be an international, multidisciplinary collaboration that is focused on coordinating information regarding all forms of pollution in countries around the world and developing solutions based on successes already achieved in other countries. We intend that this observatory will operate in close partnership with the Institute for Health Metrics and Evaluation, UN agencies, Future Earth, the Planetary Health Alliance, and major non-governmental organisations concerned with the wellbeing of the Earth's environment. A major function will be to provide data that assist countries in prioritising pollution initiatives, tracking pollution, and using pollution control metrics, including investments against pollution in countries around the world and to make these data publicly and easily available. The precise metrics to be followed are under consideration, but possibilities include monitoring country-by-country data on the status of regulations against each type of pollution; measuring exposures to key pollutants, country-by-country and regionally; reporting detailed country-by-country statistics on disease and premature death by pollution risk factor, to track performance towards the goals suggested in this report; tracking national and international investment into expanded research on disease and death due to pollution (especially soil pollution caused by heavy metals and toxic chemicals), including studies to discover new and previously unrecognised health effects of pollutants; tracking investments related to interventions against pollution, country-by-country (which can be broken down by source of investment and whether the investment is national or international and public or private); and developing a database to report the cost-efficacy of interventions against pollution, measured in terms of health outcomes.

In partnership with *The Lancet*, the Global Alliance on Health and Pollution plans to revisit the data on health and pollution periodically, and to publish updated information on global trends in pollution, pollution-related disease, and pollution control on a regular basis. The Global Alliance on Health and Pollution will also explore hosting a biennial conference on pollution that will include UN agencies, governments, and representatives of civil society and will review pollution control strategies, share project successes, and explore opportunities and the most cost-effective strategies for pollution control.

At the country level, work is underway to expand health and pollution planning in partnership with governments in low-income and middle-income countries. This work involves multiple organisations and agencies, including the Global Alliance on Health and Pollution, the World Bank, WHO, the UN Environment Programme, and the UN Development Programme. New programmes to educate global leaders and government agencies about proven solutions to pollution are also in development.

Activities to strengthen the involvement of the public and civil society in pollution control are essential because public concern provides a major impetus for governments to act against pollution. A new website is being developed by the Global Alliance on Health and Pollution to show current and, in some cases, real-time data related to pollution in countries across the world. This geocoded website links databases showing air pollution, water pollution, and soil contamination. Users can zoom down to the communities where they live, see the available information, and post their own stories and pictures about pollution. The website will incorporate a link for people to connect with local government organisations for solutions.

For this **pollution website** see http://www.pollution.org

These efforts are only the beginning, and there is much more to be done. This Commission encourages all efforts to bring the issue of pollution to public attention and supports all solutions to reduce the enormous health burden of this major, yet often hidden, global threat.

Contributors

PJL and RF developed the concept and objectives for the Commission. The full Commission met on two occasions (Nov 9–11, 2015, and June 16–17, 2016) in New York, NY, USA, with an additional meeting in January, 2016 (limited to the Health and Pollution working group, also in New York). The Commission formed four working groups to examine the burden of disease associated with environmental pollution, to calculate the economic costs of documented pollution-attributable global deaths and DALYs, to explore the intersection between pollution and inequality, and to evaluate and develop strategies and roadmaps for successful pollution control. Each working group was responsible for the design, drafting, and review of their individual sections. Working Group 1 (Health) was led by PJL. Working Group 2 (Economics) was led by MLC and AK. Working Group 3 (Environmental Justice) was led by KS. Working Group 4 (Interventions) was led by DHa and RF. Working Group leaders, along with Yewande Awe of the World Bank and Tim Kasten of UN Environment comprised the Report Steering Committee. All authors contributed to the identification of key issues and the selection of four main report sections. As co-chairs of the Commission, PJL and RF planned and coordinated all activities of the Commission, the development and review of the report drafts, and the preparation for external peer review. PJL and RF reviewed and edited all sections of this report. All authors reviewed each stage of the report and approved the final version. PJL wrote the first and subsequent drafts of the Introduction, with input from OA, MLC, RF, AH, AK, KVM, JP, and KRS. For Section 1, PJL wrote the first and subsequent drafts, with input from NB, RB, SB-O'R, JIB, PNB, TC, CM, JF, VF, DHu, BLa, KM, CJLM, FP, LDS, PDS, KRS, WAS, OCPvS, and GNY. For Section 2, MLC and AK wrote the first and subsequent drafts, with input from MG, PJL, KVM, and ASP. For Section 3, KS wrote the first and subsequent drafts, with input from OA, AH, PJL, KVM, MAM, JRo, KRS, AS, and GNY. For Section 4, DHa wrote the first draft, with subsequent drafts written and edited by RF and PJL, with input from NJRA, OA, RA, ABB, NB, AMCS, JF, AH, DHu, MK, BLo, KM, MAM, JDN, JP, JRa, JRo, CS, KRS, AS, RBS, KY, and MZ.

Declaration of interests

BLa served as an expert witness in California for the plaintiffs in a public nuisance case of childhood lead poisoning, in a Proposition 65 case on behalf of the California Attorney General's Office, in a case involving lead-contaminated water in a new housing development in Maryland, in a Canadian tribunal on a trade dispute about using lead-free galvanised wire in stucco lathing, and as a plaintiff on a case involving lead-poisoned children in Milwaukee, Wisconsin, but he received no personal compensation for these services. His expert witness fees are deposited in a research and training fund at Simon Fraser University (Burnaby, BC, Canada). MG reports grants from the US Agency for International Development, the National Science Foundation, the International Growth Centre, and the Laura and John Arnold Foundation outside the submitted work; MG also reports more than US$10 000 in stocks and bonds, including in firms that pollute and firms that are affected by pollution, as part of a diversified portfolio. All other authors declare no competing interests.

Acknowledgments

Overall coordination of the report was led by Elena Rahona, whose team included Amy Chart, Samantha Fisher, Rachael Kupka, Yaqi Li, Karen McGill, Myla Ramirez, Anthony Rivera, Petr Sharov, Angela Bernhardt, Russell Dowling, Eric Fecci, and Carol Sumkin at Pure Earth; Alvara McBean at Icahn School of Medicine at Mount Sinai; and Kelsey Pierce at Institute for Health Metrics and Evaluation. Several people lent their expertise to contribute to certain sections of the report: Bret Ericson, Christa Hasenkopf, Greg McGruder, and Nadine Steckling. The Commission received invaluable technical advice and input from many individuals, including Gilles Concordel and Marie Concordel, Elena Craft, James Godbold, Nathalie Gysi, Andrew McCartor, Sumi Mehta, Conrad Meyer, Radha Muthiah, Dietrich Plass, Ananya Roy, Baskut Tuncak, and Birgit Wolz. In particular, the authors would like to thank the following people for coordinating input from different teams: Yewande Awe, Jostein Nygard, Ernesto Sanchez-Triana, and Momoe Kanada (World Bank); Annette Prüss-Üstün (WHO); Jill Hanna and Maria Pachta (European Commission); Loïc Viatte (Swedish Ministry of Environment and Energy); Katherine Swanson and Andrea Pavlick (US Agency for International Development), Mathy Stanislaus (while serving for the US Environmental Protection Agency during the Obama Administration), Kara Estep, Mohammad (Mehrdad) Forouzanfar, and Jeff Stanaway (Institute for Health Metrics and Evaluation); Tim Kasten, Fanny Demassieux, Achim Halpaap, and Pierre Quiblier (UN Environment), Natalia Linou, and Douglas Webb (UN Development Programme); and Nilgün Tas (United Nations Industrial Development Organization). This Publication is made possible by financial assistance from the European Union, UN Industrial Development Organization, the Swedish Ministry of Environment and Energy, the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Royal Norwegian Ministry of Health and Care Services, the US Agency for International Development, the US National Institute of Environmental Health Sciences, the Icahn School of Medicine at Mount Sinai, and Pure Earth. The Global Alliance on Health and Pollution (GAHP) served through Pure Earth as secretariat for the Commission. GAHP is a collaborative body that coordinates and advocates for solutions on pollution and health in low-income and middle-income countries. Members include international agencies such as World Bank, UN Environment, United Nations Development Programme, and United Nations Industrial Development Organization, and government agencies globally. The Commission sought input and consultation from the members of GAHP, experts at the World Bank, World Health Organization and the World Health Organization network of Collaborating Centers in Children's Health and the Environment, the Consortium of Universities in Global Health, the Pacific Basin Consortium for Environment and Health, the Superfund Research Program of the US National Institute of Environmental Health Sciences, and a number of Non-Governmental Organizations including the Global Alliance for Clean Cookstoves, Clean Air Asia, Human Rights Watch, the Environmental Defense Fund, Global Poverty Project, and World Resources Institute. The contents of this publication are the sole responsibility of Pure Earth/GAHP Secretariat, the Icahn School of Medicine at Mount Sinai, and *The Lancet*, and can in no way be taken to reflect the views of the European Union or other donors or individual GAHP member agencies. The authors note that they are serving in their personal capacity. The opinions expressed in this article are the authors' own and do not reflect the views of their respective employers.

References

1 Rockström J, Steffen W, Noone K, et al. A safe operating space for humanity. *Nature* 2009; **461:** 472–75.
2 McMichael AJ, Woodward A, Muir C. Climate change and the health of nations: famines, fevers, and the fate of populations. Oxford: Oxford University Press, 2017.
3 Perera FP. Multiple threats to child health from fossil fuel combustion: impacts of air pollution and climate change. *Environ Health Perspect* 2017; **125:** 141–48.
4 Gaveau DLA, Salim MA, Hergoualc'h K, et al. Major atmospheric emissions from peat fires in Southeast Asia during non-drought years: evidence from the 2013 Sumatran fires. *Sci Rep* 2015; **4:** 6112.
5 Johnston FH, Henderson SB, Chen Y, et al. Estimated global mortality attributable to smoke from landscape fires. *Environ Health Perspect* 2012; **120:** 695–701.
6 Scovronick N, Dora C, Fletcher E, Haines A, Shindell D. Reduce short-lived climate pollutants for multiple benefits. *Lancet* 2015; **386:** e28–31.
7 National Academy of Sciences. Hidden costs of energy: unpriced consequences of energy production. Washington, DC: National Academies Press, 2010.
8 Landrigan PJ, Fuller R. Environmental pollution: an enormous and invisible burden on health systems in low-and middle income countries. *World Hosp Health Serv* 2015; **50:** 35–41.
9 Epstein PR, Buonocore JJ, Eckerle K, et al. Full cost accounting for the life cycle of coal. *Ann N Y Acad Sci* 2011; **1219:** 73–98.
10 Smith KR, Ezzati M. How environmental health risks change with development: the epidemiologic and environmental risk transitions revisited. *Annu Rev Environ Resour* 2005; **30:** 291–333.
11 Omran AR. The epidemiologic transition: a theory of the epidemiology of population change. *Milbank Q* 2005; **83:** 731–57.
12 Wilkinson P, Smith KR, Beevers S, Tonne C, Oreszczyn T. Energy, energy efficiency, and the built environment. *Lancet* 2007; **370:** 1175–87.
13 Pope Francis. Laudato si'. Encyclical letter on care for our common home. Vatican City: The Vatican, 2015.
14 Raworth K. Doughnut economics: seven ways to think like a 21st-century economist. White River Junction, VT: Chelsea Green Publishing, 2017.
15 Whitmee S, Haines A, Beyrer C, et al. Safeguarding human health in the Anthropocene epoch: report of The Rockefeller Foundation–*Lancet* Commission on planetary health. *Lancet* 2015; **386:** 1973–2028.
16 National Academy of Sciences. Exposure science in the 21st century. Washington, DC: National Academies Press, 2012.
17 Brauer M, Amann M, Burnett RT, et al. Exposure assessment for estimation of the global burden of disease attributable to outdoor air pollution. *Environ Sci Technol* 2012; **46:** 652–60.
18 Sorek-Hamer M, Just AC, Kloog I. Satellite remote sensing in epidemiological studies. *Curr Opin Pediatr* 2016; **28:** 228–34.
19 Valavanidis A, Fiotakis K, Vlachogianni T. Airborne particulate matter and human health: toxicological assessment and importance of size and composition of particles for oxidative damage and carcinogenic mechanisms. *J Environ Sci Health C Environ Carcinog Ecotoxicol Rev* 2008; **26:** 339–62.
20 Pope CA 3rd. Respiratory disease associated with community air pollution and a steel mill, Utah Valley. *Am J Public Health* 1989; **79:** 623–28.
21 Dockery DW, Pope CA, Xu X, et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med* 1993; **329:** 1753–59.
22 Thurston G, Lippmann M. Ambient particulate matter air pollution and cardiopulmonary diseases. *Semin Respir Crit Care Med* 2015; **36:** 422–32.
23 Cohen AJ, Brauer M, Burnett R, et al. Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015. *Lancet* 2017; **389:** 1907–18.
24 Krewski D, Jerrett M, Burnett RT, et al. Extended follow-up and spatial analysis of the American Cancer Society study linking particulate air pollution and mortality. *Res Rep Health Eff Inst* 2009; **140:** 5–136.

25 Meo SA, Memon AN, Sheikh SA, et al. Effect of environmental air pollution on type 2 diabetes mellitus. *Eur Rev Med Pharmacol Sci* 2015; **19:** 123–28.

26 Cosselman KE, Navas-Acien A, Kaufman JD. Environmental factors in cardiovascular disease. *Nat Rev Cardiol* 2015; **12:** 627–42.

27 Malley CS, Kuylenstierna JCI, Vallack HW, Henze DK, Blencowe H, Ashmore MR. Preterm birth associated with maternal fine particulate matter exposure: a global, regional and national assessment. *Environ Int* 2017; **101:** 173–82.

28 Chen H, Kwong JC, Copes R, et al. Living near major roads and the incidence of dementia, Parkinson's disease, and multiple sclerosis: a population-based cohort study. *Lancet* 2017; **389:** 718–26.

29 Cacciottolo M, Wang X, Driscoll I, et al. Particulate air pollutants, APOE alleles and their contributions to cognitive impairment in older women and to amyloidogenesis in experimental models. *Transl Psychiatry* 2017; **7:** e1022.

30 Heusinkveld HJ, Wahle T, Campbell A, et al. Neurodegenerative and neurological disorders by small inhaled particles. *Neurotoxicology* 2016; **56:** 94–106.

31 Casanova R, Wang X, Reyes J, et al. A voxel-based morphometry study reveals local brain structural alterations associated with ambient fine particles in older women. *Front Hum Neurosci* 2016; **10:** 495.

32 Perera FP, Chang H, Tang D, et al. Early-life exposure to polycyclic aromatic hydrocarbons and ADHD behavior problems. *PLoS One* 2014; **9:** e111670.

33 Kioumourtzoglou MA, Schwartz JD, Weisskopf MG, et al. Long-term PM2.5 exposure and neurological hospital admissions in the northeastern United States. *Environ Health Perspect* 2016; **124:** 23–29.

34 Loomis D, Grosse Y, Lauby-Secretan B, et al, for the International Agency for Research on Cancer Monograph Working Group. The carcinogenicity of outdoor air pollution. *Lancet Oncol* 2013; **14:** 1262–63.

35 Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A. The contribution of outdoor air pollution sources to premature mortality on a global scale. *Nature* 2015; **525:** 367–71.

36 Landrigan PJ, Goldman LR. Children's vulnerability to toxic chemicals: a challenge and opportunity to strengthen health and environmental policy. *Health Aff* 2011; **30:** 842–50.

37 Grandjean P, Landrigan PJ. Neurobehavioural effects of developmental toxicity. *Lancet Neurol* 2014; **13:** 330–38.

38 Pure Earth: Blacksmith Institute. Toxic Sites Identification Program (TSIP). http://www.pureearth.org/projects/toxic-sites-identification-program-tsip/ (accessed June 6, 2016).

39 Heindel JJ, Balbus J, Birnbaum L, et al. Developmental origins of health and disease: integrating environmental influences. *Endocrinology* 2015; **156:** 3416–21.

40 Burnett RT, Pope CA 3rd, Ezzati M, et al. An integrated risk function for estimating the global burden of disease attributable to ambient fine particulate matter exposure. *Environ Health Perspect* 2014; **122:** 397–403.

41 GBD 2015 Mortality and Causes of Death Collaborators. Global, regional, and national life expectancy, all-cause mortality, and cause-specific mortality for 249 causes of death, 1980–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388:** 1459–544.

42 GBD 2015 Risk Factors Collaborators. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990–2015: a systematic analysis for the Global Burden of Disease. *Lancet* 2016; **388:** 1659–724.

43 Samet JM, Burke TA, Goldstein BD. The Trump administration and the environment — heed the science. *N Engl J Med* 2017; **376:** 1182–88.

44 Gauderman WJ, Urman R, Avol E, et al. Association of improved air quality with lung development in children. *N Engl J Med* 2015; **372:** 905–13.

45 US Environmental Protection Agency: Office of Air and Radiation. The benefits and costs of the Clean Air Act from 1990 to 2020. April 2011. https://www.epa.gov/sites/production/files/2015-07/documents/fullreport_rev_a.pdf (accessed March 30, 2017).

46 Grosse SD, Matte TD, Schwartz J, Jackson RJ. Economic gains resulting from the reduction in children's exposure to lead in the United States. *Environ Health Perspect* 2002; **110:** 563–69.

47 Pirkle JL, Kaufmann RB, Brody DJ, Hickman T, Gunter EW, Paschal DC. Exposure of the U.S. population to lead, 1991–1994. *Environ Health Perspect* 1998; **106:** 745–50.

48 Annest JL, Pirkle JL, Makuc D, Neese JW, Bayse DD, Kovar MG. Chronological trend in blood lead levels between 1976 and 1980. *N Engl J Med* 1983; **308:** 1373–77.

49 Greenberg H, Leeder SR, Raymond SU. And why so great a 'no?' The donor and academic communities' failure to confront global chronic disease. *Glob Heart* 2016; **11:** 381–85.

50 Nugent R. A chronology of global assistance funding for NCD. *Glob Heart* 2016; **11:** 371–74.

51 Van Lare P, for the US Environment Protection Agency. Growing toward more efficient water use: linking development, infrastructure, and drinking water policies. 2006. https://www.epa.gov/smartgrowth/growing-toward-more-efficient-water-use (accessed March 30, 2017).

52 Bartram J, Brocklehurst C, Fisher MB, et al. Global monitoring of water supply and sanitation: history, methods and future challenges. *Int J Environ Res Public Health* 2014; **11:** 8137–65.

53 Schwarzenbach RP, Egli T, Hofstetter TB, von Guten U, Wehrli B. Global water pollution and human health. *Ann Rev Environ Resourc* 2010; **35:** 109–36

54 World Health Organization, United Nations Children's Fund, Water Supply and Sanitation Collaborative Council. Global water supply and sanitation assessment. 2000. http://www.who.int/water_sanitation_health/monitoring/jmp2000.pdf (accessed Sept 17, 2017).

55 Chafe ZA, Brauer M, Klimont Z, et al. Household cooking with solid fuels contributes to ambient PM2.5 air pollution and the burden of disease. *Environ Health Perspect* 2014; **122:** 1314–20.

56 Balakrishnan K, Cohen A, Smith KR. Addressing the burden of disease attributable to air pollution in India: the need to integrate across household and ambient air pollution exposures. *Environ Health Perspect* 2014; **122:** A6–7.

57 Yadama GN. Fires, fuel, and the fate of 3 billion: the state of the energy impoverished. Oxford: Oxford University Press, 2013.

58 Yen C, Tate JE, Hyde TB, et al. Rotavirus vaccines. *Hum Vaccin Immunother* 2014; **10:** 1436–48.

59 Florez ID, Al-Khalifah R, Sierra JM, et al. The effectiveness and safety of treatments used for acute diarrhea and acute gastroenteritis in children: protocol for a systematic review and network meta-analysis. *Syst Rev* 2016; **5:** 14.

60 Branca F, Piwoz E, Schultink W, Sullivan LM. Nutrition and health in women, children, and adolescent girls. *BMJ* 2015; **351:** h4173.

61 USAID. Budget spending. https://www.usaid.gov/results-and-data/budget-spending (accessed July 12, 2016).

62 European Commission: International Cooperation and Development. Commission implementing decision adopting a multiannual indicative programme for the thematic programme 'Global Public Goods and Challenges' for the period 2014-2020. July 23, 2014. https://ec.europa.eu/europeaid/commision-implementing-decision-adopting-multiannual-indicative-programme-thematic-programme-global_en (accessed June 6, 2016).

63 WHO. Global action plan for the prevention and control of non-communicable diseases 2013–2020. Geneva: World Health Organisation, 2013. http://apps.who.int/iris/bitstream/10665/94384/1/9789241506236_eng.pdf?ua=1 (accessed March 30, 2017).

64 Kuznets S. Economic growth and income inequality. *Am Econ Rev* 1955; **45:** 1–28.

65 Van Alstine J, Neumayer E. The environmental Kuznets curve. In: Gallagher K, ed. Handbook on trade and the environment. Cheltenham, UK: Edward Elgar Publishing, 2010.

66 Stern DI. The rise and fall of the environmental Kuznets curve. *World Dev* 2004; **32:** 1419–39.

67 Carson RT. The environmental Kuznets curve: seeking empirical regularity and theoretical structure. *Rev Environ Econ Policy* 2010; **4:** 3–23.

68 Andreoni J, Levinson A. The simple analytics of the environmental Kuznets curve. *J Public Econ* 2001; **80:** 269–86.

69 Stern DI. Environmental Kuznets curve. *Encycl Energy* 2004; 517–25.

70 Cavlovic TA, Baker KH, Berrens RP, Gawande K. A meta-analysis of environmental Kuznets curve studies. *Agric Resour Econ Rev* 2000; **29:** 32–42.

71 Lee CC, Chiu YB, Sun CH. Does one size fit all? A reexamination of the environmental Kuznets curve using the dynamic panel data approach. *Appl Econ Perspect Policy* 2009; **31:** 751–78.

72 Jamison DT, Summers LH, Alleyne G, et al. Global health 2035: a world converging within a generation. *Lancet* 2013; **382:** 1898–955.

73 Ottersen OP, Dasgupta J, Blouin C, et al. The political origins of health inequity: prospects for change. *Lancet* 2014; **383:** 630–67.

74 Hill K, You D, Inoue M, Oestergaard MZ, for the Technical Advisory Group of United Nations Inter-agency Group for Child Mortality Estimation. Child mortality estimation: accelerated progress in reducing global child mortality, 1990–2010. *PLoS Med* 2012; **9:** e1001303.

75 Michaels D. Doubt is their product: how industry's assault on science threatens your health. Oxford: Oxford University Press, 2008.

76 Ahmed K, for the World Bank. Getting to green: a sourcebook of pollution management policy tools for growth and competitiveness. 2012. http://siteresources.worldbank.org/ENVIRONMENT/Resources/Getting_to_Green_web.pdf (accessed April 17, 2017).

77 Awe Y, Nygard J, Larssen S, Lee H, Dulal H, Kanakia R. Clean air and healthy lungs: enhancing the World Bank's approach to air quality management. Washington, DC: World Bank, 2016.

78 WHO. Inheriting a sustainable world? Atlas on children's health and the environment. Geneva: World Health Organization, 2017. http://apps.who.int/iris/bitstream/10665/254677/1/9789241511773-eng.pdf?ua=1 (accessed March 7, 2017).

79 WHO. Don't pollute my future! The impact of the environment on children's health. Geneva: World Health Organization, 2017. http://apps.who.int/iris/bitstream/10665/254678/1/WHO-FWC-IHE-17.01-eng.pdf?ua=1 (accessed March 7, 2017).

80 UN Environment. The Stockholm Convention on Persistent Organic Pollutants. May 22, 2001. http://chm.pops.int/TheConvention/Overview/TextoftheConvention/tabid/2232/Default.aspx (accessed July 11, 2016).

81 WHO. Ministerial declaration for health, environment and climate change. Conference of the Parties to the UN Framework Convention on Climate Change; Marrakech, Morocco; Nov 15, 2016. http://www.who.int/globalchange/mediacentre/events/Ministerial-declaration-EN.pdf (accessed Jan 3, 2017).

82 WHO. Sixty-eighth World Health Assembly agenda item 14.6. Health and environment: addressing the health impact of air pollution. May 26, 2015. http://apps.who.int/gb/ebwha/pdf_files/WHA68/A68_ACONF2Rev1-en.pdf (accessed July 12, 2016).

83 UN Environment. Global Alliance to Eliminate Lead Paint. March 2011. http://www.who.int/ipcs/assessment/public_health/framework.pdf?ua=1 (accessed July 12, 2016).

84 European Union. Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control). Nov 24, 2010. http://eur-lex.europa.eu/eli/dir/2010/75/oj (accessed March 30, 2017).

85 Wild CP. Complementing the genome with an 'exposome': the outstanding challenge of environmental exposure measurement in molecular epidemiology. *Cancer Epidemiol Biomarkers Prev* 2005; **14:** 1847–50.

86 Wild CP. The exposome: from concept to utility. *Int J Epidemiol* 2012; **41:** 24–32.

87 Prüss-Ustün A, Vickers C, Haefliger P, Bertollini R. Knowns and unknowns on burden of disease due to chemicals: a systematic review. *Environ Health* 2011; **10:** 9.

88 Grandjean P, Landrigan PJ. Developmental neurotoxicity of industrial chemicals. *Lancet* 2006; **368:** 2167–78.

89 Engel SM, Miodovnik A, Canfield RL, et al. Prenatal phthalate exposure is associated with childhood behavior and executive functioning. *Environ Health Perspect* 2010; **118:** 565–71.

90 Bergman Å, Heindel JJ, Kasten T, et al. The impact of endocrine disruption: a consensus statement on the state of the science. *Environ Health Perspect* 2013; **121:** a104–06.

91 Roen EL, Wang Y, Calafat AM, et al. Bisphenol A exposure and behavioral problems among inner city children at 7–9 years of age. *Environ Res* 2015; **142:** 739–45.

92 Gore AC, Chappell VA, Fenton SE, et al. EDC-2: The Endocrine Society's second scientific statement on endocrine-disrupting chemicals. *Endocr Rev* 2015; **36:** E1–150.

93 Cimino AM, Boyles AL, Thayer KA, Perry MJ. Effects of neonicotinoid pesticide exposure on human health: a systematic review. *Environ Health Perspect* 2016; **125:** 155–62.

94 O'Neill J, for the review on antimicrobial resistance. Tackling drug-resistant infections globally: final report and recommendations. May, 2016. https://amr-review.org/sites/default/files/160525_Final paper_with cover.pdf (accessed Oct 4, 2016).

95 Kümmerer K. Antibiotics in the aquatic environment – a review—part II. *Chemosphere* 2009; **75:** 435–41.

96 Petrie B, Barden R, Kasprzyk-Hordern B. A review on emerging contaminants in wastewaters and the environment: current knowledge, understudied areas and recommendations for future monitoring. *Water Res* 2015; **72:** 3–27.

97 Watts N, Adger WN, Agnolucci P, et al. Health and climate change: policy responses to protect public health. *Lancet* 2015; **386:** 1861–914.

98 Haines A, McMichael AJ, Smith KR, et al. Public health benefits of strategies to reduce greenhouse-gas emissions: overview and implications for policy makers. *Lancet* 2009; **374:** 2104–14.

99 Prüss-Üstün A, Wolf J, Corvalan C, Bos R, Neira M. Preventing disease through healthy environments. Geneva: World Health Organization, 2016.

100 Hallegatte S, Bangalore M, Fay M, et al. Shock waves: managing the impacts of climate change on poverty. Washington, DC: World Bank, 2016.

101 United Nations Environment Programme. Costs of inaction on the sound management of chemicals. 2013. http://wedocs.unep.org/bitstream/handle/20.500.11822/8412/-Costs%20of%20inaction%20on%20the%20sound%20management%20of%20chemicals-2013Report_Cost_of_Inaction_Feb2013.pdf?sequence=3&isAllowed=y (accessed March 30, 2017).

102 WHO. Ambient air pollution: a global assessment of exposure and burden of disease. 2016. http://apps.who.int/iris/bitstream/10665/250141/1/9789241511353-eng.pdf?ua=1 (accessed April 17, 2017).

103 Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: closing the loop – an EU action plan for the circular economy. Brussels: European Commission, 2015.

104 Health and Environment Alliance (HEAL). Walking the Circle – the 4 guiding pillars for a Circular Economy. http://env-health.org/IMG/pdf/walking_the_circle.pdf (accessed March 30, 2017).

105 World Economic Forum. Towards the Circular Economy: accelerating the scale-up across global supply chains. January, 2014. http://www3.weforum.org/docs/WEF_ENV_TowardsCircularEconomy_Report_2014.pdf (accessed March 13, 2017).

106 GBD 2015 DALYs and HALE Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 315 diseases and injuries and healthy life expectancy (HALE), 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet* 2016; **388:** 1603–58.

107 Murray CJL, Lopez AD, for the World Health Organization, the World Bank. The global burden of disease: a comprehensive assessment of mortality and disability from diseases, injuries, and risk factors in 1990 and projected to 2020. Cambridge, MA: Harvard University Press, 1996.

108 Mathers CD, Vos T, Lopez AD, Salomon J, Ezzati M, for the World Health Organization Global Program on Evidence for Health Policy. National burden of disease studies: a practical guide, 2nd edn. October, 2001. http://www.who.int/healthinfo/nationalburdenofdiseasemanual.pdf (accessed March 30, 2017).

109 WHO International Programme on Chemical Safety. The public health impact of chemicals: knowns and unknowns, 2016. http://apps.who.int/iris/bitstream/10665/206553/1/WHO_FWC_PHE_EPE_16.01_eng.pdf (accessed Sept 13, 2017).

110 Prüss-Ustün A, Bartram J, Clasen T, et al. Burden of disease from inadequate water, sanitation and hygiene in low- and middle-income settings: a retrospective analysis of data from 145 countries. *Trop Med Int Health* 2014; **19:** 894–905.

111 Ericson B, Caravanos J, Chatham-Stephens K, Landrigan P, Fuller R. Approaches to systematic assessment of environmental exposures posed at hazardous waste sites in the developing world: the Toxic Sites Identification Program. *Environ Monit Assess* 2013; **185:** 1755–66.

112 Steckling N, Tobollik M, Plass D, et al. Global burden of disease of mercury used in artisanal small-scale gold mining. *Ann Glob Health* 2017; **83:** 234–47.
113 Steckling N, Devleesschauwer B, Winkelnkemper J, et al. Disability weights for chronic mercury intoxication resulting from gold mining activities: results from an online pairwise comparisons survey. *Int J Environ Res Public Health* 2017; **14:** 57.
114 Government of Peru Ministerio del Ambiente. Gestion de sitios contaminados. http://www.minam.gob.pe/calidadambiental/gestion-de-sitios-contaminados/ (in Spanish; accessed May 5, 2016).
115 Government of Mexico Secretaria de Medio Ambiente y Recursos Naturales. Sitios contaminados. http://www.semarnat.gob.mx/temas/gestion-ambiental/materiales-y-actividades-riesgosas/sitios-contaminados (in Spanish; accessed May 30, 2016).
116 Brandon E. The nature and extent of site contamination. In: Global approaches to site contamination law. Dordrecht: Springer Netherlands, 2013: 11–39.
117 WHO. Air quality guidelines: global update 2005, 2006. http://www.euro.who.int/__data/assets/pdf_file/0005/78638/E90038.pdf (accessed May 15, 2017).
118 WHO. WHO global urban ambient air pollution database. June 2017. http://www.who.int/phe/health_topics/outdoorair/databases/cities/en/ (accessed July 18, 2016).
119 WHO. Indoor air quality guidelines: household fuel combustion. Nov 12, 2014. http://www.who.int/indoorair/guidelines/hhfc/en/ (accessed May 15, 2017).
120 WHO. Developing national strategies for phasing out mercury-containing thermometers and sphygmomanometers in health care, including in the context of the Minamata Convention on Mercury: key considerations and step-by-step guidance. 2015. http://www.who.int/ipcs/assessment/public_health/WHOGuidanceReportonMercury2015.pdf (accessed Sept 13, 2017).
121 Pope CA 3rd, Burnett RT, Turner MC, et al. Lung cancer and cardiovascular disease mortality associated with ambient air pollution and cigarette smoke: shape of the exposure-response relationships. *Environ Health Perspect* 2011; **119:** 1616–21.
122 The Lancet. Air pollution—crossing borders. *Lancet* 2016; **388:** 103.
123 Health Effects Institute, GBD MAPS Working Group. Burden of disease attributable to coal-burning and other air pollution sources in China. August 2016. https://www.healtheffects.org/system/files/GBDMAPS-ReportEnglishFinal1.pdf (accessed Sept 13, 2017).
124 Apte JS, Marshall JD, Cohen AJ, Brauer M. Addressing global mortality from ambient PM2.5. *Environ Sci Technol* 2015; **49:** 8057–66.
125 Forouzanfar MH, Alexander L, Anderson HR, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; **386:** 2287–323.
126 National Research Council Division on Earth and Life Studies, Board on Atmospheric Sciences and Climate, Committee on the Significance of International Transport of Air Pollutants. Global sources of local pollution: an assessment of long-range transport of key air pollutants to and from the United States. Washington, DC: National Academies Press, 2009.
127 Jiang X, Zhang Q, Zhao H, et al. Revealing the hidden health costs embodied in Chinese exports. *Environ Sci Technol* 2015; **49:** 4381–88.
128 Zhang Q, Jiang X, Tong D, et al. Transboundary health impacts of transported global air pollution and international trade. *Nature* 2017; **543:** 705–09.
129 Lin J, Pan D, Davis SJ, et al. China's international trade and air pollution in the United States. *Proc Natl Acad Sci* 2014; **111:** 1736–41.
130 Thurston GD, Kipen H, Annesi-Maesano I, et al. A joint ERS/ATS policy statement: what constitutes an adverse health effect of air pollution? An analytical framework. *Eur Respir J* 2017; **49:** 1600419.
131 Wang X, Kindzierski W, Kaul P. Air pollution and acute myocardial infarction hospital admission in Alberta, Canada: a three-step procedure case-crossover study. *PLoS One* 2015; **10:** e0132769.
132 Su C, Breitner S, Schneider A, et al. Short-term effects of fine particulate air pollution on cardiovascular hospital emergency room visits: a time-series study in Beijing, China. *Int Arch Occup Environ Health* 2016; **89:** 641–57.
133 Weichenthal S, Lavigne E, Evans G, Pollitt K, Burnett RT. Ambient PM2.5 and risk of emergency room visits for myocardial infarction: impact of regional PM2.5 oxidative potential: a case-crossover study. *Environ Health* 2016; **15:** 46.
134 Milojevic A, Wilkinson P, Armstrong B, Bhaskaran K, Smeeth L, Hajat S. Short-term effects of air pollution on a range of cardiovascular events in England and Wales: case-crossover analysis of the MINAP database, hospital admissions and mortality. *Heart* 2014; **100:** 1093–98.
135 Brook RD, Franklin B, Cascio W, et al, for the Expert Panel on Population and Prevention Science of the American Heart Association. Air pollution and cardiovascular disease: a statement for healthcare professionals from the expert panel on population and prevention science of the American Heart Association. *Circulation* 2004; **109:** 2655–71.
136 Mustafić H, Jabre P, Caussin C, et al. Main air pollutants and myocardial infarction: a systematic review and meta-analysis. *JAMA* 2012; **307:** 713–21.
137 Gardner B, Ling F, Hopke PK, et al. Ambient fine particulate air pollution triggers ST-elevation myocardial infarction, but not non-ST elevation myocardial infarction: a case-crossover study. *Part Fibre Toxicol* 2014; **11:** 1.
138 Chan SH, Van Hee VC, Bergen S, et al. Long-term air pollution exposure and blood pressure in the sister study. *Environ Health Perspect* 2015; **123:** 951–58.
139 Link MS, Dockery DW. Air pollution and the triggering of cardiac arrhythmias. *Curr Opin Cardiol* 2010; **25:** 16–22.
140 Gold DR, Samet JM. Air pollution, climate, and heart disease. *Circulation* 2013; **128:** e411–14.
141 Newby DE, Mannucci PM, Tell GS, et al, for the ESC Working Group on Thrombosis, European Association for Cardiovascular Prevention and Rehabilitation, ESC Heart Failure Association. Expert position paper on air pollution and cardiovascular disease. *Eur Heart J* 2015; **36:** 83–93b.
142 Beelen R, Stafoggia M, Raaschou-Nielsen O, et al. Long-term exposure to air pollution and cardiovascular mortality: an analysis of 22 European cohorts. *Epidemiology* 2014; **25:** 368–78.
143 Kaufman JD, Adar SD, Barr RG, et al. Association between air pollution and coronary artery calcification within six metropolitan areas in the USA (the Multi-Ethnic Study of Atherosclerosis and Air Pollution): a longitudinal cohort study. *Lancet* 2016; **388:** 696–704.
144 Hamra GB, Guha N, Cohen A, et al. Outdoor particulate matter exposure and lung cancer: a systematic review and meta-analysis. *Environ Health Perspect* 2014; **122:** 906–11.
145 Franklin BA, Brook R, Arden Pope C 3rd. Air pollution and cardiovascular disease. *Curr Probl Cardiol* 2015; **40:** 207–38.
146 Kaufman JD, Adar SD, Allen RW, et al. Prospective study of particulate air pollution exposures, subclinical atherosclerosis, and clinical cardiovascular disease: the Multi-Ethnic Study of Atherosclerosis and Air Pollution (MESA Air). *Am J Epidemiol* 2012; **176:** 825–37.
147 Benziger CP, Roth GA, Moran AE. The Global Burden of Disease Study and the preventable burden of NCD. *Glob Heart* 2016; **11:** 393–97.
148 Claeys MJ, Rajagopalan S, Nawrot TS, Brook RD. Climate and environmental triggers of acute myocardial infarction. *Eur Heart J* 2017; **38:** 955–60.
149 Stafoggia M, Cesaroni G, Peters A, et al. Long-term exposure to ambient air pollution and incidence of cerebrovascular events: results from 11 European cohorts within the ESCAPE project. *Environ Health Perspect* 2014; **122:** 919–25.
150 Forastiere F, Agabiti N. Assessing the link between air pollution and heart failure. *Lancet*; **382:** 1008–10.
151 Block ML, Elder A, Auten RL, et al. The outdoor air pollution and brain health workshop. *Neurotoxicology* 2012; **33:** 972–84.
152 Volk HE, Lurmann F, Penfold B, Hertz-Picciotto I, McConnell R. Traffic-related air pollution, particulate matter, and autism. *JAMA Psychiatry* 2013; **70:** 71–77.

153 Amegah AK, Quansah R, Jaakkola JJK. Household air pollution from solid fuel use and risk of adverse pregnancy outcomes: a systematic review and meta-analysis of the empirical evidence. *PLoS One* 2014; **9:** e113920.

154 Smith KR, Bruce N, Balakrishnan K, et al, for the HAP CRA Risk Expert Group. Millions dead: how do we know and what does it mean? Methods used in the comparative risk assessment of household air pollution. *Annu Rev Public Health* 2014; **35:** 185–206.

155 Van Vliet EDS, Asante K, Jack DW, et al. Personal exposures to fine particulate matter and black carbon in households cooking with biomass fuels in rural Ghana. *Environ Res* 2013; **127:** 40–48.

156 Gao Y, Zhang Y, Kamijima M, et al. Quantitative assessments of indoor air pollution and the risk of childhood acute leukemia in Shanghai. *Environ Pollut* 2014; **187:** 81–89.

157 Ha S, Hu H, Roussos-Ross D, Haidong K, Roth J, Xu X. The effects of air pollution on adverse birth outcomes. *Environ Res* 2014; **134:** 198–204.

158 Shah PS, Balkhair T, for the Knowledge Synthesis Group on Determinants of Preterm/LBW births. Air pollution and birth outcomes: a systematic review. *Environ Int* 2011; **37:** 498–516.

159 Glinianaia SV, Rankin J, Bell R, Pless-Mulloli T, Howel D. Particulate air pollution and fetal health. *Epidemiology* 2004; **15:** 36–45.

160 Woodruff TJ, Darrow LA, Parker JD. Air pollution and postneonatal infant mortality in the United States, 1999–2002. *Environ Health Perspect* 2007; **116:** 110–15.

161 Lee EJ, Schwab KJ. Deficiencies in drinking water distribution systems in developing countries. *J Water Health* 2005; **3:** 109–27.

162 World Health Organization, UN Environment Programme, Convention on Biological Diversity. Connecting global priorities: biodiversity and human health: a state of knowledge review. 2015. https://www.cbd.int/health/SOK-biodiversity-en.pdf (accessed Feb 11, 2017).

163 European Bioplastics. Position of European Bioplastics on marine litter. August 2016. http://docs.european-bioplastics.org/publications/pp/EUBP_PP_Marine_litter.pdf (accessed March 6, 2017).

164 Hunter D. Diseases of occupations, sixth. London: Hodder Arnold H&S, 1978.

165 International Lead Association. Lead uses—statistics. http://www.ila-lead.org/lead-facts/lead-uses--statistics (accessed Oct 5, 2016).

166 Gibson JL. A plea for painted railings and painted walls of rooms as the source of lead poisoning amongst Queensland children. 1904. *Public Health Rep* 2005; **120:** 301–04.

167 Needleman HL, Gunnoe C, Leviton A, et al. Deficits in psychologic and classroom performance of children with elevated dentine lead levels. *N Engl J Med* 1979; **300:** 689–95.

168 Lanphear BP, Hornung R, Khoury J, et al. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. *Environ Health Perspect* 2005; **113:** 894–99.

169 Caravanos J, Dowling R, Téllez-Rojo MM, et al. Blood lead levels in Mexico and pediatric burden of disease implications. *Ann Glob Health* 2014; **80:** 269–77.

170 Reuben A, Caspi A, Belsky DW, et al. Association of childhood blood lead levels with cognitive function and socioeconomic status at age 38 years and with IQ change and socioeconomic mobility between childhood and adulthood. *JAMA* 2017; **317:** 1244–51.

171 Froehlich TE, Lanphear BP, Auinger P, et al. Association of tobacco and lead exposures with attention-deficit/hyperactivity disorder. *Pediatrics* 2009; **124:** e1054–63.

172 Needleman HL, Riess JA, Tobin MJ, Biesecker GE, Greenhouse JB. Bone lead levels and delinquent behavior. *JAMA* 1996; **275:** 363–69.

173 Nevin R. Understanding international crime trends: the legacy of preschool lead exposure. *Environ Res* 2007; **104:** 315–36.

174 World Health Organization. Lead poisoning and health. September 2016. http://www.who.int/mediacentre/factsheets/fs379/en/ (accessed May 15, 2016).

175 Jedrychowski WA, Perera FP, Camann D, et al. Prenatal exposure to polycyclic aromatic hydrocarbons and cognitive dysfunction in children. *Environ Sci Pollut Res* 2015; **22:** 3631–39.

176 Bellinger DC. Prenatal exposures to environmental chemicals and children's neurodevelopment: an update. *Saf Health Work* 2013; **4:** 1–11.

177 Herbstman JB, Sjödin A, Kurzon M, et al. Prenatal exposure to PBDEs and neurodevelopment. *Environ Health Perspect* 2010; **118:** 712–19.

178 Nussbaumer-Streit B, Yeoh B, Griebler U, et al. Household interventions for preventing domestic lead exposure in children. *Cochrane Database Syst Rev* 2016; **10:** CD006047.

179 Frank AL, Joshi TK. The global spread of asbestos. *Ann Glob Health* 2014; **80:** 257–62.

180 Téllez-Rojo MM, Hernández-Avila M, Lamadrid-Figueroa H. Impact of bone lead and bone resorption on plasma and whole blood lead levels during pregnancy. *Am J Epidemiol* 2004; **160:** 668–78.

181 Mandour RA, Ghanem AA, El-Azab SM. Correlation between lead levels in drinking water and mothers' breast milk: Dakahlia, Egypt. *Environ Geochem Health* 2013; **35:** 251–56.

182 Clark CS, Rampal KG, Thuppil V, et al. Lead levels in new enamel household paints from Asia, Africa and South America. *Environ Res* 2009; **109:** 930–36.

183 Jacobs DE. Environmental health disparities in housing. *Am J Public Health* 2011; **101** (suppl 1)**:** S115–22.

184 Hanna-Attisha M, LaChance J, Sadler RC, Champney Schnepp A. Elevated blood lead levels in children associated with the flint drinking water crisis: a spatial analysis of risk and public health response. *Am J Public Health* 2016; **106:** 283–90.

185 Pure Earth. World's worst pollution problems. The new top six toxic threats: a priority list for remediation. Fact sheet - lead. http://www.worstpolluted.org/projects_reports/display/127 (accessed July 18, 2016).

186 Global Burden of Disease Study 2013 Collaborators. Global, regional, and national incidence, prevalence, and years lived with disability for 301 acute and chronic diseases and injuries in 188 countries, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet* 2015; **386:** 743–800.

187 Haefliger P, Mathieu-Nolf M, Lociciro S, et al. Mass lead intoxication from informal used lead-acid battery recycling in Dakar, Senegal. *Environ Health Perspect* 2009; **117:** 1535–40.

188 Schober SE, Mirel LB, Graubard BI, Brody DJ, Flegal KM. Blood lead levels and death from all causes, cardiovascular disease, and cancer: results from the NHANES III mortality study. *Environ Health Perspect* 2006; **114:** 1538–41.

189 Aoki Y, Brody DJ, Flegal KM, Fakhouri THI, Axelrad DA, Parker JD. Blood lead and other metal biomarkers as risk factors for cardiovascular disease mortality. *Medicine (Baltimore)* 2016; **95:** e2223.

190 Fewtrell LJ, Prüss-Üstün A, Landrigan P, Ayuso-Mateos JL. Estimating the global burden of disease of mild mental retardation and cardiovascular diseases from environmental lead exposure. *Environ Res* 2004; **94:** 120–33.

191 Fuller R. Hazardous waste and toxic hotspots. In: Landrigan P, Etzel RA, eds. Textbook of children's environmental health. London: Oxford University Press, 2013: 254–61.

192 Ha E, Basu N, Bose-O'Reilly S, et al. Current progress on understanding the impact of mercury on human health. *Environ Res* 2017; **152:** 419–33.

193 Sharov P, Dowling R, Gogishvili M, et al. The prevalence of toxic hotspots in former Soviet countries. *Environ Pollut* 2016; **211:** 346–53.

194 Caravanos J, Gutierrez LH, Ericson B, Fuller R. A comparison of burden of disease from toxic waste sites with other recognized public health threats in India, Indonesia and the Philippines. *J Health Pollut* 2014; **4:** 2–13.

195 Brevik EC, Burgess LC. The influence of soils on human health. *Nat Educ Knowl* 2014; **5:** 1.

196 Chatham-Stephens K, Caravanos J, Ericson B, Landrigan P, Fuller R. The pediatric burden of disease from lead exposure at toxic waste sites in low and middle income countries. *Environ Res* 2014; **132:** 379–83.

197 Moya J, Phillips L. A review of soil and dust ingestion studies for children. *J Expo Sci Environ Epidemiol* 2014; **24:** 545–54.

198 van Wijnen JH, Clausing P, Brunekreef B. Estimated soil ingestion by children. *Environ Res* 1990; **51:** 147–62.

199 Landrigan PJ, Wright RO, Cordero JF, et al. The NIEHS Superfund Research Program: 25 years of translational research for public health. *Environ Health Perspect* 2015; **123:** 909–18.

200 US Environmental Protection Agency. Summary of the Comprehensive Environmental Response, Compensation, and Liability Act (Superfund). 1980. https://www.epa.gov/laws-regulations/summary-comprehensive-environmental-response-compensation-and-liability-act (accessed June 8, 2016).

201 European Union. Directive 2004/35/CE of the European Parliament and of the Council of 21 April 2004 on environmental liability with regard to the prevention and remedying of environmental damage. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32004L0035 (accessed Sept 13, 2017).

202 Caravanos J, Carrelli J, Dowling R, Pavilonis B, Ericson B, Fuller R. Burden of disease resulting from lead exposure at toxic waste sites in Argentina, Mexico and Uruguay. *Environ Health* 2016; **15:** 72.

203 Ericson B, Landrigan P, Taylor MP, et al. The global burden of lead toxicity attributable to informal used lead-acid battery sites. *Ann Glob Health* 2016; **82:** 686–99.

204 Pebe G, Hugo V, Escate L, Cervantes G. Niveles de plomo sanguíneo en recién nacidos de la Oroya, 2004–2005. *Rev Peru Med Exp Salud Publica* 2008; **25:** 355–60 (in Spanish).

205 Carrizales L, Razo I, Téllez-Hernández JI, et al. Exposure to arsenic and lead of children living near a copper-smelter in San Luis Potosi, Mexico: importance of soil contamination for exposure of children. *Environ Res* 2006; **101:** 1–10.

206 van der Kuijp TJ, Huang L, Cherry CR. Health hazards of China's lead-acid battery industry: a review of its market drivers, production processes, and health impacts. *Environ Health* 2013; **12:** 61.

207 UN Environment Programme. Global mercury assessment 2013: sources, emissions, releases and environmental transport. http://wedocs.unep.org/handle/20.500.11822/7984?show=full (accessed Sept 13, 2017).

208 Agricola G, Hoover HC, Hoover LH, York NY. De re metallica. Mineola, NY: Dover Books, 1950.

209 Ramazzini B, Wright WC. De morbis artificum diatribe: diseases of workers. The Latin text of 1713 revised, with translation and notes. Chicago: Chicago University Press, 1940.

210 Derickson A. Black lung: anatomy of a public health disaster. New York: Cornell University Press, 1998.

211 Rehn L. Blasengeschwülste bei Fuchsin-Arbeitern. *Archiv für Klininische Chirurgie* 1895; **50:** 240–52 (in German).

212 Rinsky RA. Benzene and leukemia: an epidemiologic risk assessment. *Environ Health Perspect* 1989; **82:** 189–91.

213 Selikoff IJ, Churg J, Hammond EC. Asbestos exposure and neoplasia. *JAMA* 1964; **188:** 22–26.

214 Takahashi K, Landrigan PJ. The global health dimensions of asbestos and asbestos-related diseases. *Ann Glob Health* 2016; **82:** 209–13.

215 Lucchini RG, Guazzetti S, Zoni S, et al. Neurofunctional dopaminergic impairment in elderly after lifetime exposure to manganese. *Neurotoxicology* 2014; **45:** 309–17.

216 Brautbar N, Williams J 2nd. Industrial solvents and liver toxicity: risk assessment, risk factors and mechanisms. *Int J Hyg Environ Health* 2002; **205:** 479–91.

217 Chisolm JJ Jr. Fouling one's own nest. *Pediatrics* 1978; **62:** 614–17.

218 Trasande L, Landrigan PJ. The National Children's Study: a critical national investment. *Environ Health Perspect* 2004; **112:** A789–90.

219 Jacobson JL, Jacobson SW. Intellectual impairment in children exposed to polychlorinated biphenyls in utero. *N Engl J Med* 1996; **335:** 783–89.

220 Rauh VA, Perera FP, Horton MK, et al. Brain anomalies in children exposed prenatally to a common organophosphate pesticide. *Proc Natl Acad Sci* 2012; **109:** 7871–76.

221 Bouchard MF, Chevrier J, Harley KG, et al. Prenatal exposure to organophosphate pesticides and IQ in 7-year-old children. *Environ Health Perspect* 2011; **119:** 1189–95.

222 Suk WA, Ahanchian H, Asante KA, et al. Environmental pollution: an under-recognized threat to children's health, especially in low- and middle-income countries. *Environ Health Perspect* 2016; **124:** A41–45.

223 UN Environment Programme. Global chemicals outlook—towards sound management of chemicals. 2013. http://web.unep.org/chemicalsandwaste/sites/unep.org.chemicalsandwaste/files/publications/GCO_web.pdf (accessed March 30, 2017).

224 Engel SM, Wetmur J, Chen J, et al. Prenatal exposure to organophosphates, paraoxonase 1, and cognitive development in childhood. *Environ Health Perspect* 2011; **119:** 1182–88.

225 Jensen TK, Frederiksen H, Kyhl HB, et al. Prenatal exposure to phthalates and anogenital distance in male infants from a low-exposed Danish cohort (2010–2012). *Environ Health Perspect* 2016; **124:** 1107–13.

226 Grube A, Donaldson D, Kiely T, Wu L, for the US Environmental Protection Agency. Pesticides industry sales and usage. 2006 and 2007 market estimates. February 2011. https://www.epa.gov/sites/production/files/2015-10/documents/market_estimates2007.pdf (accessed April 17, 2017).

227 Slotkin TA. Cholinergic systems in brain development and disruption by neurotoxicants: nicotine, environmental tobacco smoke, organophosphates. *Toxicol Appl Pharmacol* 2004; **198:** 132–51.

228 Jeschke P, Nauen R, Schindler M, Elbert A. Overview of the status and global strategy for neonicotinoids. *J Agric Food Chem* 2011; **59:** 2897–908.

229 Hopwood J, Code A, Vaughan M, et al. How neonicotinoids can kill bees: the science behind the role these insecticides play in harming bees, 2nd edn. Portland: The Xerces Society for Invertebrate Conservation, 2016.

230 Breer H, Sattelle DB. Molecular properties and functions of insect acetylcholine receptors. *J Insect Physiol* 1987; **33:** 771–90.

231 Rundlöf M, Andersson GK, Bommarco R, et al. Seed coating with a neonicotinoid insecticide negatively affects wild bees. *Nature* 2015; **521:** 77–80.

232 Woodcock BA, Isaac NJB, Bullock JM, et al. Impacts of neonicotinoid use on long-term population changes in wild bees in England. *Nat Commun* 2016; **7:** 12459.

233 Guyton KZ, Loomis D, Grosse Y, et al, for the International Agency for Research on Cancer Monograph Working Group. Carcinogenicity of tetrachlorvinphos, parathion, malathion, diazinon, and glyphosate. *Lancet Oncol* 2015; **16:** 490–91.

234 World Health Organization. Pharmaceuticals in drinking-water. 2011. http://www.who.int/water_sanitation_health/publications/ 2011/pharmaceuticals_20110601.pdf (accessed May 31, 2017).

235 Kot-Wasik A, Jakimska A, Śliwka-Kaszyńska M. Occurrence and seasonal variations of 25 pharmaceutical residues in wastewater and drinking water treatment plants. *Environ Monit Assess* 2016; **188:** 661.

236 Hunt A, Ferguson J, Hurley F, Searl A. Social costs of morbidity impacts of air pollution. OECD environment working papers, no. 99. Paris: OECD Publishing, 2016.

237 Andersen MS, Clubb DO. Understanding and accounting for the costs of inaction. In: European Environment Agency. Late lessons from early warnings. Luxembourg: Publications Office of the European Union, 2013.

238 Preker AS, Adeyi OO, Lapetra MG, Simon DC, Keuffel E. Health care expenditures associated with pollution: exploratory methods and findings. *Ann Glob Health* 2016; **82:** 711–21.

239 Institute of Medicine. Cost of environmental-related health effects: a plan for continuing study. Washington, DC: National Academies Press, 1981.

240 Smith KR, Corvalán CF, Kjellström T. How much global ill health is attributable to environmental factors? *Epidemiology* 1999; **10:** 573–84.

241 Jo C. Cost-of-illness studies: concepts, scopes, and methods. *Clin Mol Hepatol* 2014; **20:** 327–37.

242 Landrigan PJ, Schechter CB, Lipton JM, Fahs MC, Schwartz J. Environmental pollutants and disease in American children: estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. *Environ Health Perspect* 2002; **110:** 721–28.

243 Trasande L. Economics of children's environmental health. *Mt Sinai J Med* 2011; **78:** 98–106.

244 Brandt SJ, Perez L, Künzli N, Lurmann F, McConnell R. Costs of childhood asthma due to traffic-related pollution in two California communities. *Eur Respir J* 2012; **40:** 363–70.

245 Leigh JP. Economic burden of occupational injury and illness in the United States. *Milbank Q* 2011; **89:** 728–72.

246 Narain U, Sall C. Methodology for valuing the health impacts of air pollution: discussion of challenges and proposed solutions. Washington, DC: World Bank, 2016 https://openknowledge.worldbank.org/handle/10986/24440 (accessed Sept 13, 2017).

247 Golub E, Klytchnikova I, Sanchez-Martinez G, Belausteguigoitia JC, Monina CM. Environmental health costs in Colombia: the changes from 2002 to 2010. Washington, DC: World Bank, 2014.

248 World Bank. Cost of pollution in China: economic estimates of physical damages. Washington, DC: World Bank, 2007. http://documents.worldbank.org/curated/en/2007/02/7503894/cost-pollution-china-economic-estimates-physical-damages (accessed July 14, 2016).
249 Kemper K. Environmental health in Nicaragua: addressing key environmental challenges. Washington, DC: World Bank, 2013 http://documents.worldbank.org/curated/en/2013/01/17617086/environmental-health-nicaragua-addressing-key-environmental-challenges.
250 Viscusi WK, Aldy JE. The value of a statistical life: a critical review of market estimates throughout the world. *J Risk Uncertain* 2003; **27:** 5–76.
251 Alberini A, Cropper M, Krupnick A, Simon NB. Does the value of a statistical life vary with age and health status? Evidence from the US and Canada. *J Environ Econ Manage* 2004; **48:** 769–92.
252 Krupnick A, Alberini A, Cropper M, et al. Age, health and the willingness to pay for mortality risk reductions: a contingent valuation survey of Ontario residents. *J Risk Uncertain* 2002; **24:** 161–86.
253 Hammitt JK, Robinson LA. The income elasticity of the value per statistical life: transferring estimates between high and low income populations. *J Benefit-Cost Anal* 2011; **2:** 1–29.
254 Hanna R, Oliva P. The effect of pollution on labor supply: evidence from a natural experiment in Mexico City. *J Public Econ* 2015; **122:** 68–79.
255 Zivin JG, Neidell M. The impact of pollution on worker productivity. *Am Econ Rev* 2012; **102:** 3652–73.
256 Chang T, Zivin JG, Gross T, Neidell M. Particulate pollution and the productivity of pear packers. *Am Econ J Econ Policy* 2014; **8:** 141–69.
257 Carson RT, Koundouri P, Nauges C. Arsenic mitigation in Bangladesh: a household labor market approach. *Am J Agric Econ* 2010; **93:** 407–14.
258 Whittington D, Hanemann WM, Sadoff C, Jeuland M. The challenge of improving water and sanitation services in less developed countries. *Found Trends Microeconomics* 2009; **4:** 469–609.
259 Hutton G. Global costs and benefits of reaching universal coverage of sanitation and drinking-water supply. *J Water Health* 2013; **11:** 1–12.
260 Hutton G. Water and sanitation assessment paper: benefits and costs of the water sanitation and hygiene targets from the post-2015 development agenda. Copenhagen: Copenhagen Consensus Center, 2015.
261 World Bank. Environmental sustainability: a key to poverty reduction in Peru. Washington DC: World Bank, 2007.
262 Whittington D. Water and sanitation perspective paper: benefits and costs of the water, sanitation and hygiene targets for the post-2015 agenda. Copenhagen: Copenhagen Consensus Center, 2015.
263 Whittington D, Jeuland M, Barker K, Yuen Y. Setting priorities, targeting subsidies among water, sanitation, and preventive health interventions in developing countries. *World Dev* 2012; **40:** 1546–68.
264 Jeuland M, Whittington D. Cost–benefit comparisons of investments in improved water supply and cholera vaccination programs. *Vaccine* 2009; **27:** 3109–20.
265 Colborn T, Dumanoski D, Myers JP. Our stolen future: are we threatening our fertility, intelligence, and survival? New York: Penguin Books, 1997.
266 Salkever DS. Updated estimates of earnings benefits from reduced exposure of children to environmental lead. *Environ Res* 1995; **70:** 1–6.
267 Heckman JJ, Stixrud J, Urzua S. The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *J Labor Econ* 2006; **24:** 411–82.
268 Zax JS, Rees DI. IQ, academic performance, environment, and earnings. *Rev Econ Stat* 2002; **84:** 600–16.
269 Grosse S. How much does IQ raise earnings? Implications for regulatory impact analyses. *Assoc Environ Resour Econ Newsl* 2007; **27:** 17–21.
270 Rau T, Urzúa S, Reyes L. Early exposure to hazardous waste and academic achievement: evidence from a case of environmental negligence. *J Assoc Environ Resour Econ* 2015; **2:** 527–63.
271 Muennig P. The social costs of lead poisonings. *Health Aff* 2016; **35:** 1545.
272 Organization for Economic Co-operation and Development (OECD). Extension of work on expenditure by disease, age and gender. December 2013. https://www.oecd.org/els/health-systems/Extension-of-work-on-expenditure-by-disease-age-and-gender_Final-Report.pdf (accessed April 17, 2017).
273 Rannan-Eliya R. Health expenditures by disease and age, Sri Lanka 2005: preliminary findings. 3rd RCHSP-APNHAN Experts Meeting; Seoul, Korea; June 20, 2007.
274 Aikins M, Armah G, Akazili J, Hodgson A. Hospital health care cost of diarrheal disease in northern Ghana. *J Infect Dis* 2010; **202:** S126–30.
275 Alvis-Guzman N, Orozco-Africano J, Paternina-Caicedo A, et al. Treatment costs of diarrheal disease and all-cause pneumonia among children under-5 years of age in Colombia. *Vaccine* 2013; **31** (suppl 3)**:** C58–62.
276 National Research Council Subcommittee on Nutrition and Diarrheal Diseases Control. Nutritional management of acute diarrhea in infants and children. Washington, DC: National Academies Press, 1985.
277 Bhargava A. Protein and micronutrient intakes are associated with child growth and morbidity from infancy to adulthood in the Philippines. *J Nutr* 2016; **146:** 133–41.
278 Glewwe P, Miguel EA. The impact of child health and nutrition on education in less developed countries. In: Chenery HB. Handbook of Development Economics, Volume 4. Amsterdam: Elsevier, 2008: 3561–606.
279 World Bank. The cost of air pollution: strengthening the economic case for action. Sept 8, 2016. http://documents.worldbank.org/curated/en/781521473177013155/The-cost-of-air-pollution-strengthening-the-economic-case-for-action (accessed Jan 17, 2017).
280 Burr P, Fonseca C. Applying a life-cycle costs approach to water. Costs and service levels in rural and small town areas in Andhra Pradesh (India), Burkina Faso, Ghana and Mozambique. January 2013. http://www.ircwash.org/sites/default/files/20130208_8_wp_water_web_2.pdf (accessed March 30, 2017).
281 Jerven M. Poor numbers: how we are misled by African development statistics and what to do about it. New York: Cornell University Press, 2013.
282 Nordhaus W, Tobin J. Is growth obsolete? In: Economic Research: Retrospect and prospect, Volume 5, Economic growth. Washington, DC: National Bureau of Economic Research, Inc, 1972: 1–80.
283 United Nations. Poverty biggest enemy of health in developing world, Secretary-General tells World Health Assembly. May 17, 2001. http://www.un.org/press/en/2001/sgsm7808.doc.htm (accessed Sept 9, 2016).
284 Hajat A, Hsia C, O'Neill MS. Socioeconomic disparities and air pollution exposure: a global review. *Curr Environ Health Reports* 2015; **2:** 440–50.
285 UN Development Programme. Multidimensional Poverty Index (MPI). http://hdr.undp.org/en/content/multidimensional-poverty-index-mpi (accessed July 18, 2016).
286 Furie GL, Balbus J. Global environmental health and sustainable development: the role at Rio+20. *Cien Saude Colet* 2012; **17:** 1427–32.
287 Torpy JM, Lynm C, Glass RM. Poverty and health. *JAMA* 2007; **298:** 1968.
288 Grant K, Goldizen FC, Sly PD, et al. Health consequences of exposure to e-waste: a systematic review. *Lancet Glob Health* 2013; **1:** e350–61.
289 Muennig P, Fiscella K, Tancredi D, Franks P. The relative health burden of selected social and behavioral risk factors in the United States: implications for policy. *Am J Public Health* 2010; **100:** 1758–64.
290 Briggs D. Environmental pollution and the global burden of disease. *Br Med Bull* 2003; **68:** 1–24.
291 United Nations. Universal declaration of human rights. Dec 10, 1948. http://www.un.org/en/universal-declaration-human-rights/ (accessed Jan 18, 2017).
292 United Nations Human Rights: Office of the High Commissioner. The rights of the child and hazardous substances and wastes. http://www.ohchr.org/EN/Issues/Environment/ToxicWastes/Pages/RightsoftheChildHazardousSubstancesWastes.aspx (accessed March 13, 2017).

293 African Commission on Human and Peoples' Rights. African Charter on Human and Peoples' Rights, Article 24. http://www.achpr.org/instruments/achpr/#a24 (accessed July 18, 2016).
294 Organization of American States. Additional protocol to the American Convention on Human Rights in the area of economic, social and cultural rights 'Protocol of San Salvador'. http://www.oas.org/juridico/english/treaties/a-52.html (accessed July 18, 2016).
295 United Nations Environment Programme Law Division. Human rights and the environment. http://www.unep.org/divisions/delc/human-rights-and-environment (accessed Sept 13, 2017).
296 Institute on the Environment (ENSIA). Robert Bullard: the father of environmental justice. June 12, 2014. https://ensia.com/interviews/robert-bullard-the-father-of-environmental-justice/ (accessed Jan 9, 2017).
297 Bullard RD, Boulder CO. Dumping in Dixie: race, class, and environmental quality. Boulder, CO: Westview Press, 1990.
298 EJnet (Web Resources for Environmental Justice Activists). Environmental justice in the 21st century. 2001. http://www.ejnet.org/ej/principles.pdf (accessed Feb 11, 2017).
299 Nixon R. Slow violence and the environmentalism of the poor. Cambridge, MA: Harvard University Press, 2013.
300 Bailey ZD, Krieger N, Agénor M, Graves J, Linos N, Bassett MT. Structural racism and health inequities in the USA: evidence and interventions. *Lancet* 2017; **389:** 1453–63.
301 Corburn J. Concepts for studying urban environmental justice. *Curr Environ Health Rep* 2017; **14:** 61–67.
302 Solomon GM, Morello-Frosch R, Zeise L, Faust JB. Cumulative environmental impacts: science and policy to protect communities. *Annu Rev Public Health* 2016; **37:** 83–96.
303 Chakraborty J, Collins T, Grineski S. Environmental justice research: contemporary issues and emerging topics. *Int J Environ Res Public Health* 2016; **13:** E1072.
304 Watkins BX, Shepard PM, Corbin-Mark CD. Completing the circle: a model for effective community review of environmental health research. *Am J Public Health* 2009; **99** (suppl 3): S567–77.
305 Pezzullo PC. Touring 'Cancer Alley,' Louisiana: performances of community and memory for environmental justice. *Text Perform Q* 2003; **23:** 226–52.
306 Brugge D, Goble R. The history of uranium mining and the Navajo people. *Am J Public Health* 2002; **92:** 1410–19.
307 Cushing L, Faust J, August LM, Cendak R, Wieland W, Alexeeff G. Racial/ethnic disparities in cumulative environmental health impacts in California: evidence from a statewide environmental justice screening tool (CalEnviroScreen 1.1). *Am J Public Health* 2015; **105:** 2341–48.
308 Thomas-Müller C. Tar sands: environmental justice, treaty rights and Indigenous Peoples. *Can Dimens* 2008; 42.
309 Wiebe SM. Everyday exposure: indigenous mobilization and environmental justice in Canada's Chemical Valley. Vancouver: University of British Columbia Press, 2016.
310 Deguen S, Zmirou-Navier D. Social inequalities resulting from health risks related to ambient air quality—a European review. *Eur J Public Health* 2010; **20:** 27–35.
311 Steger T, for the CEU Center for Environmental Policy and Law, the Health and Environment Alliance, the Coalition for Environmental Justice. Making the case for environmental justice in central & eastern Europe. Budapest: CEU Center for Environmental Policy and Law, 2007.
312 Hedley AJ, McGhee SM, Barron B, et al. Air pollution: costs and paths to a solution in Hong Kong—understanding the connections among visibility, air pollution, and health costs in pursuit of accountability, environmental justice, and health protection. *J Toxicol Environ Health A* 2008; **71:** 544–54.
313 United Nations Development Programme. Environmental justice—comparative experiences in legal empowerment. June 12, 2014. http://www.undp.org/content/undp/en/home/librarypage/democratic-governance/access_to_justiceandruleoflaw/environmental-justice---comparative-experiences.html (accessed July 18, 2016).
314 Saha S, Pattanayak SK, Sills EO, Singha AK. Under-mining health: environmental justice and mining in India. *Health Place* 2011; **17:** 140–48.
315 Yabe J, Nakayama SMM, Ikenaka Y, et al. Lead poisoning in children from townships in the vicinity of a lead–zinc mine in Kabwe, Zambia. *Chemosphere* 2015; **119:** 941–47.
316 Bashir M, Umar-Tsafe N, Getso K, et al. Assessment of blood lead levels among children aged ≤5 years—Zamfara State, Nigeria, June–July 2012. *MMWR* 2014; **63:** 325–27.
317 Alam S, Bhuiyan JH, Chowdhury T, Techera E. Routledge handbook of international environmental law. Abingdon-on-Thames, UK; Routledge, 2013.
318 Temper L, Del Bene D, Martinez-Alier J. Mapping the frontiers and front lines of global environmental justice: the EJAtlas. *J Polit Ecol* 2015; **22:** 256.
319 The World Bank. DataBank world development indicators. PM2.5 air pollution, mean annual exposure (micrograms per cubic meter). http://databank.worldbank.org/data/reports.aspx?source=2&series=EN.ATM.PM25.MC.M3&country= (accessed Jan 4, 2017).
320 The World Bank. DataBank world development indicators. GDP per capita (current US$). http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.CD&country= (accessed Jan 4, 2017).
321 Water Supply & Sanitation Collaborative Council. Post-2015 WAST targets and indicators. http://wsscc.org/2015/02/20/post-2015-wash-targets-indicators-questions-answers/ (accessed July 18, 2016).
322 Sommer M, Caruso BA, Sahin M, et al. A time for global action: addressing girls' menstrual hygiene management needs in schools. *PLoS Med* 2016; **13:** e1001962.
323 Spitz PH. The chemical industry at the millennium: maturity, restructuring, and globalization. Philadelphia, PA: Chemical Heritage Foundation, 2003.
324 Heacock M, Kelly CB, Asante KA, et al. E-waste and harm to vulnerable populations: a growing global problem. *Environ Health Perspect* 2016; **124:** 550–55.
325 Iskander M, Meyerman G, Gray DF, Hagan S, for the International Monetary Fund. Corporate restructuring and governance in east Asia. *Finance Dev* 1999; **36:** 42–45.
326 Carmin J, Agyeman J. Environmental inequalities beyond borders: local perspectives on global injustices. Cambridge, MA: MIT Press, 2011.
327 Margai FM, Barry FB. Global geographies of environmental injustice and health: a case study of illegal hazardous waste dumping in Côte d'Ivoire. *Geospatial Anal Environ Health* 2011; **4:** 257–81.
328 Business & Human Rights Resource Centre. Trafigura lawsuits (re Côte d'Ivoire). https://business-humanrights.org/en/trafigura-lawsuits-re-cote-d'ivoire (accessed Jan 18, 2017).
329 Caravanos J, Clark E, Fuller R, Lambertson C. Assessing worker and environmental chemical exposure risks at an e-waste recycling and disposal site in Accra, Ghana. *J Health Pollut* 2011; **1:** 16–25.
330 Robinson BH. E-waste: An assessment of global production and environmental impacts. *Sci Total Environ* 2009; **408:** 183–91.
331 United Nations Sustainable Development Knowledge Platform. Transforming our world: the 2030 agenda for sustainable development. https://sustainabledevelopment.un.org/post2015/transformingourworld (accessed Jan 18, 2017).
332 GBD 2015 SDG Collaborators. Measuring the health-related Sustainable Development Goals in 188 countries: a baseline analysis from the Global Burden of Disease Study 2015. *Lancet* 2016; **388:** 1813–50.
333 World Commission on Environment and Development. Report of the World Commission on Environment and Development: our common future (Brundtland report). Oxford: Oxford University Press, 1987. http://www.un-documents.net/our-common-future.pdf (accessed March 13, 2017).
334 United Nations Development Programme. Human development report 2011. Sustainability and equity: a better future for all. 2011. http://hdr.undp.org/sites/default/files/reports/271/hdr_2011_en_complete.pdf (accessed March 13, 2017).
335 United Nations Environment Programme. Proposal regional action plan for intergovernmental cooperation on air pollution for Latin America and the Caribbean. Oct 20, 2013. http://www.pnuma.org/forodeministros/19-mexico/documentos/Proposed Regional Action Plan Atmospherc Pollution FINAL 301013.pdf (accessed Sept 27, 2016).

336 Patz JA, Frumkin H, Holloway T, Vimont DJ, Haines A. Climate change. *JAMA* 2014; **312:** 1565–80.

337 Bransford KJ, Lai JA. MSJAMA: Global climate change and air pollution: common origins with common solutions. *JAMA* 2002; **287:** 2285.

338 Harris JB, LaRocque RC, Qadri F, Ryan ET, Calderwood SB. Cholera. *Lancet* 2012; **379:** 2466–76.

339 Brewer T, Pringle Y. Beyond Bazalgette: 150 years of sanitation. *Lancet* 2015; **386:** 128–29.

340 Lawther PJ, Waller RE, Henderson M. Air pollution and exacerbations of bronchitis. *Thorax* 1970; **25:** 525–39.

341 Harada M. Minamata disease: methylmercury poisoning in Japan caused by environmental pollution. *Crit Rev Toxicol* 1995; **25:** 1–24.

342 Arnold BF, Null C, Luby SP, et al. Cluster-randomised controlled trials of individual and combined water, sanitation, hygiene and nutritional interventions in rural Bangladesh and Kenya: the WASH Benefits study design and rationale. *BMJ Open* 2013; **3:** e003476.

343 Huda TM, Unicomb L, Johnston RB, Halder AK, Yushuf Sharker MA, Luby SP. Interim evaluation of a large scale sanitation, hygiene and water improvement programme on childhood diarrhea and respiratory disease in rural Bangladesh. *Soc Sci Med* 2012; **75:** 604–11.

344 State Council of China. Law of the People's Republic of China on prevention and control of water pollution. http://www.npc.gov.cn/englishnpc/Law/2007-12/13/content_1383966.htm (accessed Sept 13, 2017).

345 Rohde RA, Muller RA. Air pollution in China: mapping of concentrations and sources. *PLoS One* 2015; **10:** e0135749.

346 Haacke O, for the US-China business council. NDRC prepares for next five-year plan, focuses on quality over quantity. https://www.uschina.org/ndrc-prepares-next-five-year-plan-focuses-quality-over-quantity (accessed Sept 12, 2016).

347 Seligsohn D, Hsu A, for ChinaFile. How China's 13th five-year plan addresses energy and the environment. March 10, 2016. http://www.chinafile.com/reporting-opinion/environment/how-chinas-13th-five-year-plan-addresses-energy-and-environment (accessed Sept 13, 2017).

348 Greenpeace. Clean Air Action Plan: the way forward. February 2016. http://www.greenpeace.org/eastasia/Global/eastasia/publications/reports/climate-energy/2016/Clean%20Air%20Action%20Plan,%20The%20way%20forward.pdf (accessed Sept 13, 2017).

349 Jingjing C, Tang J, for New Security Beat. Will China's new air law solve its pollution crisis? Nov 25, 2015. https://www.newsecuritybeat.org/2015/11/chinas-air-law-solve-pollution-crisis/ (accessed Sept 12, 2016).

350 Lin A, for NRDC Expert Blog. How China's 13th five year plan climate and energy targets accelerate its transition to clean energy. March 13, 2016. https://www.nrdc.org/experts/alvin-lin/how-chinas-13th-five-year-plan-climate-and-energy-targets-accelerate-its (accessed Sept 13, 2017).

351 China Water Risk. New 'Water Ten Plan' to safeguard China's water. 2016. http://chinawaterrisk.org/notices/new-water-ten-plan-to-safeguard-chinas-waters/ (accessed Sept 12, 2016).

352 Wang X, Lou X, Zhang N, et al. Phthalate esters in main source water and drinking water of Zhejiang Province (China): distribution and health risks. *Environ Toxicol Chem* 2015; **34:** 2205–12.

353 Jinran Z, for China Daily USA. Action plan targets soil pollution. June 1, 2016. http://usa.chinadaily.com.cn/china/2016-06/01/content_25563338.htm (accessed Sept 13, 2017).

354 China.org.cn. China announces soil pollution controls. June 1, 2016. http://www.china.org.cn/china/2016-06/01/content_38576923.htm (accessed Sept 12, 2016).

355 Dold B, Wade C, Fontboté L. Water management for acid mine drainage control at the polymetallic Zn–Pb–(Ag–Bi–Cu) deposit Cerro de Pasco, Peru. *J Geochemical Explor* 2009; **100:** 133–41.

356 McKinley G, Zuk M, Höjer M, et al. Quantification of local and global benefits from air pollution control in Mexico City. *Environ Sci Technol* 2005; **39:** 1954–61.

357 Amarsaikhan D, Battsengel V, Nergui B, Ganzorig M, Bolor G. A study on air pollution in Ulaanbaatar City, Mongolia. *J Geosci Environ Prot* 2014; **2:** 123–28.

358 The Lancet. India's air pollution: a new government and global plan. *Lancet* 2016; **387:** 96.

359 Hernandez RA. Prevention and control of air pollution in China: a research agenda for science and technology studies. *Sapiens* 2015; **8.**

360 Clean Air Asia. China Air 2016. Air pollution prevention and control progress in Chinese cities. 2016. http://cleanairasia.org/wp-content/uploads/2016/08/China-Air-2016-Report-Full.pdf (accessed June 5, 2017).

361 Martin RT, for MIT Technology Review. Substainable energy: China is on an epic solar power binge. March 22, 2016. https://www.technologyreview.com/s/601093/china-is-on-an-epic-solar-power-binge/ (accessed June 5, 2017).

362 Gunningham N. Enforcing environmental regulation. *J Environ Law* 2011; **23:** 169–201.

363 Zhang JJ, Smith KR. Household air pollution from coal and biomass fuels in China: measurements, health impacts, and interventions. *Environ Health Perspect* 2007; **115:** 848–55.

364 Vahlne N, Ahlgren EO. Policy implications for improved cook stove programs—a case study of the importance of village fuel use variations. *Energy Policy* 2014; **66:** 484–95.

365 Lan Q, Chapman RS, Schreinemachers DM, Tian L, He X. Household stove improvement and risk of lung cancer in Xuanwei, China. *J Natl Cancer Inst* 2002; **94:** 826–35.

366 Sinha B. The Indian stove programme: an insider's view - the role of society, politics, economics and education. *Boil Point* 2002; 48.

367 Block M, Hanrahan D, for Blacksmith Institute, Green Cross Switzerland. World's most polluted places report 2009: 12 cases of cleanup and success. 2009. http://www.worstpolluted.org/files/FileUpload/files/2009-report/Blacksmith-Institute-Green-Cross-Switzerland-WWPP-Report-2009.pdf (accessed Sept 13, 2017).

368 Amegah AK, Jaakkola JJK. Household air pollution and the sustainable development goals. *Bull World Health Organ* 2016; **94:** 215–21.

369 Jasper C, Le TT, Bartram J. Water and sanitation in schools: a systematic review of the health and educational outcomes. *Int J Environ Res Public Health* 2012; **9:** 2772–87.

370 Van Minh H, Nguyen-Viet H. Economic aspects of sanitation in developing countries. *Environ Health Insights* 2011; **5:** 63–70.

371 Dincer I. Renewable energy and sustainable development: a crucial review. *Renew Sustain Energy Rev* 2000; **4:** 157–75.

372 Krewski D, Rainham D. Ambient air pollution and population health: overview. *J Toxicol Environ Health A* 2007; **70:** 275–83.

373 Aziz A, Bajwa IU. Erroneous mass transit system and its tended relationship with motor vehicular air pollution (An integrated approach for reduction of urban air pollution in Lahore). *Environ Monit Assess* 2008; **137:** 25–33.

374 Welton M, Rodriguez-Lainz A, Loza O, Brodine S, Fraga M. Use of lead-glazed ceramic ware and lead-based folk remedies in a rural community of Baja California, Mexico. *Glob Health Promot* 2016; published online June 14. DOI:10.1177/1757975916639861.

375 Romieu I, Palazuelos E, Hernandez Avila M, et al. Sources of lead exposure in Mexico City. *Environ Health Perspect* 1994; **102:** 384–89.

376 Téllez-Rojo MM, Bellinger DC, Arroyo-Quiroz C, et al. Longitudinal associations between blood lead concentrations lower than 10 microg/dL and neurobehavioral development in environmentally exposed children in Mexico City. *Pediatrics* 2006; **118:** e323–30.

377 International Energy Agency. World Energy Outlook special report 2016: energy and air pollution. 2016. https://www.iea.org/publications/freepublications/publication/weo-2016-special-report-energy-and-air-pollution.html (accessed Oct 20, 2016).

378 Schug TT, Abagyan R, Blumberg B, et al. Designing endocrine disruption out of the next generation of chemicals. *Green Chem* 2013; **15:** 181–98.

379 US Environmental Protection Agency. Overview of the Clean Air Act and air pollution. 2016. https://www.epa.gov/clean-air-act-overview (accessed June 7, 2016).

380 IndiaSpend. 15 Days After Odd-Even, Delhi's PM 2.5 Levels Rise 15%. Jan 16, 2016. http://www.indiaspend.com/cover-story/15-days-after-odd-even-delhis-pm-2-5-levels-rise-15-67571 (accessed Sept 13, 2017).

381 Sharma M, Dikshit O. Comprehensive study on air pollution and green house gases (GHGs) in Delhi. Final report: air pollution component. January 2016. http://delhi.gov.in/DoIT/Environment/PDFs/Final_Report.pdf (accessed April 1, 2017).

382 Hutton G, Chase C. Water supply, sanitation and hygiene. In: Mock C, Kobusingye O, Nugent R, Smith K, eds. Disease control priorities volume 7: injury prevention and environmental health, 3rd edn. Washington, DC: World Bank, 2017.

383 Ashraf N, Berry J, Shapiro JM. Can higher prices stimulate product use? Evidence from a field experiment in Zambia. *Am Econ Rev* 2010; **100:** 2383–413.

384 Dupas P, Hoffmann V, Kremer M, Zwane AP. Targeting health subsidies through a nonprice mechanism: a randomized controlled trial in Kenya. *Science* 2016; **353:** 889–95.

385 Dupas P, Miguel E. Impacts and determinants of health levels in low-income countries. *Handbook of Field Experiments* 2016; **2:** 3–654.

386 Guiteras R, Levinsohn J, Mobarak AM. Sanitation subsidies. Encouraging sanitation investment in the developing world: a cluster-randomized trial. *Science* 2015; **348:** 903–06.

387 IDinsight. Microfinance loans to increase sanitary latrine sales: evidence from a randomized trial in rural Cambodia. June 2013. http://idinsight.org/insights/wtp/IDinsight policy brief - microfinance loans for latrines in Cambodia.pdf (accessed Jan 26, 2017).

388 Pimentel D. Amounts of pesticides reaching target pests: environmental impacts and ethics. *J Agric Environ Ethics* 1995; **8:** 17–29.

389 WHO. The world health report 2003 - shaping the future. 2003. http://www.who.int/whr/2003/en/whr03_en.pdf (accessed Sept 13, 2017).

390 The economics of ecosystems & biodiversity. Agriculture and food. www.teebweb.org/agriculture-and-food (accessed July 14, 2016).

391 International Institute for Sustainable Development. Water quality monitoring system design. September 2015. http://www.iisd.org/library/water-quality-monitoring-system-design (accessed Sept 13, 2017).

392 Marć M, Tobiszewski M, Zabiegała B, Guardia M de la, Namieśnik J. Current air quality analytics and monitoring: a review. *Anal Chim Acta* 2015; **853:** 116–26.

393 Ikram J, Tahir A, Kazmi H, Khan Z, Javed R, Masood U. View: implementing low cost air quality monitoring solution for urban areas. *Environ Syst Res* 2012; **1:** 10.

394 Hidy GM, Brook JR, Demerjian KL, Molina LT, Pennell WT, Scheffe RD. Technical challenges of multipollutant air quality management. Dordrecht: Springer Netherlands, 2011.

395 Choi BC. The past, present, and future of public health surveillance. *Scientifica (Cairo)* 2012; 875253.

396 Caravanos J, Ericson B, Ponce-Canchihuamán J, et al. Rapid assessment of environmental health risks posed by mining operations in low- and middle-income countries: selected case studies. *Environ Sci Pollut Res Int* 2013; **20:** 7711–18.

397 Beaglehole R, Bonita R. Global public health: a new era, 2nd edn. London: Oxford University Press, 2009.

398 Leitao J, Chandramohan D, Byass P, et al. Revising the WHO verbal autopsy instrument to facilitate routine cause-of-death monitoring. *Glob Health Action* 2013; **6:** 21518.

399 Health Effects Institute. Assessing the health impact of air quality regulations: concepts and methods for accountability research. September 2003. https://www.healtheffects.org/publication/assessing-health-impact-air-quality-regulations-concepts-and-methods-accountability (accessed June 5, 2017).

400 National Research Council. Estimating the public health benefits of proposed air pollution regulations. Washington, DC: National Academies Press, 2002.

401 Samet JM, Zeger SL, Dominici F, et al. The National Morbidity, Mortality, and Air Pollution Study. Part II: Morbidity and mortality from air pollution in the United States. *Res Rep Health Eff Inst* 2000; **94:** 5–70.

402 Braun JM, Yolton K, Dietrich KN, et al. Prenatal bisphenol A exposure and early childhood behavior. *Environ Health Perspect* 2009; **117:** 1945–52.

403 European Commission on the Environment. REACH. Aug 24, 2016. http://ec.europa.eu/environment/chemicals/reach/reach_intro.htm (accessed Jan 31, 2017).

404 Schmidt CW. TSCA 2.0: A new era in chemical risk management. *Environ Health Perspect* 2016; **124:** A182–86.

405 The Lancet. Law: an underused tool to improve health and wellbeing for all. *Lancet* 2017; **389:** 331.

406 Gilliland F, Avol E, McConnell R, et al. The effects of policy-driven air quality improvements on children's respiratory health. Boston, MA: Health Effects Institute, 2017.

407 Kotzé LJ, Paterson A. The role of judiciary in environmental governance: comparative perspectives. Amsterdam: Wolters Kluwer, 2009.

408 Gao J, Xu G, Ma W, et al. Perceptions of health co-benefits in relation to greenhouse gas emission reductions: a survey among urban residents in three Chinese cities. *Int J Environ Res Public Health* 2017; **14:** E298.

409 World Health Organization Regional Office for Europe. 2017 Healthy Cities Pécs Declaration. WHO European Healthy Cities Network Annual Business and Technical Conference; Pécs, Hungary; March 1–3, 2017. http://www.euro.who.int/__data/assets/pdf_file/0005/334643/Pecs-Declaration.pdf (accessed May 2, 2017).

410 Organisation for Economic Cooperation and Development (OECD). OECD environmental outlook to 2050: the consequences of inaction. Paris: OECD Publishing, 2012.

411 Giles-Corti B, Vernez-Moudon A, Reis R, et al. City planning and population health: a global challenge. *Lancet* 2016; **388:** 2912–24.

412 United Nations Department of Economic and Social Affairs, Population. World urbanization prospects: the 2014 revision: highlights. 2014. https://esa.un.org/unpd/wup/publications/files/wup2014-highlights.pdf (accessed Sept 13, 2017).

413 Sundseth K, Pacyna JM, Pacyna EG, Munthe J, Belhaj M, Astrom S. Economic benefits from decreased mercury emissions: projections for 2020. *J Clean Prod* 2010; **18:** 386–94.

414 Hall J V, Brajer V, Lurmann FW. Air pollution, health and economic benefits—lessons from 20 years of analysis. *Ecol Econ* 2010; **69:** 2590–97.

415 Spangenberg JH. The environmental Kuznets curve: a methodological artefact? *Popul Environ* 2001; **23:** 175–91.

416 Reinalda B. The Ashgate research companion to non-state actors. Abingdon-on-Thames, UK: Routledge, 2016.

417 Court J, Mendizabal E, Osborne D, Young J, for Overseas Development Institute. Policy engagement: how civil society can be more effective. 2006. https://www.odi.org/sites/odi.org.uk/files/odi-assets/publications-opinion-files/200.pdf (accessed Sept 13, 2017).

418 Duflo E, Greenstone M, Pande R, Ryan N. Truth-telling by third-party auditors and the response of polluting firms: experimental evidence from India. *Q J Econ* 2013; **128:** 1499–545.

Annex F – Meetings Held

Agency	Type of Agency	Country	Meeting Date	In Person/ Phone	With Whom? (name, Title)	Email of Contact	Comments (What was discussed? e.g. Commision, TSIP, Remediation)
Ethiopia, Ministry of Environment	LMIC	Ethiopia	Oct-17	in person			
Indonesia, Ministry of Environment and Forests	LMIC	Indonesia	Oct-17	in person			
Cambodia, Ministry of Environment	Bilateral agency	Cambodia	4-Oct-17	Phone call	Pak Sokharavuth	sokharavuth@online.com.kh	GAHP Strategic planning 1:1 consultations
Madagascar, Ministry of Environment and Forests	LMIC	Madagascar	5-Oct-17	Phone call	Marthe Rahelimalala	martheraheli@gmail.com	GAHP Strategic planning 1:1 consultations
City of Montevideo	LMIC	Uruguay	6-Oct-17	Phone call	Gabriella Feola	gabriella.feola@imm.gub.uy	GAHP Strategic planning 1:1 consultations
Dept of Pollution Control Thailand	LMIC	Thailand	6-Oct-17	phone call	Chayawee Wangcharoeng	chayawee@gmail.com	GAHP Strategic planning 1:1 consultations
UN Environment (UNEP)	International Organization	international organization	6-Oct-17	phone call	Fanny Demassieux	Fanny.Demassieux@unep.org	GAHP Strategic planning 1:1 consultations
Asian Development Bank	Multilateral Agency	HQ	7-Oct-17	phone call	Eduardo Banzon	ebanzon@adb.org	GAHP Strategic planning 1:1 consultations
European Commission (Directorate-General for Development)	Bilateral agency	HQ	7-Oct-17	phone call	Maria Pachta, Jill Hanna	Maria.PACHTA@ec.europa.eu	GAHP Strategic planning 1:1 consultations
UNDP	International Organization	international organization	7-Oct-17	phone call	Douglas Webb	douglas.webb@undp.org	GAHP Strategic planning 1:1 consultations
UNIDO	International Organization	international organization	7-Oct-17	phone call	Stephan Sicars, Nilgun Tas	s.sicars@unido.org	GAHP Strategic planning 1:1 consultations
World Bank	Multilateral Agency	HQ	7-Oct-17	phone call	Monserrate Meiro Lorenzo	mmeirolorenzo@worldbank.org	GAHP Strategic planning 1:1 consultations
ACP Presentation	Bilateral agency	EU	12-Oct-17	live video			Commission presentation
EU Council presentation	Bilateral agency	HQ	17-Oct-17	live video			Commission presentation
US Department of State	Bilateral agency	HQ	18-Oct-17	in person	Katherine Weber	weberkp@state.gov	Discussion about scope of lead pollution globally
US EPA	Bilateral agency	USA	18-Oct-17	in person	Walker Smith	smith.walker@epa.gov	Discussion about scope of lead pollution globally
USAID	Bilateral agency	HQ	18-Oct-17	in person	Katie Swanson	kswanson@usaid.gov	Discussion about scope of lead pollution globally
NY Commission Launch Event	Lancet Commission Event	Lancet Commission Event	23-Oct-17	in person			Commission launch event
Senegal, Ministry of Environment	LMIC	Senegal	24-Oct-17	phone call	Aita Seck	aitasec@yahoo.fr	GAHP Strategic planning 1:1 consultations
ACP EU Joint Parliament	Bilateral agency	EU	26-Oct-17	in person	Charitini Michaelidou	charitini.michaelidou@europarl.europa.eu	Commission presentation and policy/programming planning discussion
Brussels Commission Launch Event	Lancet Commission Event	Lancet Commission Event	26-Oct-17	in person			Commission launch event
UN Environment North America Pollution Event	Lancet Commission Presentation	international organization	26-Oct-17	in person			Commission presentation
European Commission (Directorate-General for Environment	Bilateral agency	HQ	27-Oct-17	in person	Jorge Rodriguez Romero	Jorge.RODRIGUEZ-ROMERO@ec.europa.eu	Commission presentation and policy/programming planning discussion

CSIH Canadian Conference on Global Health	Lancet Commission Event	Lancet Commission Event	31-Oct-17	in person			Commission launch event
Canada, Privy Council Office	Bilateral agency	Canada	1-Nov-17	in person	John Wall, Glenn Hargrove, Elizabeth May (green party)	John.wall@pco-bcp.gc.ca Glenn.hargrove@pco-bcp.gc.ca	Commission presentation
Nigeria, Ministry of Environment	LMIC	Nigeria	1-Nov-17	phone call	Kitan Oluwagbuyi	kitanogungbuyi@yahoo.com	GAHP Strategic planning 1:1 consultations
Sweden, Ministry of Environment and Energy	Bilateral agency	Sweden	8-Nov-17	in person	Asa Norrman and team		Commission presentation and policy/programming planning discussion
Sweden, Ministry of Foreign Affairs	Bilateral agency	Sweden	8-Nov-17	in person	Anders Nordstrom		Commission presentation and policy/programming planning discussion
Sweden, Swedish International Development Agency (SIDA)	Bilateral agency	Sweden	8-Nov-17	in person	Pia Engstrand		Commission presentation and policy/programming planning discussion
UK The Department for International Development (DFID, UK)	Bilateral agency	UK	10-Nov-17	in person	John Carstensen, Sally Taylor, Julian Wright		Commission presentation and policy/programming planning discussion
European External Action Service	Bilateral agency	HQ	16-Nov-17	in person	Maria Del Carmen Marques Ruiz	Maria-Del-Carmen.MARQUES-RUIZ@eeas.europa.eu	Commission presentation
European Clean Air Forum	Lancet Commission Presentation	Lancet Commission Presentation	17-Nov-17	in person	VARIOUS		Commission presentation
UNEA3		Kenya	2-Dec-17	in person	VARIOUS: including Ministers of Environment for 18 countries, including Argentina, Botswana, Brazil, Cambodia, Ghana, Eritrea, Ethiopia, India, Indonesia, Kenya, Nepal, Nigeria, Peru, Sri Lanka, Sudan, Togo and Zambia. Donor agencies included DFID, Sweden, US DoS, US EPA, EC, Norway, Germany and others.		GAHP, scope of pollution and health, Commission findings and recommendations, policy/programming discussions
GAHP Annual meeting	GAHP Annual Meeting	Kenya	3-Dec-17	in person	VARIOUS: more than 30 agencies		Commission overview
UN Environment (UNEP)	international Organization		3-Dec-17	in person	Erik Solheim		Commission discussion, policy/programming planning discussion
Green Tent GAHP Event		Kenya	6-Dec-17	in person	VARIOUS		Commission presentation, panel
UNEA3 Side Event		Kenya	6-Dec-17	in person	VARIOUS		Commission presentation
Switzerland, Swiss Development Cooperation	Bilateral agency	Switzerland	14-Dec-17	in person	Jacques Mader and team	jacques.mader@eda.admin.ch	Commission presentation and policy/programming planning discussion
WHO	international Organization	Switzerland	21-Dec-17	in person	Tedros head of WHO		Commission discussion, policy/programming planning discussion
Nepal, Department of Environment	LMIC	Nepal	8-Jan-18	teleconference	Durga Prasad, DG		Follow up of UNEA3, how can GAHP help Nepal tackle pollution discussion, HPAP
WB Commission Launch Event			11-Jan-18	in person			Commission launch event

European Commission, DevCo	Donor	EU	12-Jan-18	teleconference	Maria Pachta		
Argentina, Ministry of Environment	LMIC	Argentina	17-Jan-18	teleconference			Follow up of UNEA3, how can GAHP help Argentina tackle pollution discussion, HPAP
Cote D'ivoire	lmic		17-Jan-18				Follow up of UNEA3, how can GAHP help Argentina tackle pollution discussion, HPAP
Global Chemical Outlook Steering Committee Meeting			17-Jan-18	in person			
UNICEF			1-Feb-18	in person	Ericha Kochi		Follow up from Davos, Policy Programming Ideas with UNICEF
Sweden, Ministry of Environment and Energy	Bilateral agency	Sweden	5-Feb-18	in person	Maria Ohlman, Stina Anderson		Follow up of Lancet Comission, programming/policy discussion
Sweden, Ministry of Foreign Affairs	Bilateral agency	Sweden	5-Feb-18	in person			Follow up of Lancet Comission, programming/policy discussion
Cambodia, Ministry of Environment	LMIC	Cambodia	5-Feb-18	teleconference	Pak Sokharavuth		Follow up of UNEA3, how can GAHP help Sudan tackle pollution discussion, HPAP
Finland, Ministry of Environment	Bilateral agency	Finland	6-Feb-18	in person	Elina Rautalahti	Elina.Rautalahti@ym.fi	Commission Report and discussion
Sweden, Swedish International Development Agency (SIDA)	Bilateral agency	Sweden	7-Feb-18	teleconference	Pia Engstrand		Follow up of Lancet Comission, programming/policy discussion
Agence Francaise de Development	Donor	France	9-Feb-18	In person	Christophe Paquet		
SDC	Donor	Switzerland	22-Feb-18	teleconference	Karin Gross		Presentation of PE and GAHP work and programming/policy discussion for future collaboration
African Development Bank	Donor		23-Feb-18	teleconference	Anthony Nyong; Roxanne		Presentation of PE and GAHP work and programming/policy discussion for future collaboration
UNDP	Un Agency	NY USA	27-Feb-18	in person	Doug Webb, Natalia Linou, Adriana Dinu		Commission presentation, PE work examples, discussion on future collaboration
Canada, Permanent Mission to the UN	bilateral agency	n	16-Mar-18	in person	Ambassador Blais		Commission presentation
UNICEF	Un Agency	NY USA	20-Mar-18	in person	David Anthony, Nick Rees		Commission presentation, PE work examples, discussion on future collaboration
China Development Forum 2018		China	24-Mar-18	in person	Liu Dashan, Chairman of CECEP		Liu Dashan made a key note speech on pollution prevention and control using data an dinformation from the Lancet Commission report.
South Korea, Permanent Mission to UN	bilateral agency	NY USA	27-Mar-18	in person			Follow up of Lancet Commission, programming/policy discussion
France, Permanent Mission to UN	bilateral agency	NY USA	5-Apr-18	in person			Follow up of Lancet Commission, programming/policy sion, NCDs
Brazil, Permanent Mission to UN	bilateral agency	NY USA	12-Apr-18	in person			Follow up of Lancet Commission, programming/policy discussion, NCDs
France, Ministry of Environment and Ecology	bilateral agency	France	18-Apr-18	in person	Tudor Alexis		Follow up of Lancet Commission, programming/policy discussion, Pollution Summit hosted by France
France, Ministry of Environment and Ecology	bilateral agency	France	19-Apr-18	in person	Benoit Faraco, Denis Voisin		Follow up of Lancet Commission, programming/policy discussion, Pollution Summit hosted by France
UN Environment	Un Agency	France	19-Apr-18	in person	Fanny Demmassieux		GAHP update, Strategic discussion, India and Africa programming
UNICEF	Un Agency	NY USA	20-Apr-18	in person			Commission presentation data on panel

GUAPO	multilateral organization	France	23-Apr-18	teleconference	Elsa Martayan	Conversation on how to coordinate on air pollution in cities. Connect to IOM CALCC proposal, DoE of Nepal, MoE Argentina.
European Environment Agency	Bilateral agency	Denmark	1-Jun-18	in person		Expert presentation and participation at EEA Expert Workshop on "LT Effects of Chemical Exposures: Connecting health and socio-economic assessmets"

La Dolores, Colombia
Proyecto de evaluación e intervención por contaminación de plomo

PURE EARTH
BLACKSMITH INSTITUTE

USAID
FROM THE AMERICAN PEOPLE

Enero, 2018

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

TABLA DE CONTENIDO

1. DESCRIPCIÓN DEL SITIO

La parcelación industrial La Dolores es un corregimiento ubicado en el perímetro rural de Palmira del departamento del Valle del Cauca, Colombia. Es una zona de tipología reticulada, esto es, una estructura conformada por una evidente malla urbana que ordena unas manzanas muy bien definidas [**1**]. Se encuentra ubicada en límites con Santiago de Cali. La Dolores es la zona industrial más importante que tiene Palmira. A este corregimiento acuden trabajadores de Palmira, Cali, Yumbo y Jamundí. Tiene 18 kilómetros cuadrados, que incluyen la vereda Piles, y en él confluyen las vocaciones industrial, habitacional, agrícola y turística [**2**].

De acuerdo al censo estimado del 2015 por la Secretaría de Planeación, el 1.6% de la población total de la ciudad de Palmira pertenece al corregimiento La Dolores. Tiene una población de 1106 habitantes, de los cuales 67 predios residenciales (255 habitantes) están clasificados en el estrato 1. El resto de la población de estrato 2 está ubicada en 224 predios residenciales (851 habitantes) (Anexo 2) [**3**].

En el sector El Paso (La Dolores) se aplicó el Programa de Identificación de Sitios Contaminados – TSIP (por sus siglas en inglés) ejecutado por Pure Earth y financiado por la Oficina para el Desarrollo Industrial de Estados Unidos USAID. El sitio está ubicado entre las transversales cero y uno con calles dos y tres. La transversal cero, linda con el Rio Cauca al noreste de Santiago de Cali (Anexo 1). Esta zona de interés, se encuentra rodeada de varias industrias de recuperación y fundiciones de metales, entre las cuales se encuentran algunas dedicadas en forma específica a la recuperación de plomo de baterías de carro ya en desuso y algunas de ellas se encuentran en proceso de expansión de su operación, teniendo en cuenta la rentabilidad que brinda este negocio. Dos de estas industrias están ubicadas a una distancia que oscila entre los 50 y 200 metros de las viviendas que se distribuyen por la calle tres. El sector El Paso tiene una población estimada de 200[*] habitantes (Datos cedidos de censo de 2017 *en curso* por la Secretaria de Salud de Palmira, Anexo 3) que pertenecen al estrato socioeconómico 1 y 2. De esta cifra, el 23% corresponde a niños entre los 0 y 14 años.

2. ANTECEDENTES

Antes del año 2010 la parcelación industrial La Dolores no contaba con abastecimiento de agua potable [4]. En su momento habitaban 243 familias que adoptaron prácticas de abastecimiento de agua no potable tales como captación de pozo profundo y recolección de aguas lluvias. También, se

[*] El informe no oficial de la Secretaria de Salud de Palmira reporta 180 habitantes. Se ha aproximado a una cifra cerrada porque según información de fuentes confiables de la Secretaria de Salud hay una fracción pequeña de la población pendiente por censar.

alternaba con la compra de galones de agua potable que se transportaba en canoas, carretillas o vehículos desde la ciudad de Santiago de Cali hacia La Dolores. En septiembre del año 2010 gracias a la gestión de un líder de la junta de acción comunal, la comunidad de la parcelación industrial La Dolores inauguró el acueducto residencial suministrado por Emcali, empresa que en la actualidad es la encargada de facturar a los habitantes de La Dolores [4].

De acuerdo a información facilitada por uno de los líderes de la comunidad, información recolectada en la fase de campo inicial de las investigaciones TSIP, hace aproximadamente 6 años se han radicado quejas y derechos de petición ante la Corporación Autónoma Regional del Valle del Cauca-CVC, Secretaria de Salud Palmira y Alcaldía de Palmira por el impacto que la comunidad del sector El Paso recibe a diario en sus hogares debido a emisiones de gases aparentemente no controladas de las industrias ubicadas en ese sector por la recuperación de plomo. Como respuesta a las quejas presentadas por la comunidad, en febrero del año 2015, la Secretaria de Salud de Palmira efectuó a través del laboratorio Clínico & Microbiológico Elmer Arboleda un tamizaje de plomo en sangre a 51 individuos del corregimiento La Dolores. La selección de la población osciló entre los 16 y 78 años de edad, 61% mujeres y 38% hombres. Según reporte de la Secretaria de Salud de Palmira del 04 de Marzo de 2015, se considera intoxicación desde 77 µg /dL y en población no expuesta al plomo es aceptable hasta 38 µg /dL (Anexo 10). En tal caso, ninguno de los 51 casos analizados presenta exposición no obstante, de acuerdo a la Organización Mundial de la Salud-OMS "*Incluso las concentraciones en sangre que no superan los 5 µg/dl –nivel hasta hace poco considerado seguro– pueden entrañar una disminución de la inteligencia del niño, así como problemas de comportamiento y dificultades de aprendizaje" (http://www.who.int/ipcs/features/lead..pdf)*. Igualmente El Centro para el Control de Enfermedades (CDC) de los Estados Unidos reporta que los niveles a los cuales se debe considerar atención de seguimiento tanto para niños y como adultos es de 5 µg /dL [5], [7].

Entre el 2015 y el 2017, se realizaron dos estudios de material particulado PM 10, PM 2.5 y Plomo realizado por la Corporación Autónoma Regional del Valle del Cauca -CVC. El primero de ellos realizó un monitoreo entre septiembre del 2015 y junio del 2016 que evidenció el incumplimiento en los criterios de emisión conforme a la Resolución 610/2010 del Ministerio de Ambiente y Desarrollo Sostenible- MADS (Anexo 4). El segundo informe tuvo un monitoreo corto entre diciembre 2016 y enero 2017, en una época de lluvia. Los resultados indicaron concentraciones de plomo inferiores a los valores de referencia conforme a lo declarado por la Res. 610/2010.

En la fase de campo de la investigación de sitios TSIP se pudo evidenciar que una de las empresas de fundición de plomo tiene un proyecto de expansión en curso que aumentaría su capacidad de procesamiento de 22.000 baterías/mes a 80.000 baterías/mes. El proceso de fundición es frecuente con periodos máximos de fundición entre 14-15 días. En el momento de la visita en campo también se puede evidenciar que la actividad está permitida por CVC ya que cumple con todos los permisos que le exigen según la regulación ambiental existente. Sin embargo, en una visita de seguimiento y control ejecutada por CVC el 26 de Octubre de 2016 existe evidencia de incumplimientos a ciertos aspectos auditados (Anexo 5): El primero, relacionado con en el plan de manejo ambiental PMA 0721-00229 de 2009 para el aprovechamiento de baterías, el segundo, con el incumplimiento de las especificaciones técnicas establecidas para emisiones atmosféricas. En la actualidad, su licencia ambiental para la extensión de la industria está siendo tramitada. Para otra empresa del área la CVC también hizo unas exigencias puntuales.

Cabe anotar que según acuerdo 109 por el cual se adopta el Plan de Ordenamiento Territorial del municipio de Palmira (POT), la parcelación industrial La Dolores está clasificada como un núcleo especializado y su asignación de los usos del suelo se determina como Área de Actividad Industrial Mixta. Los núcleos especializados son aquellos cuyas características y usos principales corresponden a industrial manufacturero, agroindustrial e investigación científica con actividades complementarias de apoyo al uso principal (Anexo 6, Anexo 7).

3. VISITA DE INSPECCIÓN Y TOMA DE MUESTRAS

Pure Earth realizó la primera visita de inspección durante los días 14 y 15 de junio de 2017 en donde se seleccionaron 9 puntos que se describen enseguida y que se encuentran asociados en el informe CO-5399 de la base de Datos de Sitios Contaminados de Pure Earth. Es importante resaltar que cinco de las nueve muestras seleccionadas se tomaron dentro de las viviendas más expuestas porque fue en ellas que se identificó un ambiente notablemente denso de material particulado, así mismo el vapor metálico que emanan ambas plantas de recuperación de plomo se percibe intenso, fuerte y algunas veces sofocante. Igualmente se desarrollaron entrevistas con la comunidad, docentes, policía, líderes comunales, gerente de una de las fábricas fundidora de plomo, registro de evidencias fotográficas, coordenadas del sitio y de los puntos de muestreo seleccionados.

(Toma de muestras de suelo superficial en predios residenciales de La Dolores)

Tabla 1. Resultados de muestreo TSIP, La Dolores, El Paso.

Muestra No.	Tipo de muestra	Características de la recolección	Coordenadas	Concentración reportada

1	Agua	Tubería que proviene de tanque aéreo (Acumulación de aguas lluvias con posible material particulado. Lejos de las industrias referentes.	Long:76.474915 Lat:3.501042;	5.4 µg/L
2	Agua	2 días expuesta a la intemperie	Long:76.483137 Lat:3.498254	88µg/L
3	Agua	Caneca del tercer piso de la vivienda con aparentes partículas metálicas visibles. Tiempo de permanencia > 1 día	Long: 76.483379 Lat:3.498099	370µg/L
4	Suelo	Mezcla de suelo de plantas del último piso y barrido de casa (partículas que se asientan en la ropa y piso)	Long:76,483379 Lat:3.498099	6423 mg/kg
5	Agua	De tanque de lavado de ropa (t permanencia<1 día)	Long:76.483232 Lat:3.498183	81µg/L
6	Suelo	Mezcla suelo de plantas del segundo piso más barrido de casa	Long:76.484022 Lat:3.497592	86mg/kg
7	Suelo	Cultivo de caña cercano a la población.	Long: 76.484706 Lat:3.497566	23mg/kg
8	Suelo	Canal de agua que desemboca a entrada principal de una de las industrias fundidoras	Long: 76.482814 Lat:3.49672	8937mg/kg
9	Suelo	Frente a entrada de otra industria fundidora	Long: 76.482814 Lat:3.49672	7663mg/kg

4. *VISITA DE ANÁLISIS DETALLADO CON XRF*

El equipo técnico de Pure Earth y los representantes de USAID realizaron el 23 de agosto de 2017 una visita al sitio de la Dolores. El objetivo de la visita fue hacer una confirmación de los datos obtenidos en la primera investigación haciendo mediciones in-situ con la pistola de XRF con el fin de determinar la extensión de la contaminación en el sitio.

El XRF (X-Ray Fluorescence) es un equipo de fluorescencia de rayos X que permite la identificación de metales pesados presentes en el sitio de la lectura. Este equipo puede ser calibrado acorde a las necesidades de identificación y para este estudio está calibrado acorde a los parámetros de calibración y certificación europeos ERM y del Instituto Nacional de Tecnología y Estándares de Estado Unidos (Anexo 11).

(Toma de lecturas con XRF en predios residenciales de La Dolores)

En el sector, se realizaron mediciones in-situ con el equipo XRF desde la zona de mayor influencia del contaminante, esto es calle 3 entre transversal 1 y 0, recorriendo toda la manzana del sector Paso del Comercio entre calle 2 y 3 y finalizando por la transversal 0. La trayectoria que se realizó fue la siguiente: Inicialmente, se tomaron muestras de suelo cerca de las casas (entre 1 y 2 m) contiguas a las industrias de fundición de plomo activas. Posteriormente, en suelo agrícola, a menos de 50 m de las viviendas, donde se localiza un extenso cultivo de caña de azúcar hacia el nororiente de Cali. Después por la Calle 3 girando por la transversal 0. También se realizaron lecturas en suelo cubierto de vegetación sin asentamientos de ningún tipo. El recorrido siguió por la calle 2 donde se ubican las entradas principales de las dos industrias fundidoras de plomo reconocidas hasta finalizar la calle. Por último, se continuó por la transversal 0 en el sentido de la Calle 3 hasta completar prácticamente toda la manzana.

La frecuencia de las lecturas del XRF se realizó cada 10 m durante todo el recorrido, se identificó y se registró para cada medición las coordenadas correspondientes con ayuda del equipo GPS.

Posterior a la visita se sostuvo una reunión con la Secretaria de Salud de Palmira y La Autoridad Ambiental Regional (Corporación Autónoma del Valle del Cauca – CVC). En esta reunión se evidenció la falta de estrategias de gobierno para atender este tipo de situaciones en forma conjunta por las diversas instituciones involucradas, las cuales comparten información, pero sus alcances son totalmente diferentes. Por ejemplo, se pudo evidenciar la falta de coordinación entre las dos instituciones para ejercer acciones concretas, ya que no existe ningún protocolo o plan de acción a desarrollar en forma conjunta para dar respuesta a esta problemática. La Secretaria de Salud de Palmira recibe permanentemente quejas y solicitudes sobre la afectación a la salud de la población, y por otro lado la CVC ejecuta las acciones que están dentro del marco normativo actual para controlar la operación de fundición de plomo y las mediciones ambientales que están a su alcance.

Al final de la reunión se pudo acordar que esto requiere de un trabajo conjunto y coordinado de las dos instituciones, con el fin de tomar acciones tanto en pro de la salud de la población como del medio ambiente, para lo cual Pure Earth ofrece en primera instancia desarrollar un plan de acción que conlleve acciones encaminadas en las que se identifiquen puntos de sinergia para las dos instituciones.

5. RESULTADOS DE PLOMO EN EL AMBIENTE

a. Laboratorio

De acuerdo al informe de ensayo **BO1705638 y BO1705639** entregado por el laboratorio SGS se puede concluir que tres de las nueve muestras tomadas en el sitio La Dolores arrojan valores de plomo por encima del valor permisible para suelo residencial, esto es, según la Agencia de Protección Ambiental de Estados Unidos (EPA) de 400 mg/kg. En cambio, las muestras de agua están dentro del valor de referencia de 5,000 µg/L para agua de irrigación. Sin embargo, se debe hacer una revisión más profunda de esta agua ya que los límites permisibles para agua potable están en el orden de 10 a 15 µg/L [8] y aunque la comunidad expresa que el agua de lluvia que recolectan se utiliza para labores domésticas, también algunos vecinos mencionaron que el agua puede ser utilizada para dar de beber a los animales.

En el Anexo 8 se encuentran los resultados de los análisis de todas las muestras. Las resaltadas en recuadro rojo hacen referencia a las muestras de suelo con altas concentraciones de Plomo. De todas ellas, la muestra No. 4 se considera la de mayor impacto en el resultado de las mediciones ya que se tomó de una vivienda que está localizada justo detrás de una de las fábricas de fundición de plomo. La muestra No. 4 confirma la presencia de plomo en el aire que se libera como material particulado (emisión atmosférica) y se deposita posteriormente en el suelo. Las muestras No. 8 y 9 provienen de las entradas vehiculares de las fábricas fundidoras de Plomo activas, sendas industrias están localizadas atrás del sector residencial afectado.

La muestra No. 8 presentó una concentración de 8,937 mg/kg Pb. Se tomó en la desembocadura de una canal de agua que viene de una de las industrias activas lo cual puede dar una idea de las características de su proceso y del plan de manejo ambiental al interior de sus instalaciones. Las concentraciones de las muestras de agua No. 2, 3 y 5 se tomaron de tanques de agua y se han señalado en amarillo porque pueden ser potencialmente toxicas respecto al tiempo de permanencia de la caneca expuesta al aire libre y a su uso. Una de las razones por las que se muestrearon las canecas de recolección de aguas lluvias que dispone la comunidad del sector El Paso es porque este tipo de prácticas hace parte de la cultura del sitio afectado y actualmente continua siendo una hábito recoger el agua lluvia para lavado de ropa, riego y limpieza en general. El potencial impacto radica en que la caneca puede permanecer 1 día o más de 5 días a la intemperie antes de ser usada, por lo que puede representar una fuente de acumulación de partículas de plomo que caen por gravedad o por acción facilitada de la lluvia.

b. XRF (X-Ray Fluorescence)

Se evidenciaron valores de plomo muy por encima del valor de referencia (400ppm) establecido por la EPA, los cuales son mostrados en su distribución en el mapa anexo (Anexo 9). En puntos relativamente distantes de la zona de influencia, la concentración de plomo también arrojó niveles altos indicando la dispersión de polvo por corrientes de aire o tránsito de vehículos pesados permanentes que pueden trasladar el material particulado suspendido en el aire o generar remolinos de polvo y partículas que se dispersan por todo el sector.

Llama la atención que existen lecturas superiores a 2,000 mg/kg en el área residencial del sector El Paso en La Dolores frente a las casas y en zonas verdes de acceso disponible, donde los residentes están en continua exposición.

6. SENSIBILIZACIÓN CON LA COMUNIDAD

Comunidad Adulta

El 4 de diciembre de 2017 se realizó una reunión con la comunidad adulta de la población de la Dolores donde se presentó el programa de evaluaciones detallada que se ha venido desarrollando durante el año 2017 y los resultados de las mediciones ambientales ejecutadas a nivel de laboratorio y del XRF.

Igualmente se presentó el plan intervención a desarrollar en el corregimiento de la Dolores, el cual incluye tomas de muestra de plomo en sangre a una muestra de la población expuesta, esto debido a los altos niveles de concentración de plomo encontrados en las evaluaciones.

Finalmente se expusieron los problemas a la salud que pueden adquirirse por la exposición continua a plomo y a su vez las diferentes recomendaciones para evitar su exposición e ingreso al cuerpo por vía de inhalación, ingestión o contacto dérmico. Estas recomendaciones fueron entregadas en un material tipo calendario a la población con el fin que frecuentemente recuerden los medios de prevención.

(Reunión de sensibilización con la Comunidad Adulta de La Dolores)

Comunidad Infantil

Para el día 5 de diciembre de 2017 una población cercana a los 120 niños del sector del Paso en La Dolores fue convocada en el colegio Sebastián de Belalcazar, con el fin de hacer una actividad lúdica y de recreación enfocada a tratar temas de contaminación por plomo.

Esta actividad fue soportada por un docente especialista en este tipo de actividades sociales, quien utilizó elementos que de manera transversal se conjugan para que la temática de la contaminación logre un carácter lúdico-pedagógico. Esta característica de la actividad se llevó a cabo en cuatro etapas conformadas por narración oral y ronda, video cortometraje, gymkhana y actividad manual para comunicar el mensaje a los niños sobre los problemas de la exposición a plomo y como evitar estar en contacto con este contaminante.

(Actividad Lúdica y de sensibilización con la Comunidad Infantil de La Dolores)

Al final de esta actividad se entregó un cuaderno de notas para el año escolar 2018, el cuál fue diseñado con un cuento infantil en su interior con ayuda de una profesional social, el cual cuanta la historia de un personaje villano llamado "El Plomo" y como se puede prevenir su contacto.

(Entrega de material lúdico a población infantil de La Dolores)

7. TOMA DE MUESTRAS Y RESULTADOS DE PLOMO EN SANGRE

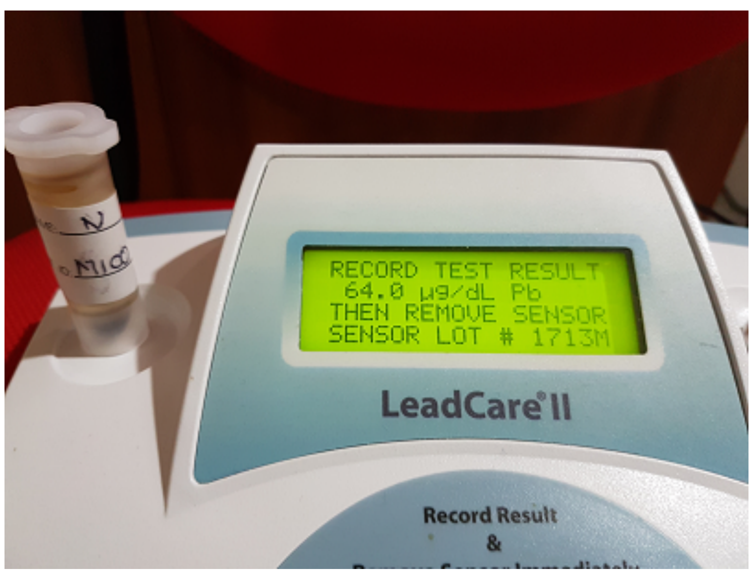
Muestreo

Los días 4 y 5 de diciembre de 2017 se llevó a cabo la jornada de toma de muestras de sangre a la población seleccionada en el puesto de salud de La Dolores prestado por la Secretaria de Salud de Palmira. Para poder desarrollar esta toma de muestras en humanos y poder determinar si existe algún nivel de plomo en ellas, fue necesario desarrollar un protocolo que fue avalado por el Comité de Ética Internacional de Pure Earth. El protocolo aprobado consistió en los siguientes pasos:

1. Comunicación del procedimiento a la persona seleccionada, la cual registraba su consentimiento con la firma de un documento escrito en el cual admite conocer el procedimiento a seguir y los riesgos a los cuales se enfrenta.
2. En el caso que la persona seleccionada fuera un menor de edad, un acudiente, especialmente sus padres, debían firmar el consentimiento correspondiente con el fin de aceptar la toma de muestra y así mismo hacerse responsable de los posibles riesgos.
3. Los datos de las personas seleccionadas para la toma de muestras se registraron en una base de datos privada en donde a cada persona se le asignaba un código, con el cual sería marcada su muestra y posteriormente su entrega del resultado. Cabe anotar que todos los datos registrados en la base de datos son netamente confidenciales y solo podrán ser compartidos con aquellas instituciones competentes en el área de la salud, en este caso corresponde a la Secretaria de Salud del Municipio quien recibirá el 100% de la información incluyendo el detalle de los resultados obtenidos.
4. La toma de las muestras fue realizada por personal de la salud, en condiciones completamente higiénicas garantizando la preservación de la muestra según el protocolo para su análisis.

(Toma de muestras de sangre en población adulta e Infantil de La Dolores)

5. Las muestras fueron analizadas antes de las 24 horas a través del equipo LEAD CARE II, el cual cuenta con un rango de desde la "no detección" hasta un valor máximo de 65 μg/dL de plomo en sangre. El tiempo de procesamiento que requiere el equipo por cada muestra es de 3 minutos.



(Lectura de plomo en sangre por equipo Lead Care II)

6. El valor obtenido por el equipo se registró en un formato de resultados, el cual solo cuenta con el código del individuo muestreado para ser ingresado a la base de datos privada.
7. El resultado fue entregado a cada una de las personas muestreadas en forma individual y confidencial, dando a conocer el resultado y su nivel acorde a lo estipulado en el protocolo. Para aquellas personas cuyo resultado registraba algún valor, el resultado se acompañaba con una hoja informativa en la cual se dan las instrucciones y recomendaciones a seguir en casa, la dieta y estilo de vida con el fin de reducir o evitar la exposición al plomo.
8. Se recomienda a todas aquellas personas que reportaron valores de plomo en sangre que soliciten un análisis de muestra confirmatoria por parte de la entidad de salud que corresponda.
9. Según el protocolo avalado por el comité de ética de Pure Earth, para todas aquellas personas que reportaron valores de plomo en sangre se hará un monitoreo en sus lugares de residencia, para poder determinar la causa y fuente de exposición y a su vez brindar las recomendaciones pertinentes para romper la exposición al contaminante.
10. Igualmente, el protocolo incluye una nueva jornada de medición de plomo en sangre en un periodo de 6 meses.
11. El número de muestras de sangre tomadas y analizadas fueron:

Adultos	102
Niños	66
Total	168

Resultados

Los resultados obtenidos para todas las muestras tomadas son:

Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)	Codigo	Nivel Pb (ug /dL)
D001	11,9	D035	36,2	D069	0	D103	14	D137	18,9
D002	10,1	D036	38,2	D070	0	D104	10,8	D138	8,5
D003	9,6	D037	3,6	D071	0	D105	9,6	D139	10
D004	24	D038	9,6	D072	6,7	D106	0	D140	5
D005	20,4	D039	14,9	D073	11	D107	0	D141	9,4
D006	16,5	D040	18,5	D074	0	D108	0	D142	10,1
D007	23,1	D041	51,7	D075	8,2	D109	9,6	D143	6,9
D008	16,2	D042	16,9	D076	9,1	D110	3,8	D144	3,9
D009	15,1	D043	12,8	D077	3,6	D111	20,4	D145	8,6
D010	20,1	D044	12,2	D078	0	D112	10,1	D146	8,8
D011	8,7	D045	4,2	D079	3,8	D113	5,7	D147	7,8
D012	6,5	D046	8,3	D080	5,4	D114	0	D148	10,5
D013	9,8	D047	16,6	D081	3,6	D115	9,1	D149	22,2
D014	7,3	D048	11,6	D082	8,7	D116	65	D150	11,3
D015	18,6	D049	10,8	D083	0	D117	0	D151	10,5
D016	24,9	D050	16	D084	11,8	D118	19.2	D152	0
D017	14	D051	3,3	D085	32,1	D119	0	D153	0
D018	4	D052	15,6	D086	0	D120	12,5	D154	0
D019	12,7	D053	20,2	D087	7,2	D121	18	D155	0
D020	10,6	D054	12,2	D088	65	D122	4,7	D156	0
D021	26,7	D055	4,9	D089	20,4	D123	N.D	D157	3,6
D022	25,4	D056	25,4	D090	31,2	D124	21,9	D158	16,8
D023	18,9	D057	0	D091	9,4	D125	12,3	D159	4,2
D024	14,3	D058	9,7	D092	0	D126	29	D160	7,2
D025	8	D059	19,1	D093	5.3	D127	3,8	D161	0
D026	42,1	D060	15,1	D094	34,7	D128	5,2	D162	0
D027	16,2	D061	20,4	D095	23,6	D129	13,1	D163	0
D028	36,1	D062	11,5	D096	19,4	D130	14,2	D164	18,2
D029	19	D063	10,3	D097	54,4	D131	10,8	D165	0
D030	21,3	D064	5,6	D098	20,8	D132	20,6	D166	0
D031	11,7	D065	15,8	D099	33,5	D133	7,3	D167	0
D032	21,6	D066	4,7	D100	24,5	D134	0	D168	0
D033	21,4	D067	20,1	D101	0	D135	13,6		
D034	16,5	D068	3,9	D102	6,1	D136	5,1		

Teniendo en cuenta la información disponible presentamos a continuación un análisis de los datos con algunas anotaciones:

- Los valores presentados en cero “0”, corresponden a lecturas no detectables por el equipo, es decir que la muestra se encuentra libre de plomo.
- Los valores presentados como “65 μg/dL”, corresponden a lecturas máximas que otorga el equipo, es decir que el valor de plomo puede estar mucho más alto en la muestra procesada.
- Para un mejor análisis y consistencia en los datos 3 valores fueron descartados por no contar con la información de la edad de las personas, sin embargo, estas muestras corresponden a personas de la tercera edad y su resultado fue cero “0”, es decir no detectable para plomo en sangre.
- Un análisis estadístico de la población adulta es:

Años de Edad									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
99	48,84	16,63	18.00-84.00	26,50	18,00	36,50	48,00	63,00	84,00

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
99	11,18	11,93	0-65.00	11,75	0	3,60	8,8	15,35	65,00
* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.									

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)**	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
76	14,56	11,67	3.6-65.0	11,38	3,6	7,30	10,8	18,68	65,00
* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo. ** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 23.									

- Un análisis estadístico de la población infantil es:

Años de Edad									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
66	7,99	4,56	0.33-16.00	7,75	0,33	4,25	8,50	12,00	16,00

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
66	15,27	10,97	0.00-65.00	11,90	0,00	8,50	14,15	20,4	65,00

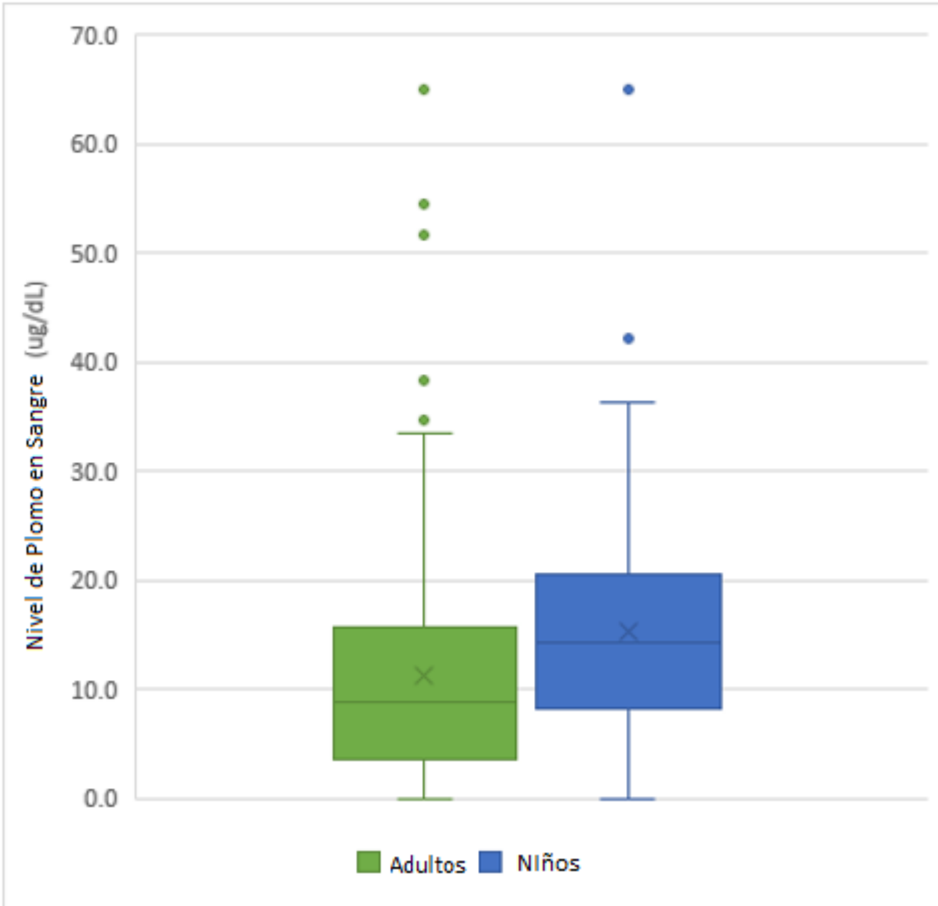
* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

Nivel de Plomo en Sangre (ug/dL)*									
Total (N)**	**Promedio**	**D. Estandar**	**Rango**	**IQR**	**Q0 (Min)**	**Q1**	**Q2 (Median)**	**Q3**	**Q4 (Max)**
62	16,26	10,58	3.0-65.00	11,05	3,30	9,65	15	20,70	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.
** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 4.

IQR= El rango intercuartílico (IQR) es una medida de la variabilidad, cuyo valor es igual a la diferencia del tercer y primer cuartil de un conjunto de datos. Análogamente a cómo una desviación estándar (SD) puede modificar un promedio, se presenta un IQR junto con una mediana, o el segundo cuartil de un conjunto de datos, para describir la variabilidad de un conjunto de datos dado.

Debido a la naturaleza de estos datos de BLL, los valores de la mediana son una mejor medida de la tendencia central que los valores promedio. Específicamente, estos datos no se distribuyen normalmente y el conjunto de datos contiene valores cero (niveles de plomo en sangre de 0 mg / dl), lo que hace que los valores promedio estén sesgados. Además, la tecnología LeadCare II utilizada para medir BLL tiene un valor de umbral superior de 65.00 □g / dL, lo que significa que los valores verdaderos para algunos individuos pueden haber sido más altos que los valores máximos en este conjunto de datos. Por lo tanto, los valores medios son mediciones más adecuadas, ya que no se ven afectados por los extremos superior e inferior.



(Resultado Promedio de Niveles de plomo en Sangre en Población de La Dolores)

Los diagramas de caja ilustran rangos intercuartílicos con barras, cada una de las cuales contiene una línea que denota el valor mediano. Los puntos se extienden en cualquier extremo de las barras hacia el cuartil cero (o el valor mínimo) y el cuarto cuartil. Los puntos representan valores atípicos, o puntos de datos individuales que están significativamente alejados de los datos restantes. Por último, los valores promedio en estos diagramas de caja están representados por una "x"

Hallazgos

Teniendo en cuenta la información analizada es posible identificar algunos hallazgos, los cuales serán tenidos en cuenta para la generación de los planes de acción y monitoreo, al igual de la búsqueda de estrategias en forma conjunta con la Secretaria de Salud de Palmira y la CVC.

Algunos puntos importantes son:

- El 84% de las muestras realizadas reportan valor de plomo en Sangre.
- El 39 % de la población muestreada corresponde a población infantil.

- Los datos poseen una distribución normal estándar.
- El promedio de edad fue de 48.80 años para adultos y de 7.99 para niños.
- El valor promedio de plomo en sangre fue de 11.18 μg/dL para adultos y de 15,27 μg/dL para niños.
- Dos muestras reportaron valores de “65 μg/dL”, una corresponde a un adulto y a otra a un niño.

8. PLANES DE ACCIÓN

A continuación, se presentan las actividades a desarrollar a futuro en pro de eliminar el contacto con el plomo a la población expuesta en el municipio de La Dolores. Cabe anotar que todos los planes aquí expuestos serán compartidos, discutidos y ajustados en forma conjunta con la Secretaria de Salud de Palmira y la CVC.

Actividad	**Fecha de ejecución**
Diseño de protocolos para hacer monitoreo en residencias y estilo de vida a los individuos que reportaron valores de plomo en sangre. El objetivo es levantar información detallada de la residencia, estilo de vida y generar recomendaciones específicas a la persona monitoreada.	Enero – Junio 2018
Jornada de capacitación a funcionarios de la autoridad ambiental local (CVC) y de la secretaria de salud, en la inspección e identificación de anomalías en los procesos de fundición de plomo. (Capacitación dada por Brian Wilson de la Asociación Internacional de Plomo –ILA-) .	Febrero – Marzo 2018
Visita de inspección y seguimiento a las pantas de fundición de plomo con el fin de aplicar los conocimientos adquiridos en la capacitación de procesos de fundición de plomo.	Marzo 2018
Jornada de monitoreo para toma de muestra de sangre y determinación de plomo en población ya estudiada en el mes de Diciembre de 2017.	Junio 2018

9. *ANEXOS*

Anexo 1. Mapa satelital del sector El Paso en La Dolores

Anexo 2. Estimación de predios y población La Dolores

ESTIMACIÓN DE NÚMERO DE PREDIOS Y POBLACIÓN POR ESTRATO SOCIOECONÓMICO SECTOR RURAL 2015															
CENTRO POBLADO (CORREGIMIENTO)	COMUNA	PREDIOS RESIDENCIALES						POBLACIÓN ESTIMADA							
		ESTRATO					TOTAL PREDIOS	ESTRATO					TOTAL POBLACIÓN	
		1	2	3	4	5		1	2	3	4	5		
La Acequia		55	251	0	0	0	306	209	954	-	-	-	1.163	1,6%
La Torre	8	103	708	7	0	0	818	391	2.690	27	-	-	3.108	4,4%
Rozo		548	3261	25	0	0	3834	2.082	12.392	95	-	-	14.569	20,6%
La Herradura		57	209	1	0	0	267	217	794	4	-	-	1.015	1,4%
Matapalo		18	142	0	28	0	188	68	540	-	106	-	714	1,0%
Obando	9	80	112	1	0	0	193	304	426	4	-	-	733	1,0%
Palmaseca		130	573	3	0	0	706	494	2.177	11	-	-	2.683	3,8%
Caucaseco		156	131	0	1	0	288	593	498	-	4	-	1.094	1,6%
Guanabanal		222	297	0	0	0	519	844	1.129	-	-	-	1.972	2,8%
Juanchito	10	32	3876	2	0	0	3910	122	14.729	8	-	-	14.858	21,0%
La Dolores		67	224	0	0	0	291	255	851	-	-	-	1.106	1,6%
Piles		32	16	0	0	0	48	122	61	-	-	-	182	0,3%
Bolo Alizal		62	97	2	0	0	161	236	369	8	-	-	612	0,9%
Bolo La Italia	11	98	178	0	0	0	276	372	676	-	-	-	1.049	1,5%
Bolo San Isidro		52	549	11	0	0	612	198	2.086	42	-	-	2.326	3,3%
Amaime		64	857	0	0	0	921	243	3.257	-	-	-	3.500	5,0%
Boyacá	12	22	277	0	0	0	299	84	1.053	-	-	-	1.136	1,6%
La Pampa		182	91	0	0	0	273	692	346	-	-	-	1.037	1,5%
Barrancas	13	78	195	2	0	0	275	296	741	8	-	-	1.045	1,5%
Guayabal		58	175	6	0	0	239	220	665	23	-	-	908	1,3%

Anexo 3. Documento no oficial de la secretaría de salud

POSIBLE AFECTACIÒN A LA SALUD POR PLOMO EN EL CORREGIMIENTO DE LA DOLORES MUNICIPIO DE PALMIRA-VALLE DEL CAUCA

OBJETIVOS

- Identificar la población vulnerable por posible contaminación por plomo.
- Realizar un análisis sintomático de la población.
- Definir la población para realizar tamizaje en sangre.
- Relacionar el componente sintomático con la cercanía a las industrias críticas.

ÁREA DE ESTUDIO

El corregimiento de La Dolores se localiza al occidente del municipio de Palmira limita al noroeste con el municipio de Yumbo y al oeste con el Municipio de Cali, del cual se encuentra separado por el rio Cauca. El acceso al corregimiento es por la vía Cali-Palmira. Las vías internas no se encuentran pavimentadas, cuenta con nomenclatura, servicio de acueducto y gas natural; adema con un puesto de salud, estación de Policía y una institución educativa. Según el Plan de Ordenamiento Territorial del Municipio de Palmira, acuerdo 109 de 2001, todo el corregimiento es catalogado como área de actividad industrial.

Al ser una zona industrial se encuentran diferentes tipos de empresas que llevan a cabo actividades de metalistería, fundición, recuperación de materiales, producción de cemento y papel. Las viviendas son dispersas, sin embargo existe una zona densamente poblada conocida como el sector El Paso, ubicado en la calle 3 entre transversal 0 y 1.

El dato del número de viviendas actuales no es claro, sin embargo se presume de 130 unidades habitacionales, de las cuales aproximadamente 64 se localizan en el sector El Paso, para un estimado de 180 personas. A continuación se presenta un dato preliminar por edades de los niños del sector El Paso.

Niños	Cantidad
<1 año	7
1-2 años	5
3-4 años	2
5-6 años	6
7-8 años	7

Centro Administrativo Municipal de Palmira - CAMP
Carrera 27 No. 29 -32: Código Postal 763533
www.palmira.gov.co
TELEFONO:2718246-2710251-2707486

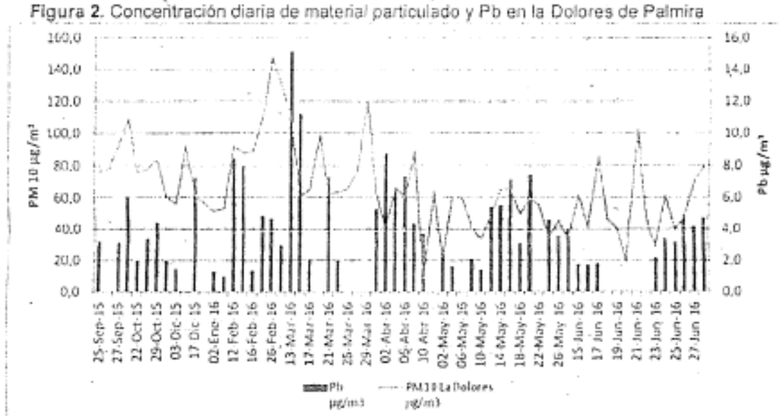
Anexo 4. Resultados Informe CVC

Corporación Autónoma Regional del Valle del Cauca

Tabla 5. Evaluación de las concentraciones de Plomo reportadas durante septiembre 25 de 2015 a 28 de junio de 2016 en el corregimiento de La Dolores con respecto a la normativa vigente

Estadístico	Plomo µg/m³	Norma Anual MADS	Norma Diaria MADS	Cumplimiento
Promedio	4,40	0,5	1,5	No
Desv. Estándar	2,83			
Máximo	15,11			
Mínimo	0,96			
Excedencias	44			

Figura 2. Concentración diaria de material particulado y Pb en la Dolores de Palmira



Hubo 15 días en que no se registró plomo en el aire, la concentración de PM10 en esos días osciló entre 19,0 µg/m³ y 120,0 µg/m³

Se observa durante los fines de semana un marcado descenso en las concentraciones de plomo.

Corporación Autónoma Regional del Valle del Cauca

alveolos pulmonares, en donde se realiza el intercambio gaseoso con la corriente sanguínea.[2]

Las partículas menores a 10 micrómetros (PM10) son generadas principalmente por la resuspensión del polvo del suelo, la minería, la erosión y el tráfico vehicular, mientras que las partículas menores a 2.5 micrómetros (PM2.5) son emitidas por procesos de fundición y de combustión de diesel, gasolina o carbón.

B. Plomo

El plomo es una potente neurotoxina que se acumula gradualmente en algunos tejidos del cuerpo humano. Su exposición puede generar diversos daños en riñones, sistema hepático, sistema gastrointestinal y sistema óseo. Los niños son particularmente vulnerables al plomo ya que puede afectar su desarrollo neurológico. El daño ocasionado por la exposición al plomo dependerá de la dosis, tiempo de exposición y estado de salud en que encuentra la persona expuesta.

El plomo se emite en forma de partículas durante actividades industriales como la explotación minera, metalurgia, refinación de metales, fabricación de pintura y soldadura.

Tabla 4. Evaluación de las concentraciones de PM10 reportadas durante septiembre 25 de 2015 a 28 de junio de 2016 en el corregimiento de La Dolores con respecto a la normativa vigente y los valores guía de la OMS

Estadístico	PM10 µg/m³	Norma Anual MADS	Anual OMS	Cumplimiento
Promedio	57,15	50	20	No
Desv. Estándar	33,46			
Máximo	148,20			
Mínimo	2,32			
Excedencias	6			

Anexo 5. Visita de seguimiento y control a industrias de la Dolores

CVC
Corporación Autónoma Regional del Valle del Cauca

Página 1 de 7
0721-592392016

Palmira, 26 de Octubre de 2016.

CONTRALORÍA MUNICIPAL DE PALMIRA
No. Rad 0127 Fecha: 20-01-2017
Hora: 10:45 Folios: 4 anexos
Recibido Por:

Señor:
ALICIA SARASTI CAICEDO
Jefe Oficina de Medio Ambiente y Participación Ciudadana
Contraloria Municipal de Palmira
Calle 30 No 30-17 Esquina
Palmira, Valle Del Cauca.

Referencia: Respuesta oficio 130-30-01-1147 2098

Dando respuesta a su solicitud frente al derecho de petición del señor Guillermo Rosero, me permito informarle que la petición de cierre de la Empresa Fundimetales por motivos de salud pública no es de nuestra competencia.

Es importante informarle que la CVC realizo visitas y actuaciones administrativas de acuerdo con sus competencias no solo en la Empresa Fundimetales sino en diferentes actividades de fundición en la Parcelación Industrial La Dolores, las cuales se describe a continuación:

Las actuaciones realizadas a las empresas se describen asl:

A y G Ingeniería Fundimetales.

Se realizó visita de seguimiento y control al permiso de vertimientos líquidos, plan de manejo ambiental, premiso de emisiones atmosféricas, concesión de aguas subterráneas y se evaluó la gestión de residuos peligrosos. En las dos visitas se evidenciaron entre otras los siguientes incumplimientos:

1. El plan de manejo ambiental PMA 0721- 00229 de 2009, para el aprovechamiento de baterías se estaba incumpliendo por la capacidad de almacenamiento la cual estaba establecida en el plan para 300 baterías y en el momento de la visita habían más de 7000 baterías. Medida preventiva impuesta en flagrancia el 13 de septiembre de 2016.

2. La obligación No 8 del permiso de emisiones atmosféricas referente a la medición de calidad de aire, fue entregada a destiempo y no cumple con las especificaciones técnicas establecidas en la Resolución 0720 No 0721-001006-2014.

Anexo 6. Plano A-20B Perímetro uso del suelo en el corregimiento La Dolores

Anexo 7. Acuerdo 106 del POT

   b) Construcción de la red de alcantarillado.
   c) Estudio para localización y construcción de un sistema de aguas servidas.
   d) Protección de las fuentes para abastecimiento de agua: quebradas La Veranera, Las Truchas, Los Chorros, La Muela y los ríos Cabuyal y Toche.
   e) Construcción sistema eléctrico zona alta.
3. Para el Sistema Vial:
   a) Recuperación sistema vial. Construcción de obras de arte (cunetas conformación y cobertura de taludes)
4. Para el Marco Ambiental:
   a) Proyectos de seguridad alimentaria, biodiversidad de flora y fauna y conservación de suelos con barreras vivas.
5. Para la producción agropecuaria:
   a) Optimizar el distrito de riego en ladera de Toche la Veranera.
   b) Construir el distrito de riego en ladera de Cabuyal.
   c) Conservación de suelos y aguas en el área de influencia de los distritos de riego en ladera de Toche y Cabuyal.

Capitulo 3 Núcleos Especializados

Artículo 159. Núcleos Especializados. Definición.
Son aquellos cuyas características y usos principales corresponden a industrial manufacturero, Agroindustrial e investigación científica con actividades complementarias de apoyo al uso principal.

Corresponden a esta definición los núcleos establecidos en el artículo 40 del presente acuerdo.

Parágrafo: El Municipio de Palmira adelantará en un plazo no mayor a tres (3) años contados a partir de la vigencia de este Plan, un proceso de concertación entre los interesados, para identificar las áreas aledañas al perímetro urbano de la cabecera municipal, requeridas para la ubicación de un núcleo especializado para la localización de pequeñas y medianas industrias agroindustriales y manufactureras de bajo impacto ambiental.

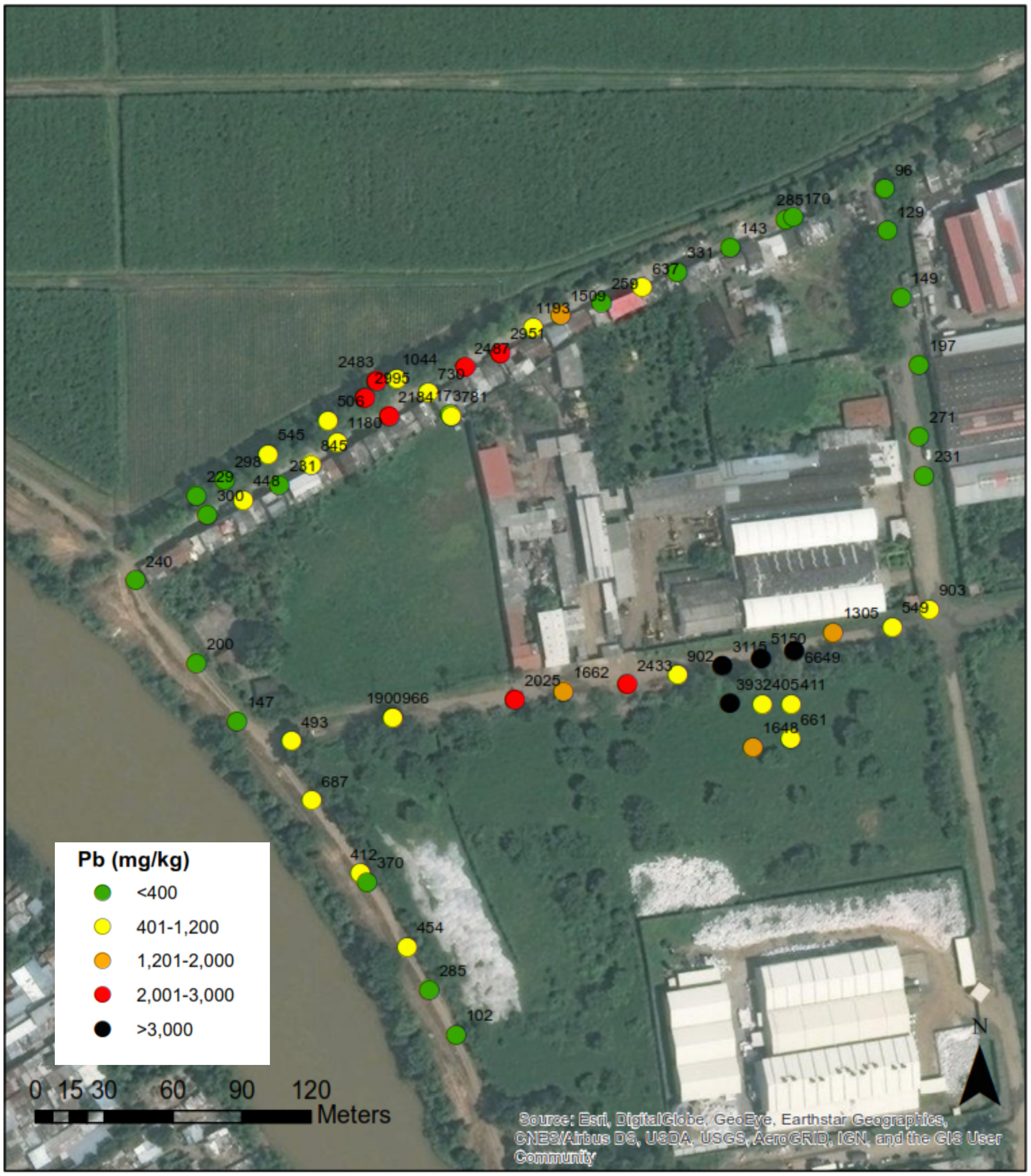
Artículo 160. La Dolores. Delimitación., Clasificación del suelo y áreas de actividad.
Para efectos de la asignación de los usos del suelo se determina como Area de Actividad Industrial Mixta, tal como aparece en el plano No. A20 del cual forma parte integral del presente acuerdo.

Artículo 161. Directrices de Ordenamiento de La Dolores.
Se determinan para el Centro Poblado La Dolores, las siguientes directrices de ordenamiento:
1. Para los Usos del suelo
   a) Consolidar el asentamiento con carácter exclusivamente industrial y mantener la ocupación residencial existente.
2. Para los Servicios Públicos

Anexo 8. Resultados de laboratorio

Sample Sector	Sample Type Sampling Media Pathway	Population	Test Result Latitude Longitude	Units	Rec Level	BI
1	targeted Water - Irrigation/Bathing/Washing Dust/soil/inhalation/ingestion	300	5.40000000 3.501042 76.474915	ug/l or ppb	5000.00000000	0
2	targeted Water - Irrigation/Bathing/Washing Dermal contact	0	88.00000000 3.498254 76.483137	ug/l or ppb	5000.00000000	0
3	targeted Water - Irrigation/Bathing/Washing Dermal contact	150	370.00000000 3.498099 76.483379	ug/l or ppb	5000.00000000	0
4	composite Soil - Residential Dust/soil/inhalation/ingestion	100	6423.00000000 3.498099 76.483379	mg/kg or ppm	400.00000000	4
5	targeted Water - Irrigation/Bathing/Washing Food ingestion	50	81.00000000 3.498183 76.483232	ug/l or ppb	5000.00000000	0
6	composite Soil - Residential Dust/soil/inhalation/ingestion	0	86.00000000 3.497592 76.484022	mg/kg or ppm	400.00000000	0
7	targeted Soil - Agriculture Food ingestion	0	23.00000000 3.497566 76.484706	mg/kg or ppm	400.00000000	0
8	targeted Soil - Industrial Dust/soil/inhalation/ingestion	50	8937.00000000 3.49672 76.482814	mg/kg or ppm	1200.00000000	4
9	targeted Soil - Industrial Dust/soil/inhalation/ingestion	0	7663.00000000 3.49672 76.482814	mg/kg or ppm	1200.00000000	-INF

Anexo 9. Mapa del análisis XRF



Anexo 10. Tamizaje de plomo en sangre

	SECRETARÍA DE PROTECCIÓN EN SALUD	CÓDIGO:	FO-SPB-100
	PROCESO: SALUD PÚBLICA	VERSIÓN:	1.0
	SUBPROCESO: VIGILANCIA EN SALUD PUBLICA	FECHA:	04-29-2011
ALCALDÍA DE PALMIRA (V) NIT: 891.380.007-	OFICIO	TRD:1152.9- 061	

Tamizaje de Plomo en sangre Corregimiento La Dolores

Por: Christian Gonzalez, MD Epidemiólogo Palmira
Fecha: 04 de marzo de 2015

Contexto

La Comuna rural 10 del Municipio de Palmira está integrada por los Corregimientos de La Dolores, Guanabanal, Caucaseco, Juanchito.

El Corregimiento de La Dolores se ha sentido afectada por la presencia de una industria de fundición de plomo, que recicla el plomo de baterías y lo pone a disposición de consumidores institucionales de este metal en su forma sólida.

Por esta razón y como parte de la presencia institucional de la Secretaria de Salud de Palmira se realizaron valoraciones médicas a la población, tendientes a verificar la presencia de sintomatología sugestiva de intoxicación aguda o crónica por plomo, sin encontrarse casos compatibles.

Se decidió profundizar en la búsqueda realizando pruebas de laboratorio en la comunidad para determinar los niveles de plomo en sangre.

Población y muestra

Se seleccionó una muestra de 51 adultos en residencias cercanas a la citada industria a razón de una persona por vivienda, con la condición de que efectivamente permaneciera la mayor parte del tiempo en el corregimiento, cuya identificación se realizó a través de la Junta de Accion Comunal.

La muestra de población seleccionada oscila entre los 16 y los 78 años de edad, 61% mujeres y 39% hombres.

Resultados

De acuerdo a los valores de referencia del Ministerio de Salud y Proteccion Social se considera intoxicación desde los 77 µg/dl y en población no expuesta al plomo es aceptable hasta 38 µg/dl de plomo en sangre.

En las 51 pruebas realizadas los niveles de plomo en sangre oscilan entre 2 y 14 µg/dl, considerándose dentro del rango normal.

Se sugiere hacer pruebas de plomo en sangre a algunos niños de 0 a 15 años de edad que cumplan los criterios de selección ya que este grupo etario no fue evaluado, y complementar la investigación realizando mediciones sobre otras formas de contaminación ambiental que se estimen pertinentes.

Anexo 11. Certificaciones Equipo XRF

National Institute of Standards & Technology

Certificate of Analysis

Standard Reference Material® 2709a

San Joaquin Soil

Baseline Trace Element Concentrations

This Standard Reference Material (SRM) is intended primarily for use in the analysis of soils, sediments, or other materials of a similar matrix. One unit of SRM 2709a consists of 50 g of dried, powdered, agricultural soil.

Certified Values: The certified concentrations for 19 elements, expressed as mass fractions [1] on a dry-mass basis, are provided in Table 1. Certified values are based on results obtained from critically evaluated independent analytical techniques. A NIST certified value is a value for which NIST has the highest confidence in its accuracy in that all known or suspected sources of bias have been investigated or taken into account [2].

Reference Values: The reference values for 15 constituents, expressed as mass fractions on a dry-mass basis, are provided in Table 2. The reference values are based on results obtained from a single NIST analytical method. Reference values are non-certified values that are the best estimate of the true value; however, the values do not meet NIST criteria for certification and are provided with associated uncertainties that may not include all sources of uncertainty [2].

Information Values: The values for 10 elements are provided in Table 3 for information purposes only. These are non-certified values with no uncertainty assessed. The information values included in this certificate are based on results obtained from one NIST method.

Expiration of Certification: The certification of SRM 2709a is valid, within the measurement uncertainties specified, until **1 November 2018**, provided the SRM is handled in accordance with the instructions given in this certificate (see "Instructions for Use"). This certification is nullified if the SRM is damaged, contaminated, or otherwise modified.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive technical changes occur that affect the certification before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

E.A. Mackey and R.R. Greenberg of the NIST Analytical Chemistry Division were responsible for coordination of the technical measurements leading to certification.

Statistical analyses were performed by J.H. Yen of the NIST Statistical Engineering Division.

The support aspects involved in the issuance of this SRM were coordinated through the NIST Measurement Services Division.

Stephen A. Wise, Chief
Analytical Chemistry Division

Gaithersburg, MD 20899
Certificate Issue Date: 7 April 2009

Robert L. Watters, Jr., Chief
Measurement Services Division

Addendum to Certificate

Standard Reference Material® 2709a

San Joaquin Soil

Baseline Trace Element Concentrations

Leachable Concentrations Determined Using USEPA Methods 200.7 and 3050B

The mass fraction values contained in the NIST Certificate of Analysis for SRM 2709a represent the total element content of the material. The measurement results used to provide the certified, reference, or information values are obtained from methods that require complete sample decomposition, or from nondestructive analytical methods such as instrumental neutron activation analysis or prompt gamma-ray activation analysis. Where complete sample decomposition is required, it can be accomplished by digestion with mixed acids or by fusion. For mixed-acid decomposition, hydrofluoric acid must be included in the acid mixture used to totally decompose siliceous materials such as soils and sediments.

In its monitoring programs, the U.S. Environmental Protection Agency (USEPA) has established a number of leach methods for the preparation of soil samples for the determination of extractable elements. Eight laboratories participated, seven of which used USEPA Method 200.7; the remaining laboratory used USEPA SW-846 Method 3050B for preparation of soil samples. All elements were determined in leachates by inductively coupled plasma optical emission spectrometry. Six of the eight laboratories provided individual results from duplicate portions, and these results were averaged together to provide one result for each element from each participating laboratory. Results rejected as outliers by the USEPA Contract Laboratory Program (CLP) officials were not included. Results are summarized in Table A1. The ranges of mass fraction values, median values (to two significant figures), and the number of results included for each are given for 23 elements. The percent recovery values based on the ratios of the median values to the total element content (from the certified, reference, or information values in the Certificate of Analysis) are listed in the last column of Table A1. **Note that the certified values provided as total mass fractions in the Certificate of Analysis are the best estimate of the true mass fraction values for this material.**

This USEPA CLP Study was coordinated by Clifton Jones, Quality Assurance and Technical Support Program, Shaw Environmental & Infrastructure Group, Las Vegas, NV, under the direction of John Nebelsick, USEPA, Analytical Services Branch. The participating laboratories are listed in Table A2.

Table A1. Results from Laboratories Participating in the EPA Contract Laboratory Program Study.

Element	n	Range (mg/kg)			Median (mg/kg)	Recovery (%)
Aluminum	7	13000	-	17000	16000	22
Antimony	2	1.2	-	1.5	1.4	88
Arsenic	8	6.4	-	10	7.8	74
Barium	8	350	-	400	380	39
Beryllium	7	0.50	-	0.72	0.61	--
Cadmium	5	0.33	-	0.66	0.40	110
Calcium	8	12000	-	14000	12000	65
Chromium	8	46	-	67	53	41
Cobalt	8	8.2	-	13	10	81
Copper	7	24	-	28	27	81
Iron	8	22000	-	26000	24000	70
Lead	7	8.1	-	11	9.2	53
Magnesium	7	9700	-	11000	10000	71
Manganese	8	380	-	450	420.0	79
Mercury	8	0.79	-	0.92	0.87	97
Nickel	8	59	-	71	66	77
Potassium	8	2600	-	4000	2900	14
Selenium	5	0.69	-	1.9	0.95	63
Silver	4	0.14	-	4.1	0.64	--
Sodium	7	460	-	610	500	4
Thallium	2	0.74	-	1.6	1.2	200
Vanadium	8	43	-	71	48	44
Zinc	8	69	-	87	79	77

Table A2. List of CLP and non-CLP Participating Laboratories

A4 Scientific, Inc.
Bonner Analytical Testing Co.
Chem Tech Consulting Group
Datachem Laboratories, Inc.
Liberty Analytical Corporation
MSE Laboratory Services
Shealy Environmental
SVL Analytical Inc.

Institute for Reference Materials and Measurements

ERM European Reference Materials

CERTIFICATE OF ANALYSIS

ERM®- EC680k

LOW DENSITY POLYETHYLENE		
	Mass Fraction	
	Certified value [1)] [mg/kg]	Uncertainty [2)] [mg/kg]
As	4.1	0.5
Br	96	4
Cd	19.6	1.4
Cl	102.2	3.0
Cr	20.2	1.1
Hg	4.64	0.20
Pb	13.6	0.5
S	76	4
Sb	10.1	1.6

1) Unweighted mean value of the means of 5-14 accepted sets of data, each set being obtained in a different laboratory and/or with a different method of determination. The value is traceable to the International System of Units (SI).
2) The certified uncertainty is the expanded uncertainty estimated in accordance with the Guide to the Expression of Uncertainty in Measurement (GUM) with a coverage factor k = 2.78 for Cr and k = 2 for all other elements, corresponding to a level of confidence of about 95 %.

This certificate is valid for one year after purchase.

Sales date:

The minimum amount of sample to be used is 150 mg.

NOTE

European Reference Material ERM®-EC680k was produced and certified under the responsibility of the IRMM according to the principles laid down in the technical guidelines of the European Reference Materials® co-operation agreement between BAM-IRMM-LGC. Information on these guidelines is available on the internet (http://www.erm-crm.org).

Accepted as an ERM®, Geel, May 2007

Signed: ______________________

Prof. Dr. Hendrik Emons
Unit for Reference Materials
EC-DG JRC-IRMM
Retieseweg 111
2440 Geel, Belgium

All following pages are an integral part of the certificate.

10. REFERENCIAS

[**1**] Situación Económica de Palmira y su Área de Influencia (Pradera, Florida y Candelaria). 2015. P. 5-7. http://www.ccpalmira.org.co/portal/images/Docs/Situacion_economica/INFORME%20SITUACION%20ECONOMICA%202015.pdf

[**2**] http://www.elpais.com.co/valle/corregimiento-de-la-dolores-quiere-hacer-parte-de-rozo.html

[**3**] Población La Dolores Anuario 2015

[**4**] http://www.elpais.com.co/valle/corregimientos-de-la-dolores-y-caucaseco-tendran-agua-potable.html

[**5**] https://www.cdc.gov/nceh/lead/acclpp/lead_levels_in_children_fact_sheet.pdf

[**6**] Acuerdo 106 del 2001 Pág. 54.

[7] https://www.cdc.gov/niosh/topics/ables/description.html

[8] https://www.atsdr.cdc.gov/csem/csem.asp?csem=34&po=8

Esta publicación es posible gracias el generoso apoyo del pueblo estadounidense a través de la Agencia Para el Desarrollo Internacional

Benchmarking Assessment Tool Training Workshop

Training Course
Cali - Colombia

April 9 – 11, 2018

475 Riverside Drive, Suite 860, New York, NY 10115 Ph. +1.212.870.3490 Fax +1.870.3488
www.pureearth.org

General Information

Location

- City: Cali
- Place: Colombian Association Of Sanitary And Environmental Engineering - ACODAL
- Address : Calle 10N #9N-34, Cali, Valle del Cauca

Assistants

- 25 people in total

Name	Institution
Brian Wilson	ILA
Brenda Natalia Lopez Niño	ILA
Sandra M. Gualtero	Pure Earth
Alfonso Rodríguez	Pure Earth
Vanessa Vega Hernandez	Pure Earth
Natahalia Paredes	Pure Earth
John Sandoval	Pure Earth
Lina Garcia	Pure Earth
Astrid Eliana Reyes Peña	Ministerio de Ambiente
Carlos Jairo Ramirez	Ministerio de Ambiente
Carlos Manuel Pineda	Ministerio de Ambiente
John Jairo Noreña	Alcaldia Malambo
Geinny Vasquez	CRA
Adriana Maria Zapata	Ideam
Carlos Daniel Urrea	Ideam
Angela Maria Sanchez	Dagma
Neftali Jimenez Restrepo	Dagma
Gustavo Adolfo Ortega Hungria	Dagma
Abelardo Angulo Cabezas	Dagma
Isabela Caicedo	Secretaria Valle
Jairo Guzman	Secretaria Salud Valle
Rodrigo Pavón	Johnson Control
Juan Héctor Vargas	Johnson Control
Carlos Romero	Johnson Control
Mario Herrera	Johnson Control

- Pure Earth Team

- Goverment Officials

Trainers

Brian Wilson Natalia López

Course Development and Practical Exercise

PURE EARTH BLACKSMITH INSTITUTE — ila International Lead Association — USAID FROM THE AMERICAN PEOPLE

Agenda and program

Day – Training Pure Earth Team: April 9, 2018

Same topics of the agenda, but in only one day for the Pure Earth Team.

Day 1: April 10, 2018

Hora	*Actividad*	*Responsable*
8:15 – 8:30	Registration	
8:30 - 8:45	Welcome Cali – Introduction Coourse	Pure Earth
8:45 - 9:00	Presentation Assisstant	Everyone
9:00 – 9:15	TSIP Advance Project	Pure Earth Internacional
9:15 – 9:30	Environmental Liabilities	Ministry of Environment
9:30 – 9:45	Hazardous Waste in Colombia	IDEAM
9:45 – 10:00	Hazardous Waste in Cali	DAGMA
10:00 - 10:15	Coffee Break	
10:15 - 11:45	The ESM of ULAB Recycling: Collection, Temporary Storage, Transportation	ILA / Pure Earth
11:45 - 12:45	The ESM of ULAB Recycling: Reception, Breaking, Smelting, Refining	ILA / Pure Earth
12:45 - 13:45	Lunch	
13:45 - 14:05	The Use and Application of the BAT Process for Site Assessment	ILA / Pure Earth
14:05 - 16:00	Simulated Site Inspection and Assessment and Afternoon Break	Todos
16:00 - 16:15	Coffee Break	
16:15 - 17:20	Review and questions sesión 1	Todos
17:20 - 17:30	Presentation of the BAT Accreditation Certificates	ILA

Day 2: April 11 , 2018

Hora	*Actividad*	*Encargado*
8:30 - 8:45	Assembly and Morning Coffee/Tea	Todos
8:45 - 9:00	Review and questions sesión 1	Todos
9:00 – 9:30	Environmental Sampling and Monitoring	ILA / JCI
9:30 – 10:00	Laboratory Analysis	ILA / JCI
10:00 - 10:15	Coffee Break	
10:15 - 11:00	The Next Steps and Action Plans	Pure Earth
11:00 – 11:45	Workshop Review and Close	Todos
12:00 – 13:00	Lunch and Close	

Satisfaction Survey Results

At the conclusion of the course, participants were asked to complete a survey to evaluate their experience. The survey consisted of twelve questions, assessing features such as the organization, clarity and usefulness of the training. Participants were asked to rate their agreement to each question from one to five, with a low score indicating a negative assessment and a high score a positive assessment. Of the participants, eighteen completed the survey.

In general, the results of the survey were positive. The average scores were 4.6/5 among all participants, 4.8/5 among government officials, and 4.2/5 among non-government participants. Additionally, when asked to rate their overall satisfaction with the course from 1-10, the average score was 8.7, with government officials averaging 9.0 and non-government officials 7.8.

List Assistants

Fecha: Abril 9 de 2018
Lugar: ACODAL - CALI

Taller - Herramienta de evaluación comparativa para el manejo de baterías usadas de plomo en Colombia – BAT

Apellido, Nombre	Email	Número de Teléfono	Nombre de la Institución	Marque Uno: Personal del Gobierno local	Personal del Gobierno Nacional	Otro
Rodríguez, Alfonso	arodriguez@pureearth.org	3142079683	Pure Earth			X
Jon Jairo Sandoval C.	zaratustra70@hotmail.com	3186652137	Pure Earth			X
Vega H., Vanessa	vanevega4@gmail...	3013188051	Pure Earth			X
Nathalia Paredes	nparedesamado@yahoo.com	3168224 75	Pure Earth			X
Gualtero, Sandra	sgualtero@pureearth.org	1-201419-8284	Pure Earth			X
Natalia López	natalopez78@gmail.com	3507852265	CONSULTANT.			X
BRIAN WILSON	bwilson@ila-lead.org		ILA			X

Fecha: Abril 10 de 2018
Lugar: ACODAL - CALI

Taller - Herramienta de evaluación comparativa para el manejo de baterías usadas de plomo en Colombia – BAT

Apellido, Nombre	Email	Número de Teléfono	Nombre de la Institución	Marque Uno: Personal del Gobierno local	Personal del Gobierno Nacional	Otro
Pavan, Rodrigo	rodrigo.pavan@jci.com	1(414)902 3615	JCI			+
Vasquez Ginny	gvasquez@cvc...gov.co	3686626 ext 108	CRA		X	
Noreña John Jairo	zozanoga@gmail.com	3008143361	Alcaldía Palmira	X		
REYES PEÑA ASTRID ELIANA	aereyes@minambiente.gov.co	3137474997	MIN. AMBIENTE		X	
Carlos Manuel Pineda	cpineda@minambiente.gov.co	310637601	MINAMBIENTE		X	
Carlos Jairo Ramírez	cjramirez@	3002037924	MADS		X	
Carlos Romero	carlos.romero.ripane@jci.com	3137371060	JCI			X
Juan H Vargas	Juan.H.Vargas@jci.com		JCI			X
Herrera Mario	mario.herrera.tere@jci.com	7102592179	JCI			
Angela Sánchez	angela.sanchez@...univalle.edu.co	3155348119	DAGMA.	X		
García D. Lina Fernanda	linofg14@gmail.com	3157003497.	Pure Earth.			X.

Fecha: Abril 10 de 2018
Lugar: ACODAL - CALI

Taller - Herramienta de evaluación comparativa para el manejo de baterías usadas de plomo en Colombia – BAT

Apellido, Nombre	Email	Número de Teléfono	Nombre de la Institución	Marque Uno: Personal del Gobierno local	Personal del Gobierno Nacional	Otro
Isabela Caudo	chumycaudo@hotmail.com	3126705181	UES Valle	X		
Adriana Zapata	azapata@ideam.gov.co	3106790821	IDEAM		X	
Daniel Urrea	currea@ideam.gov.co	3178775639	IDEAM.		X.	
Jairo Guzman Angel	Jguzman@valledelcauca.gov.	3168906641	S.D.S.- S. Amb.	X		
Abelardo Angulo C	abelardoangulocpl@hotmail.com	3170104733	DAGMA - GAE.	X		
Gustavo Adolfo Ortega	gaol19@hotmail.com	3175755967	DAGMA GAE	X		
Neftalí Jiménez Restrepo	neftali.jimenez@cali.gov.co	3163480110	DAGMA - GAE	X		
Nathalia Paredes	nrparedescamacho@yahoo.com	3162522475	Pure Earth			X
John J. Sandoval	zancutosta.jo@hotmail.com	3186652137	Pure Earth			X

Fecha: Abril 11 de 2018
Lugar: ACODAL - CALI

Taller - Herramienta de evaluación comparativa para el manejo de baterías usadas de plomo en Colombia – BAT

Apellido, Nombre	Email	Número de Teléfono	Nombre de la Institución	Marque Uno: Personal del Gobierno local	Personal del Gobierno Nacional	Otro
Pavón, Rodrigo	rodrigo.pavon@jci.com	4(414)9023615	JCI.			
Juan H Vargas R	Juan.H.Vargas@jci.com	52 81 82549215	JCI			
Carlos Manuel Pineda	cpineda@minambiente.gov.co	3106257601	MADS.		X	
Geinny Vasquez V.	gvasquez@minambiente.gov.co	3686626	CRA		X	
Isabela Caudo	chumycaudo@hotmail.com	3126705181	UES Valle	X		
John Jairo Noreña G.	jnorenaga@gmail.com	3008143361	Alcaldía Palmira	X		
Romero, Carlos	carlos.romero.figueroa@jci.com	3137771060	JCI			X
Carlos J. Ramirez	cjramirez@	3002037924	MADS		X	
Vega V, Daniella	Daniella.0414@gmail	3013188051	PURE EARth			X

Fecha: Abril 11 de 2018
Lugar: ACODAL - CALI

Taller - Herramienta de evaluación comparativa para el manejo de baterías usadas de plomo en Colombia – BAT

Apellido, Nombre	Email	Número de Teléfono	Nombre de la Institución	Marque Uno		
				Personal del Gobierno local	Personal del Gobierno Nacional	Otro
JAMES CAICEDO.	gerencia@gemaconsultry.co	3113990990.	SCI-MAC-GEIMA			
Adriana Zapata	azapata@ideam.gov.co	3106790321	IDEAM		X	
DANIEL CORREA A	correa@ideam.gov.co	3173775634 3527160 ext 1601	IDEAM		X	
Garcia D. Lina F.	linafg1[illegible]@gmail.com	3152003197.	Pure. Earth.			X
Gustavo Adolfo Ortega	gaoh19@hotmail.com	3176755967	Dagma GAE	X		
Angela Ma Sanchez	angela.sanchez@correounivalle.edu.co	3155348119	DAGMA GAE	X		
Jairo Guzman A	Jguzman@valledelcauca.gov.co	3168906641	SDS-S. Amb	X		
Neftali Jimenez Restrepo	neftali.jimenez@cali.gov.co	3162480110	DAGMA -GAE	X		
ASTRID E. REYES	aereyes@minambiente.gov.co	3137474997	MINAMBIENTE			X

Report on the Benchmarking Assessment Tool (BAT) Training Workshop for the Environmentally Sound Management of Used Lead Acid Batteries in Cali, Colombia.

April 2018

Brian Wilson, MRSC

Table of Contents

1. Objectives of the BAT Training Workshop

- An outline and explanation of the procedures required to manage the collection and recycling of Used Lead Acid Batteries (ULAB) in an environmentally sound manner with due regard to the occupational health and safety of the workers and populations living close to recycling facilities.
- To understand the how the Benchmarking Assessment Tool (BAT) can be used and applied during plant inspections to assess the environmental, safety and occupational health performance of any ULAB operation from battery collection, temporary storage, transportation and recycling.
- To learn how to apply the BAT process in such a manner as to generate not only an assessment of EHS performance of a simulated recycling operation, but also to be able to provide recommendations for improvements if possible.
- To learn how in cooperation with the relevant Government Agencies in Colombia, Pure Earth have identified Lead contaminated sites and were now in the process of preparing remediation projects.
- To review the procedures for the integrated management of "environmental liabilities".
- To overview the National Legislation for the control of hazardous waste
- To learn how the local authorities in Cali manage and monitor hazardous waste.
- To review the procedures undertaken by the Lead Industry in Cali to quantitatively monitor environmental performance.
- To receive an overview of the MAC-Johnson Controls ULAB recycling operation in Cali.

.

2. Introduction to BAT, its Uses and Application

Whilst it is necessary to have legislation and guidelines for the recovery of Used Lead Acid Batteries (ULAB), standards for Safety, Occupational Health and Environmental Performance, without independent inspection, monitoring, evaluation and verification of the ULAB recovery phases from collection through to recycling, there is no guarantee of conformance with Good Practice or compliance with prevailing legislation.

Moreover, it is equally important that any monitoring tool provides a comprehensive and easy to use evaluation process that is consistent with the Internationally Recognised Guidance Notes, the Basel Convention Technical Guidelines, and Colombian national and regional legislation, including safety, occupational health and sustainability.

The Benchmarking Assessment Tool (BAT) is not a substitute for the quantitative analysis of atmospheric emissions, effluent discharges and occupational exposure measurements. Indeed, it is essential to confirm a company's performance with regard to the environmental, safety and occupational health with quantitative data. Nevertheless, appropriate use of the BAT will enable a trained regulator to not only reach an informed assessment of HSE performance, but to identify the areas of non-compliance and if required, prepare a series of improvements measures designed to bring the operation up to the required standards.

The BAT Form is a questionnaire and it is designed to ensure the questions posed by a Regulator provide a consistent approach to each assessment and it also means that the Benchmarking Assessment can be made without being an expert in the Basel Convention Technical Guidelines or Best Practice for ULAB recycling. The questions posed by the BAT form are also designed so that conformance with good practice or non-conformance can be identified depending on whether the answers given or observations made during the site inspection are in the green zones, that is, the answers provided by the company or observations made during a site inspection are consistent with good HSE practice, International protocols and conform to the HSE legislation in Colombia.

The Benchmarking Tool is suitable for the Assessment of Environmental Performance of any phase in the Life Cycle of the Lead Acid Battery from the Mining of Lead Bearing Ore, through Smelting, Lead Refining, Battery Manufacture, Retailing, Used Lead Acid Battery (ULAB) Recovery, that is, collection, temporary storage and transport, and Recycling.

The BAT format is applicable to informal and formalized ULAB recycling operations.

Site inspections by Government Environmental, Health and Safety Agencies, as an essential and integral part of the ESM licensing procedure for ULAB recovery and recycling operations, would constitute good practise, but even when site visits are undertaken, they are often confined to the recycling plant and do not examine the supply chain, that is the suppliers of ULAB.

In this context, such licensing inspections are traditionally focused on one site or one operation, such as Lead Smelting or ULAB collection. The BAT is, however, holistic in its approach and examines the whole recovery process in order to ensure the minimum of environmental and health impacts during the recovery phases including collection, temporary storage, packaging and transport.

3. The BAT Training Workshop

The Workshop was divided into two distinct training sessions. The first session, comprising of one full day in the classroom, was attended by 20 delegates drawn from Regulatory and Enforcement Agencies in Colombia, Safety and Occupational Health Specialists from the respective Government Agencies and the leading ULAB recycling company in Colombia, MAC – Johnson Controls.

The BAT Workshop Delegates

The first session of the morning of the first day was given over to the Colombian Government Agencies responsible for the environmental management, such as the Ministry of the Environment and Sustainable Development (Ministerio de Ambiente y Desarrollo Sostenible), the Institute of Hydrology, Meteorology and Environmental Studies (IDEAM) and the Administrative Department of Environmental Management (DAGMA).

The presentations outlined the policies, laws and procedures the various Government Agencies have initiated and implemented at national and local levels to monitor pollution and control hazardous waste.

Carlos Manuel Pineda：Ministry of the Environment and Sustainable Development

Adriana María Zapata Maya: Institute of Hydrology, Meteorology and Environmental Studies

Abelardo Angulo Cabezas: Administrative Department of Environmental Management

An interactive and participative session followed that covered the practical and technical aspects of recycling ULAB in a sustainable and environmentally sound manner with due regard to the occupational health and safety of those working in the industry and of the wellbeing of any population centres in the proximity of ULAB recycling operations. The technical information and guidance provided was aimed at small and medium sized Lead smelting operations, typical of those found in Nations in transition.

Brenda Natalia Lopez, Pure Earth: Facilitating the discussion on the ESM of ULAB

The technical sessions comprise of three sessions. The first session described the effective, safe and environmentally sound methods of collecting, packaging and transporting ULAB. The second session including ULAB and introduced a practical approach to achieve a closed loop for the management of effluent. The final session included smelting and refining options and the management of by-products such as the furnace residues and dust.

Rodrigo Pavón, Johnson Controls: Explaining how to optimise furnace energy efficiency

The final session of day one outlined the principles, the progressive methodology and application of the Benchmarking Assessment Tool (BAT) with a focus on environmentally sound practices and processes.

The first two sessions of the second day were givent to Johonson Controls

James Caicedo, *Explaining how Johnson Controls monitors it environmental performance*

The first presentation outlined the procedures that the Cali plant follows to monitor and evaluate the company's environmental performance and the second explained how the company has implemented a closed loop from the sale of Lead Battery to the recycling of the ULAB.

Juan Héctor Vargas，Johnson Controls: Explaining how the closed loop system operates

For the final session of the workshop the delegates were divided into five groups comprising of a mix of environmental specialists, regulators and industry personnel. The delegates were then shown a film that simulates a ULAB recycling plant inspection using real footage of a unknown recycling plant in the Americas. The groups were tasked to carry out a BAT analysis of the operation as seen in the video using the BAT forms provided and then compile conclusions about the HSE performance and if appropriate, compile cost effective recommendations for improvements.

At the end of the exercise each group was invited to present their observations in a plenary session with the other groups commenting and, in some instances, adding to the observations and recommendations or offering alternatives.

Without question all the groups used the BAT process to good effect and achieved a high standard of critical observations, and from the assessments, drawing conclusions about the state of HSE performance and were able to prepare a series of recommendations for HSE improvements.

Each delegate was presented with an ILA endorsed Certification of Accreditation for the Use and Application of the BAT process.

4. Conclusions

The classroom BAT simulation exercise demonstrated that the delegates can use and apply the BAT process to conduct a plant inspection and assess the level of HSE performance, identify deficiencies in operating practices and make comprehensive recommendations to raise standards.

All the delegates confirmed that the BAT process was logical and easy to apply providing them with a framework that facilitated a thorough inspection of the recycling operations including not only the impact on the environment, but also occupational health and safety issues.

Whilst the BAT process for HSE assessment cannot and will not replace the need for a quantitative analysis of environmental performance, the BAT process does provide valuable pointers as to the likely environmental performance as well as the procedures for minimising occupational exposures and maintaining a safe place of work.

Sandra M. Gualtero, Pure Earth Latin America Regional Director, closing the Workshop

5. Appendices

5.1. Delegate List

Nombre	Institución
Brian Wilson	ILA
Brenda Natalia Lopez Niño	Pure Earth
Sandra M. Gualtero	Pure Earth
Alfonso Rodríguez	Pure Earth
Vanessa Vega Hernandez	Pure Earth
Nathalia Paredes	Pure Earth
John Sandoval	Pure Earth
Lina Garcia	Pure Earth
Astrid Eliana Reyes Peña	Ministerio de Ambiente
Carlos Jairo Ramirez	Ministerio de Ambiente
Carlos Manuel Pineda	Ministerio de Ambiente
John Jairo Noreña	Alcaldia Malambo
Geinny Vasquez	CRA
Adriana María Zapata Maya	Ideam
Carlos Daniel Urrea Hernández	Ideam
Angela Maria Sanchez	Dagma
Neftali Jimenez Restrepo	Dagma
Gustavo Adolfo Ortega Hungria	Dagma
Abelardo Angulo Cabezas	Dagma
Isabela Caicedo	Secretaria Valle
Jairo Guzman	Secretaria Salud Valle
Rodrigo Pavón	JCI
Juan Héctor Vargas	JCI
Carlos Romero	MAC JCI
Mario Herrera	MAC JCI

5.2 Agenda

Agenda del Taller de Cali

El GAR/ESM del BAPU Reciclaje para reguladores, monitoreo, evaluación del sitio y licencias

Día 1: martes 10 de abril de 2018

Tiempo	Evento	Responsable
08:00 – 08:30	Registro y café / té	Todos
08:45 - 08:50	Palabras de bienvenida Cali	Pure Earth
08:50 - 09:00	Presentaciones	Participantes
09:00 - 09:10	Objetivos; Logística, arreglos domésticos y seguridad	Pure Earth
09:10 - 09:30	Proyectos de Tierra Pura en Colombia	Pure Earth
09:30 - 10:00	Pasivos Ambientales	MADS
10:00 - 10:30	Registro de Residuos Peligrosos	IDEAM
10:30 – 11:00	Gestión Residuos Peligrosos Cali	DAGMA
11:00 – 12:00	El GAR de BAPU – Parte 1 – Recolección	ILA
12:00 – 13:00	Almuerzo	
13:00 – 14:30	El GAR de BAPU – Parte 2 – Trituración	ILA
14:30 – 16:00	El GAR de BAPU – Parte 3 – Fundición	ILA
16:00 – 17:00	El Uso y la Aplicación del Proceso BAT	ILA

Día 2: miércoles 11 de abril de 2018

Tiempo	Evento	Responsable
08:30 – 08:45	Asamblea y Café / Té	
08:45 – 09:30	Muestreo y Monitoreo Ambiental	JCI
09:30 - 10:30	Ciclo Cerrado y la GAR de BAPU	JCI
10:30 - 11:45	Inspección y Evaluación Simulada del Sitio	ILA
11:45 – 12:15	Informes de Grupo	Participantes
12:15 - 12:30	Revisión del taller y cierre	Pure Earth

5.3 Handout: Introducción a Pure Earth

Reducción de la Amenaza por la contaminación Toxica Química en Países de Ingresos Medios y Bajos

Alfonso Rolando Rodriguez Pinilla
Pure Earth
Director Country
arodriguez@pureearth.org

INTRODUCCIÓN

- PURE EARTH (Instituto Blacksmith) es una organización sin ánimo de lucro fundada en Nueva York en 1999.
- Se enfoca en la identificación y limpieza de sitios contaminados (fuentes fijas) por substancias tóxicas químicas, en países de ingresos bajos y medianos, donde exista un impacto en la salud humana.
- Ha completado 50 proyectos de limpieza en 20 países.
- Desde el 2009, ha implementado el Programa de Identificación de Sitios Contaminados (TSIP).

PURE EARTH

Alianza Global para la Salud y contra la Contaminación (GAHP)

Organismo colaborativo cuyo objetivo es coordinar recursos y actividades que ayuden a resolver los problemas creados por la contaminación química toxica y a prevenir futuros focos en países de medianos y bajos ingresos.

GAHP
GLOBAL ALLIANCE ON HEALTH AND POLLUTION
Partnering to rid the world of toxic hotspots

- Creada en Julio de 2012.
- Miembros de GAHP: Banco Mundial, Banco de Desarrollo Asiático, Banco Interamericano de Desarrollo, Comisión Europea, Pure Earth, entre otros.
- Miembros de GAHP en **Colombia** :Instituto Nacional de Salud, Secretaria de Salud de Cundinamarca, Ministerio de Ambiente y Desarrollo Sostenible , Ministerio de salud y Protección Social, Secretaria Distrital de Ambiente de Bogota y DAGMA.
- Pure Earth ejerce la Secretaría de GAHP

PURE EARTH

Reducción de la Amenaza de la contaminación Toxica Química en Países de Ingresos Medios y Bajos

Agencia Implementadora: *USAID*
Agencia Ejecutora: *Pure Earth*
Alcance geográfico: *Bangladesh, Filipinas, Vietnam, Colombia, Senegal, Jamaica, Mongolia and India*
Timeline: *Abril 2016 – Septiembre 2018*

Objetivos

1. **TSIP**
2. **Mainstreaming**
3. **Pilot Projects**

TSIP - ETAPAS DEL PROGRAMA

ETAPA 1:

- Determinar Interés Gobierno – Establecer alcance
- Entrenamiento en protocolo de evaluación de sitios contaminados (ISS) – 2 días – investigadores y representantes del gobierno
- Realizar ISSs
- QA/QC

ETAPA 2:

- Compartir información y resultados de las evaluaciones con el gobierno nacional y local
- Identificar prioridades y sitios críticos
- Crear un plan de acción
- Identificar las fuentes de financiación para proyectos de diagnostico detallado, caracterización y limpieza

ETAPA 3:

- Diseño de la intervención – proyectos pilotos

PURE EARTH

TSIP (Toxic Site Investigation Program)

Resultados 2009 - 2015

3200 sitios identificados; 2300 visitados; 49 países.

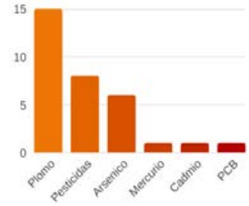
PURE EARTH

Map based on data collected as part of the Toxic Sites Identification Program (2009-2015)

Pure Earth
475 Riverside Drive, Suite 860
New York, NY

- Other Contaminants
- Cadmium
- Chromium (Hex)
- Chromium (Total)
- Lead
- Mercury - elemental
- Pesticides

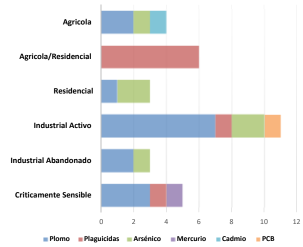
TSIP EN COLOMBIA



En lo corrido del año 2017, se han realizado 33 Investigaciones realizadas en 5 departamentos que comprenden 6 contaminantes.

La población total en riesgo estimada es de 77.216 personas

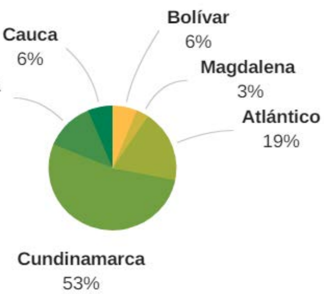
Se presenta un 64% de avance en las investigaciones, la meta para el 2017 es de 50 sitios evaluados.



11 de los 32 sitios investigados presentan contaminación en sectores industriales activos, siendo el plomo el principal contaminante.

PURE EARTH

INVESTIGACIONES POR DEPARTAMENTO



Cundinamarca	17
Valle del Cauca	4
Cauca	2
Bolívar	2
Magdalena	1
Atlántico	6

PURE EARTH

EVALUACIONES DETALLADAS

PROPÓSITO

Determinar la existencia de contaminación por metales pesados, enfocados principalmente a plomo por antecedentes encontrados.

METODOLOGÍA

- Revisión de los antecedentes existentes
- Visita exploratoria
- Visita de inspección y medición
- Medición con pistola XRF
- Toma de muestras de suelo y agua (Laboratorio)
- Análisis de información
- Propuesta de Planes de Acción

PURE EARTH

TOMA DE LECTURAS



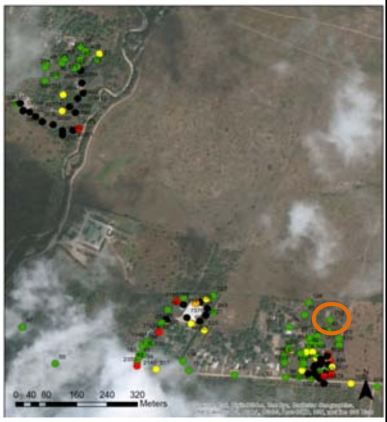

PURE EARTH

PISTOLA DE FLUORESCENCIA RAYOS X


Más de 220 muestras fueron tomadas, distribuidas en las 5 antiguas plantas de fundición y zonas urbanas de Malambo. (Plomo, Arsénico y Cobre)

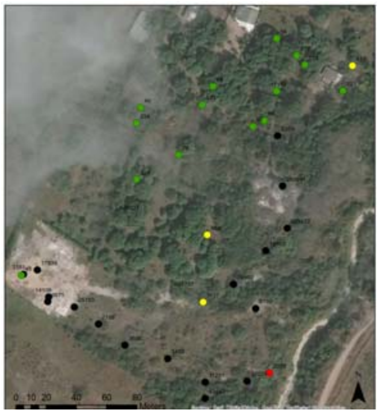
PURE EARTH

EVALUACIÓN DETALLADA PLOMO - MALAMBO



Pb (mg/kg)
- <400
- 401-1,200
- 1,201-2,000
- 2,001-3,000
- >3,000

EVALUACIÓN DETALLADA PLOMO – MALAMBO – VEREDA EL CARMEN

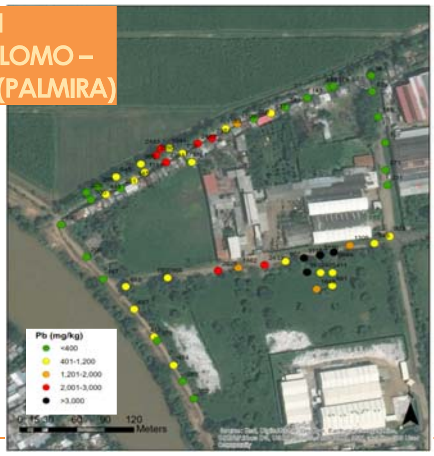


Pb (mg/kg)
- <400
- 401-1,200
- 1,201-2,000
- 2,001-3,000
- >3,000

EVALUACIÓN DETALLADA PLOMO – MALAMBO - LA BONGA

Pb (mg/kg)
- <400
- 401-1,200
- 1,201-2,000
- 2,001-3,000
- >3,000

EVALUACIÓN DETALLADA PLOMO – LA DOLORES (PALMIRA)



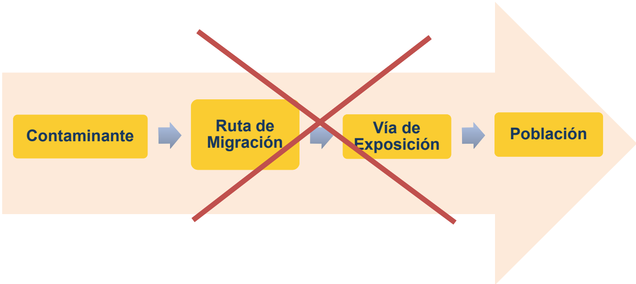
Proyecto de Intervención para la Prevención de contaminación con plomo en olombia

Sandra Gualtero – Coordinadora Region
Joe Hayes – Miembro TAB Pure Earth
Vaenssa Vega - investigadora Pure Earth
Alfonso Rodriguez Pinilla – Director Colombia

FONDOS DE FINANCIACIÓN

USAID + UNIDO

OBJETIVO DE INTERVENCIÓN



ACTIVIDADES REALIZADAS

Capacitación de los problema del plomo a la comunidad adulta.

Actividades lúdicas y recreativas para los niños de las Veredas la Bonga y el Carmen

Evaluación de Plomo en sangre

ACTIVIDADES DESARROLLADAS

- Programa de Socialización de problemas a la salud que puede generar la exposición a plomo

Adultos

Niños

ACTIVIDADES DESARROLLADAS

- . Toma de muestras de sangre.

Toma de Muestra de sangre

Lectura de nivel de plomo por Lead Care II

ACTIVIDADES DESARROLLADAS

- Construcción Celda de Seguridad para enterramiento de escoria con plomo.

ACTIVIDADES DESARROLLADAS

- Valoración detallada de casas con exposición a Plomo.

HERRAMIENTAS DE PREVENCIÓN: AGENDA ESCOLAR

HERRAMIENTAS DE PREVENCIÓN: AGENDA ESCOLAR

RESULTADOS OBTENIDOS

Años de Edad

Total (N)	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
66	7,99	4,56	0.33-16.00	7,75	0,33	4,25	8,50	12,00	16,00

Nivel de Plomo en Sangre (ug/dL)*

Total (N)	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
66	15,27	10,97	0.00-65.00	11,90	0,00	8,50	14,15	20,4	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

Nivel de Plomo en Sangre (ug/dL)*

Total (N)**	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
62	16,26	10,58	3.0-65.00	11,05	3,30	9,65	15	20,70	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.
** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 4.

Niños

RESULTADOS OBTENIDOS

Años de Edad

Total (N)	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
99	48,84	16,63	18.00-84.00	26,50	18,00	36,50	48,00	63,00	84,00

Nivel de Plomo en Sangre (ug/dL)*

Total (N)	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
99	11,18	11,93	0-65.00	11,75	0	3,60	8,8	15,35	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.

Nivel de Plomo en Sangre (ug/dL)*

Total (N)**	Promedio	D. Estandar	Rango	IQR	Q0 (Min)	Q1	Q2 (Median)	Q3	Q4 (Max)
76	14,56	11,67	3.6-65.0	11,38	3,6	7,30	10,8	18,68	65,00

* Los valores calculados pueden ser ligeramente menores que los verdaderos debido a los 'altos' reportados en las muestras que se informa como 65.00 ug / dL debido al valor umbral de medida del equipo.
** Estos valores se calcularon excluyendo los valores de "0" cero, los cuales corresponden a valores no detectables por el equipo , de los cuales hubo 23.

Adultos

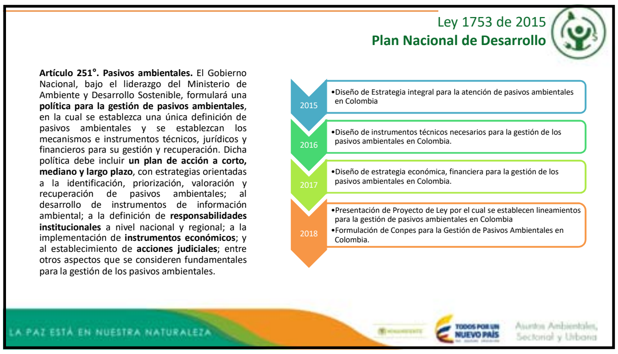
Próximos Pasos

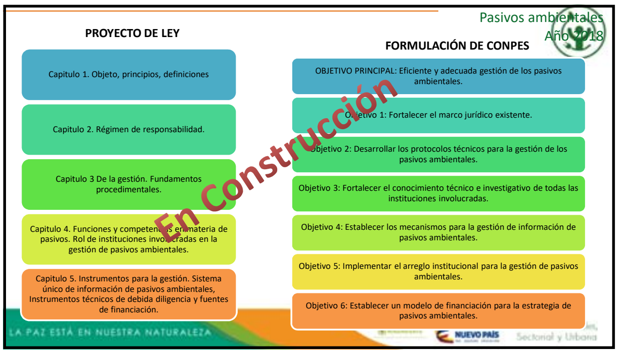
- Taller sobre uso el Uso y la Aplicación de la Herramienta para un Análisis Comparativo (BAT) sobre el Manejo Ambientalmente Adecuado (ESM) de las Baterías de Ácido-Plomo- Usadas (BAPU) en Colombia –
- Malambo – house assessment and recommendations
- BLL monitoring

Adultos

PREGUNTAS

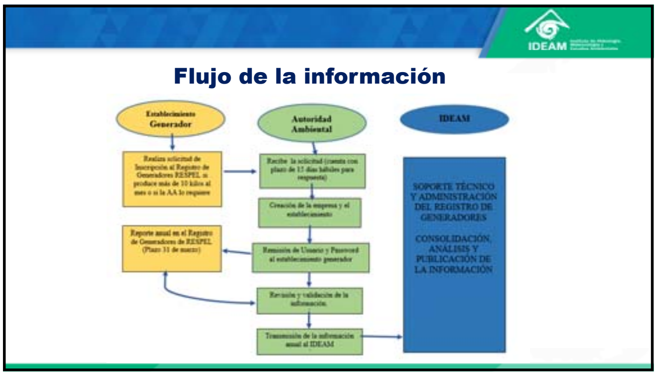
5.4 Handout: Pasivos Ambientales




Pasivos ambientales
Año 2018
PROYECTO DE LEY
Capitulo 1. Objeto, principios, definiciones
Capitulo 2. Régimen de responsabilidad.
Capitulo 3 De la gestión. Fundamentos procedimentales.
Capitulo 4. Funciones y competencias en materia de pasivos. Rol de instituciones involucradas en la gestión de pasivos ambientales.
Capitulo 5. Instrumentos para la gestión. Sistema único de información de pasivos ambientales, Instrumentos técnicos de debida diligencia y fuentes de financiación.
FORMULACIÓN DE CONPES
OBJETIVO PRINCIPAL: Eficiente y adecuada gestión de los pasivos ambientales.
Objetivo 1: Fortalecer el marco jurídico existente.
Objetivo 2: Desarrollar los protocolos técnicos para la gestión de los pasivos ambientales.
Objetivo 3: Fortalecer el conocimiento técnico e investigativo de todas las instituciones involucradas.
Objetivo 4: Establecer los mecanismos para la gestión de información de pasivos ambientales.
Objetivo 5: Implementar el arreglo institucional para la gestión de pasivos ambientales.
Objetivo 6: Establecer un modelo de financiación para la estrategia de pasivos ambientales.
En Construcción
LA PAZ ESTÁ EN NUESTRA NATURALEZA
NUEVO PAÍS
Sectorial y Urbana

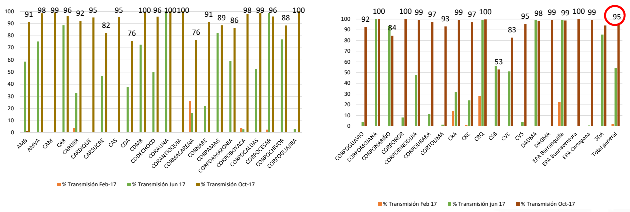

MINAMBIENTE
TODOS POR UN NUEVO PAÍS
Asuntos Ambientales, Sectorial y Urbana

5.5 Handout: Registro de Residuos Peligrosos



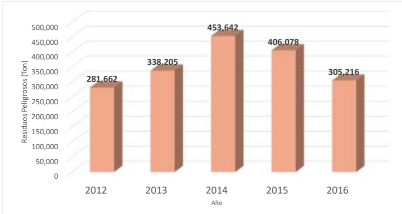
Informe nacional de residuos peligrosos 2016

INFORMACIÓN VALIDADA Y **TRANSMITIDA** POR LAS AUTORIDADES AMBIENTALES
(PARA LA FECHA DE CONSULTA DE LOS REPORTES DE INFORMACIÓN OCTUBRE -17 - 95%)

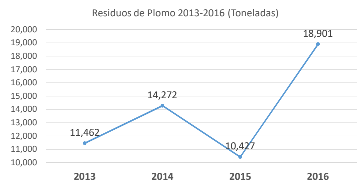


Generación de residuos peligrosos 2016

Disminuyó el 25% de la generación con respecto al año 2015



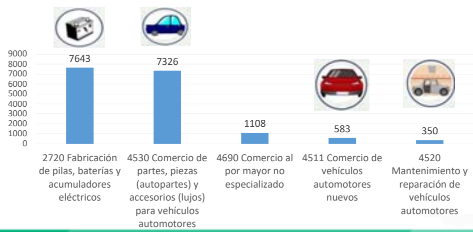
Plomo: Y31 – A1160 –A3030
Desechos que tengan como constituyentes: Plomo, compuestos de Plomo, acumuladores de plomo.



Baterías plomo ácido

Generación de residuos de plomo reportados 2013 -2016

Principales actividades generadoras de residuos de Plomo 2016 (Toneladas)



Principales departamentos y municipios donde se reporta mayor generación de respel de Pb

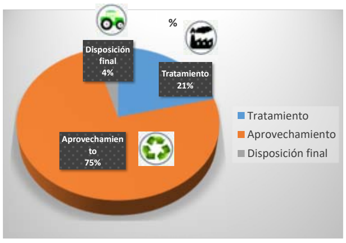
Primeros 5 departamentos

- Atlántico – 39% - 7.378 ton
- Bogotá - 16% - 3.058 ton
- Valle – 15% - 2.979 ton
- Antioquia – 8% - 1.518 ton
- Cundinamarca – 3% - 733 ton

Primeros 5 municipios

- Malambo – 37% - 7.093 ton
- Bogotá - 16% - 3.058 ton
- Cali – 11% - 2.108 ton
- Medellín – 6% - 1.209 ton
- Yumbo– 3% -645 ton

Gestión de residuos peligrosos de Pb 2016

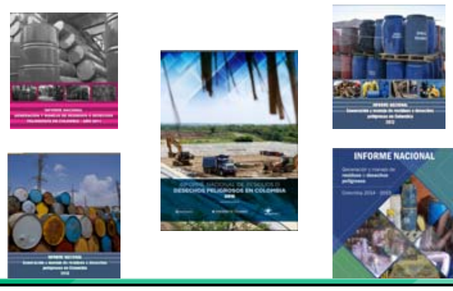


Principal aprovechamiento – reciclado o recuperación de metales – 8.680 Ton

Principal tratamiento - FQCO 3.839 Ton

Principal tipo de disposición final – celda de seguridad - 696 Ton

Informes nacionales de residuos peligrosos 2011- 2016



GRACIAS¡

Datos de contacto:
Correo:
azapata@ideam.gov.co
Teléfono: 3527160
Extensión: 1601

ila
International Lead Association

PURE EARTH
BLACKSMITH INSTITUTE

Taller
Herramienta para un Análisis Comparativo

Cali – Colombia
Abril 2018

El Uso y la Aplicación de la Herramienta para un Análisis Comparativo (BAT) sobre Manejo Ambientalmente Adecuada (ESM) de las Baterías de Ácido-Plomo Usadas (BAPU) en Colombia

USAID
FROM THE AMERICAN PEOPLE

El Uso y la Aplicación de la Herramienta para un Análisis Comparativo (BAT) sobre la Gestión Ambientalmente Adecuada (ESM) de las Baterías de Ácido-Plomo Usadas (BAPU) en Colombia

Tabla de Contenido

1. Introducción

El crecimiento en la demanda de vehículos en Colombia, así como el crecimiento de la denominada Energía Verde (como en el uso de paneles solares) significa que la demanda de Baterías de Ácido-Plomo (BAP) igualmente crecerá, incrementando en el corto y mediano plazo la cantidad de Baterías de Ácido-Plomo Usadas (BAPU) generadas.

Si la industria del Plomo no es consciente de la gestión ambiental y la seguridad ocupacional, la Comunidad Internacional ejercerá presión para que se mejore el desempeño de ésta industria en estos aspectos. Sin embargo, es completamente posible hacer cambios en la agenda ambiental antes que la comunidad internacional detecte la necesidad de intervenir. Para alcanzar esta cooperación, es necesario que las autoridades y la industria trabajen en conjunto para mejorar el desempeño ambiental, reducir la exposición ocupacional y elevar los estándares de seguridad en una manera constructiva y costo-efectiva. Esto puede ser realizado con la ayuda de la Herramienta para un Análisis Comparativo.

Dentro del contenido de este Taller se abordará:

- Cómo la Herramienta para un Análisis Comparativo – BAT puede ser usada como parte del proceso de licenciamiento para las plantas BAPU
- Cómo la gestión de las BAPU puede ser sostenible, ambientalmente adecuada y rentable
- Cómo la industria y las autoridades del gobierno pueden trabajar en conjunto para reducir el número de operaciones sub-estándar
- Cómo aplicar la Herramienta de Análisis Comparativo para mejorar la eficiencia del reciclaje, rentabilidad, seguridad, salud ocupacional y desempeño ambiental de una manera constructiva

2. El manejo de las BAPU por medio de una Gestión Ambientalmente Adecuada

Los gobiernos están conscientes de las consecuencias tóxicas debido al reciclaje inapropiado de las BAPU, y deberían asegurar que las regulaciones para la gestión ambientalmente adecuada y la seguridad en la manipulación de las BAPU son consistentes con las guías técnicas de Basilea y la legislación nacional.

Reciclar recursos valiosos como las BAPU es esencial para la economía de Colombia y en particular para el sector de fabricación local de BAP, ya que actualmente el medio de almacenamiento de energía para la Generación de Energía Alternativas es la Batería de Ácido-Plomo y este es el mercado de mayor crecimiento en el uso de BAP.

La Convención de Basilea sobre el Control de los Movimientos Transfronterizos de Residuos Peligrosos y su Disposición existe para facilitar el control y la disposición ambientalmente adecuada o el reciclaje de residuos peligrosos y no peligrosos. Hay guías publicadas que definen cuál es el significado de la Gestión Ambientalmente Adecuada de las BAPU. El estricto seguimiento de las Guías de la Convención de Basilea para la Gestión Ambientalmente Adecuada (ESM, por su sigla en inglés) de las BAPU significaría que solamente las BAP completas sin drenar deberían entregarse a los fundidores secundarios de plomo.

Sin embargo, esto no es siempre el caso y frecuentemente el electrolito de la batería es drenado de la BAPU antes de ser transportado a la fundidora.

3. Reciclaje Sostenible, Ambientalmente Adecuado y Rentable

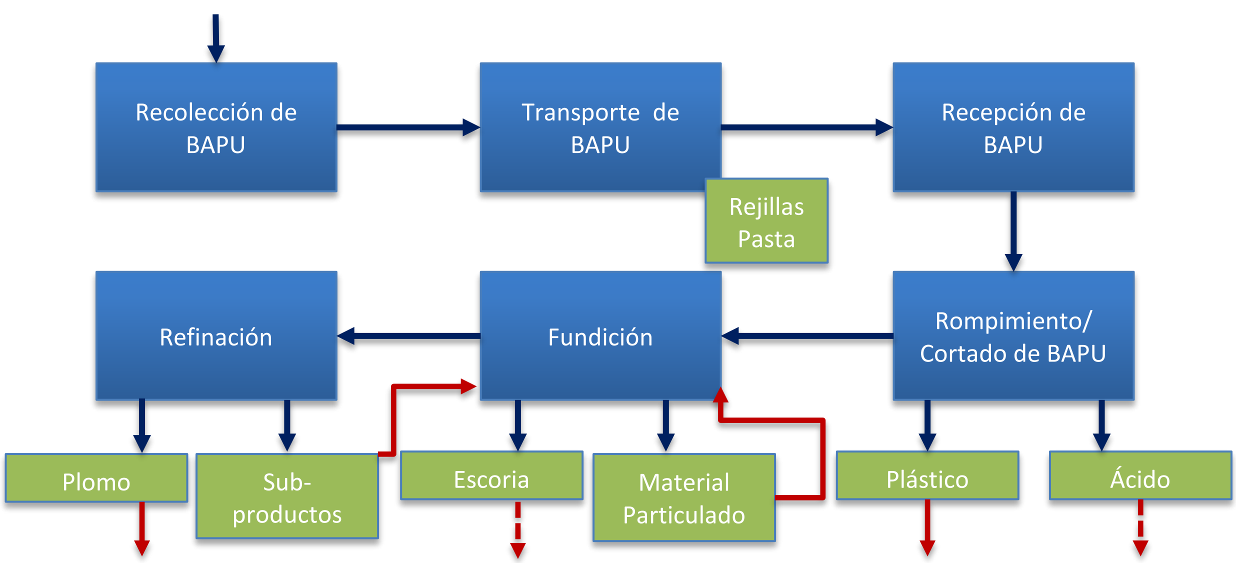
A continuación, se encuentran los ejemplos de opciones prácticas y viables para la gestión ambientalmente adecuada de las Baterías de Ácido-Plomo Usadas. Estas técnicas de gestión representan riesgos a la salud si se realizan de manera incorrecta. Sin embargo, estos riesgos pueden ser mitigados con procedimientos apropiados, y el proceso completo de las BAPU puede ser realizado de manera segura y rentable con una planeación y manejo cuidadoso, reduciendo la cantidad de residuos peligrosos producidos durante el proceso.

Estas oportunidades pueden ser la diferencia entre un negocio con licencia y un sector no organizado y no regularizado, ambos en términos de la viabilidad, los riesgos a la salud y la Gestión Ambientalmente Adecuada – ESM.

3.1. Proceso de Reciclaje

Hay cinco pasos del proceso de reciclaje para BAPU:

1. La recolección de las BAPU, su embalaje y transporte al fundidor.
2. Drenaje de las BAPU o del electrolito ácido contenido en ellas, y el tratamiento para su disposición, reuso o conversión a un producto comercializable.
3. La separación de los componentes con características orgánicas, que son los plásticos, y los componentes inorgánicos (rejilla metálica y pasta de batería).
4. Fundir la rejilla metálica, la pasta de plomo de la batería, y reciclar los terminales.
5. Refinar los lingotes de plomo para la venta.



El gráfico de flujo de proceso muestra la recolección de BAPU, el transporte y la recepción. Seguido del rompimiento de las BAPU para separar el plástico, el electrolito y los componentes metálicos; la fundición de las fracciones metálicas donde se genera plomo sin refinar, escoria y material particulado (incluyendo polvo y humo de plomo capturados en el filtro de mangas). El paso final es la refinería de los lingotes de plomo sin refinar para remover cualquier impureza remanente y producir los lingotes de plomo puro (99.97% o 99.99%).

3.1.1 Recolección, Embalaje y Transporte de las BAPU

El primer paso en el proceso es la recolección de las BAPU. Las baterías deberían ser recolectadas con el electrolito de la batería y no deben estar drenadas. Ellas deberían estar almacenadas en posición vertical, y separadas por tamaño. Antes de transportarlo a una fundidora, las BAPU deberían ser transferidas a un contenedor plástico a prueba de fugas especialmente diseñado y aprobado por la ONU para transportar BAPU o a estibas en tres o cuatro capas.

Recipiente de plástico aprobado por las UN

BAPU en estibas

El grado de apilamiento dependerá de la altura de las BAPU. Entre dos capas de BAPU debería ser colocado cartón grueso para prevenir algún movimiento durante su transporte. Finalmente, las BAPU deberían estar embaladas o empacadas para prevenir movimiento durante el transporte. Usando el contenedor aprobado por la ONU a prueba de fugas para la recolección de las BAPU permitiría que las BAPU puedan ser transportadas en cualquier vehículo.

A pesar de todas las otras precauciones, los vehículos usados para transportar las BAPU deberían estar dedicados a esta labor, con licencia para transportar residuos peligrosos, y exhibir las calcomanías necesarias que definen al residuo, así como los riesgos asociados al residuo (tener la Hoja de Datos de Seguridad – MSDS) y un numero de contacto en caso de emergencia.

3.1.2 Drenaje de las BAPU y Tratamiento del electrolito

Dependiendo del proceso el electrolito de la batería puede ser separado antes del rompimiento o durante el rompimiento, en caso de que se esté usando una sierra de batería o un molino de martillos, pero en cualquiera de los procesos usados, la consideración del proceso de tratamiento para la disposición o el reuso del electrolito es el mismo.

Idealmente, el electrolito de la batería debería ser recuperado, reacondicionado y devuelto a los fabricantes de Batería de Acido-Plomo (BAP) para llenar las nuevas baterías. Sin embargo, solo pocas plantas de reciclaje tienen esos procesos y la inversión en los equipos necesarios, hasta el momento, ha sido muy costosa para hacer del reacondicionamiento un proceso viable. Pero los químicos de la empresa Wirtz han desarrollado un proceso de reacondicionamiento que es apropiado para la Pymes porque no es costoso y produce un ácido sulfúrico diluido que puede ser apropiado para la venta a los fabricantes de BAP. Alternativamente, el electrolito ácido puede ser neutralizado y hay dos formas para realizarlo.

La primera forma de neutralización involucra la adición de hidróxido de sodio al electrolito para producir sulfato de sodio y agua, y en una manera similar, carbonato de sodio puede ser añadido para producir sulfato de sodio y agua, pero este proceso también liberará dióxido de carbono.

El sulfato de sodio es usado en la manufactura de vidrio, jabones y detergentes, pero la purificación involucra destilación al vacío y el equipo es costoso y no necesariamente apropiado para las Pyme en Colombia.

Indonesia - Adoquines

La segunda opción ha sido ampliamente adoptada para las Pyme globalmente. Básicamente, cal o hidróxido de calcio es añadido al electrolito ácido y mezclado para precipitar el sulfato de calcio, mejor conocido como Yeso. El yeso es un producto comercializable y puede ser vendido a la industria cementera, éste se usa en casi todos los muros de pared. Recientemente estos materiales pueden ser incorporados en la mezcla de cemento con la escoria del horno para producir losas de pavimento sin lixiviados.

3.1.3 Separación de los Componentes de las BAPU

La mayoría de las plantas recicladoras de BAPU han seleccionado comprar un destructor de baterías con un molino de martillos para romper las BAPU. No hay duda de que estos destructores realicen y alcancen una buena separación hidro-gravitacional de los componentes de las baterías, así como plásticos, rejillas metálicas y pasta, pero ellos son costosos al comprarlos y al operarlos.

Disyuntor de batería mecánico

Una alternativa económica y aprobada por la Administración de Seguridad e Higiene Ocupacional de los Estados Unidos (OSHA), es el serrado de las baterías. Este modelo es rápido, eficiente y perfectamente seguro, también es ventilado para prevenir el ácido vaporizado alrededor de la sierra como se muestra en el modelo a continuación.

Sierra Ventilada de Batería

La sierra remueve la sección superior de la batería exponiendo los platos que contienen las rejillas y la pasta, las rejillas son removidas fácilmente y puestas en canecas apropiadas para ser llevadas a la fundición. Las carcasas de polipropileno son lavadas y vendidas a un reciclador de plásticos.

Las ventajas para las Pyme es que es posible separar el plástico blanco del plástico de color y obtener así un alto precio por el polipropileno blanco.

La instalación de una peletizadora también le agregaría valor al polipropileno recuperado y al efluente neutralizado. Este efluente, una vez filtrado, puede ser usado para el enjuague de los pedazos de polipropileno para remover las trazas de óxidos y sulfatos.

3.1.4 Fundición

La pasta de batería contiene óxidos de plomo y sulfato de plomo. Durante la fundición, el sulfato de plomo genera el plomo metálico, que es extraído, y el dióxido de azufre que es liberado. El gas de dióxido de azufre combinado con agua, ya sea como niebla o lluvia, forma ácido sulfúrico diluido, es por ello que se le llama Lluvia Ácida, y ésta formación debe ser evitada. Es por ello que el dióxido de azufre tiene que ser removido desde el horno para que las emisiones a la atmósfera cumplan con los estándares nacionales y las normas internacionales.

Esencialmente hay tres opciones para remover el sulfuro de la pasta de batería:

- Antes de la fundición

- Durante la fundición
- Después de la fundición

Empezando con el proceso de desulfurización antes de la fundición, allí hay dos opciones a considerar.

La primera opción es similar al segundo método que ya se discutió para el tratamiento del electrolito de la batería, y que es la adición de Carbonato de Sodio en un lodo agitado de la pasta de la batería que contenga sulfato de plomo en un recipiente de mezclado.

Este es un proceso lento, pero eventualmente el Sulfato de plomo se convertirá en Carbonato de Plomo, el cual es precipitado, y el Sulfato de Sodio estará en solución. El Carbonato de Plomo puede ser cargado al horno y se descompondrá en Oxido de Plomo y Dióxido de Carbono. Nosotros observaremos la operación del horno en breve, y consideraremos la manera en la cual el Plomo es extraído del Oxido de Plomo.

Hay otro uso para el Sulfato de Sodio que no ha sido listado anteriormente y que está en la industria de papel. En 1883 Carl Dahl inventó el "Proceso Kraft" para hacer papel. Kraft en el lenguaje alemán significa "Fuerza" o "Fuerte" y lo que Carl Dahl encontró fue que, mediante la adición de sulfato de sodio a la mezcla de pulpa de papel, el papel se reforzaba considerablemente. Así, si ustedes tienen industria del papel, allí hay otra oferta para el sulfato de sodio.

La opción dos involucra la mezcla de Carbonato de Amonio con la Pasta de Plomo, éste reacciona con el Sulfato de Plomo para formar Carbonato de Plomo y Sulfato de Amonio. El Sulfato de Amonio es un fertilizante y una fuente rica de nitrógeno. Convertir un residuo peligroso en un fertilizante es un buen ejemplo de uso adecuado de los recursos. Éste proceso fue desarrollado y ahora es comercializado por Engitec de Italia.

La de-sulfurización de la BAPU será considerada después en la sección de fundición.

Actualmente, hay dos procesos pirometalúrgicos que son populares entre los fundidores en la mayoría de los países de bajo y mediano ingreso económico, y particularmente apropiados para las operaciones a pequeña escala, que es de alrededor de 50.000 toneladas de producción de plomo por año. Los dos procesos son:

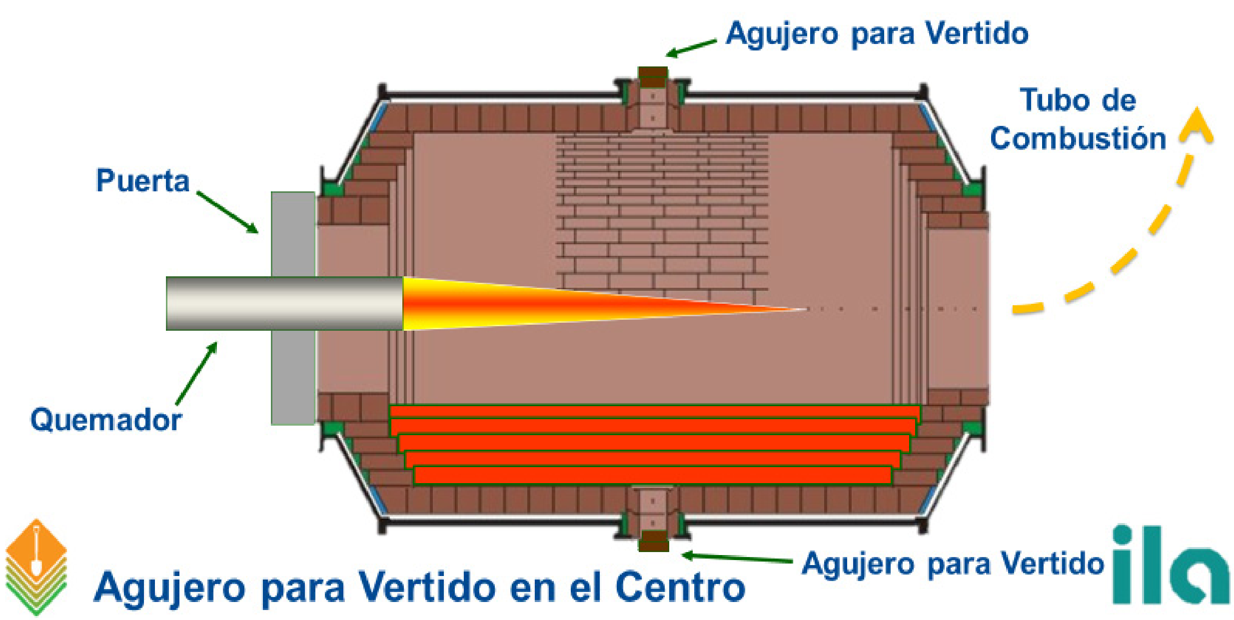
- Alto Horno
- Horno rotatorio

El Alto Horno no será discutido en detalle aquí porque esta tecnología está siendo retirada a nivel mundial para dar paso a tecnologías más flexibles que reciclen de manera efectiva todos los sub-productos y unos con mayor eficiencia energética.

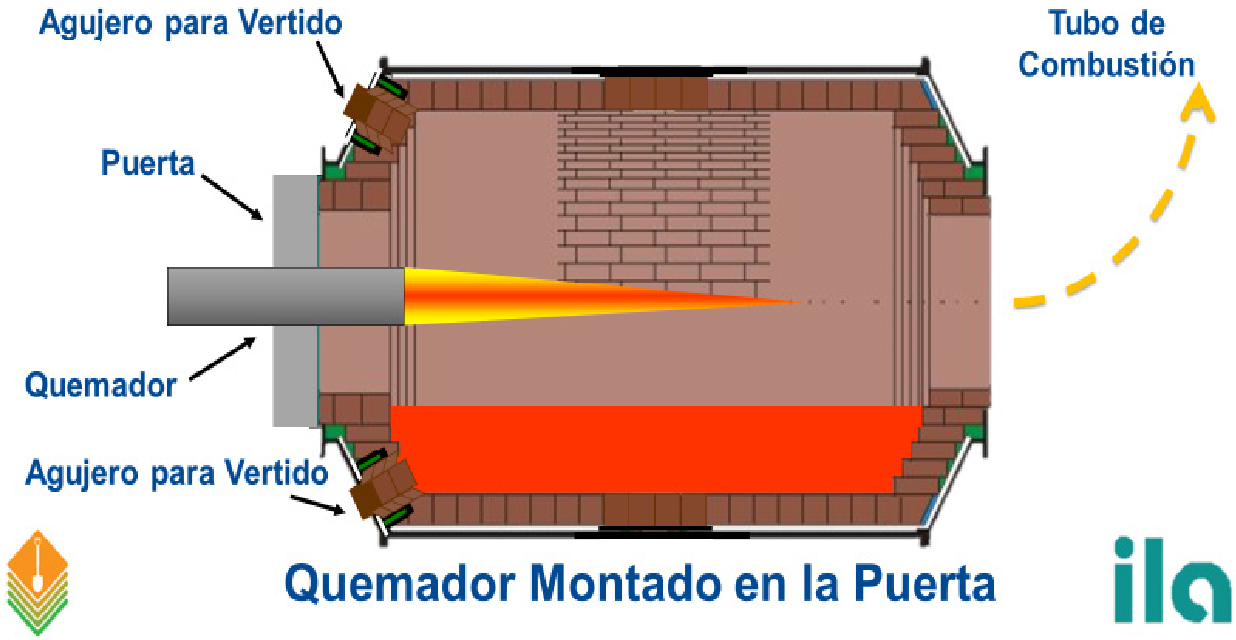
Para los lectores que no estén familiarizados con un Horno Rotatorio, por favor observar la imagen a continuación. No es fácil de observar el quemador o adentro del horno porque es hermético con campanas de ventilación y ductos para mantener la limpieza.

Sin embargo, en el esquema a continuación, se muestra su composición interna. El horno tiene un tambor de acero que está revestido con materiales refractarios para proteger el tambor metálico durante la operación de fundición, el quemador puede ser encendido usando aceite recuperado, o gas, o una mezcla de combustible con oxígeno y este puede ser instalado en la puerta o en la parte posterior del horno. Las purgas pueden ser localizadas en el centro del tambor o en el frente del horno.

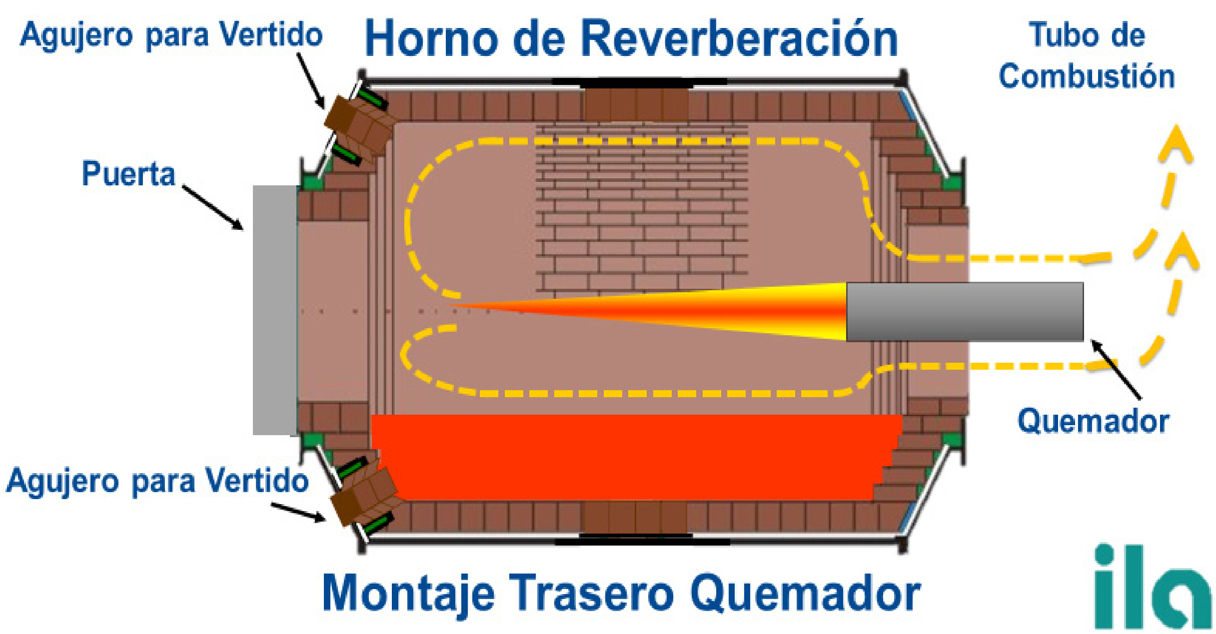
Horno Rotatorio



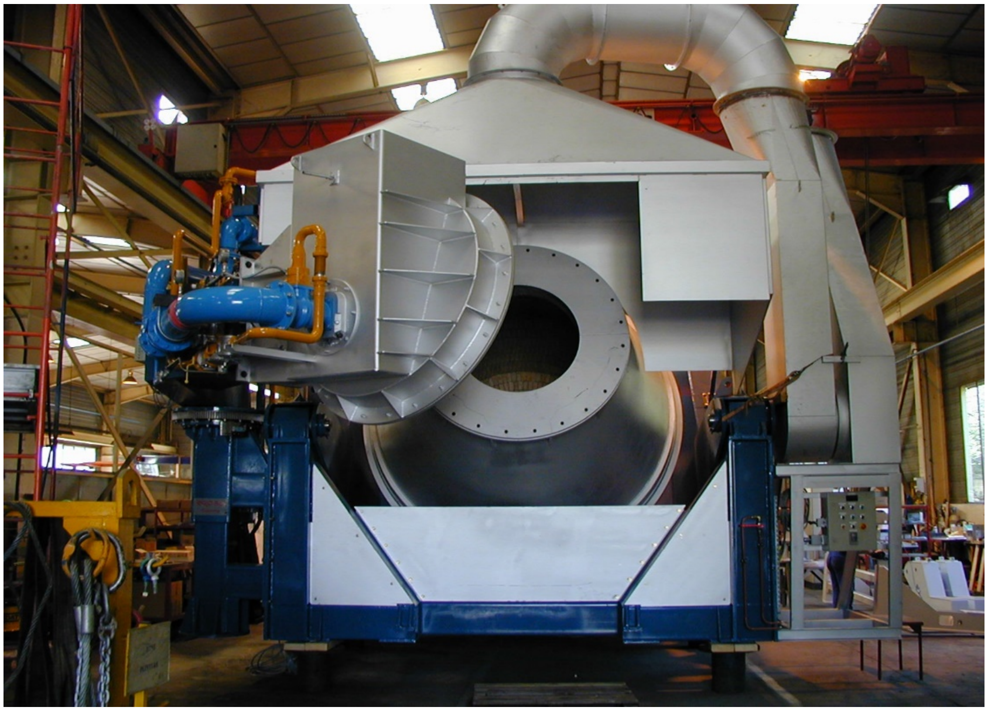
Esta es la configuración para la localización de las purgas en el frente del horno y allí esta una operación típica de purga para ese tipo de horno.



Si el quemador está instalado en la parte posterior del horno, éste es más eficiente energéticamente porque el calor del quemador tiene un doble paso a través del horno antes de escapar a la chimenea de combustión.



Un tercer método de purga del horno rotatorio es a través de la carga frontal inclinando el tambor del horno desde la parte posterior.



Horno Rotatorio Inclinado *(Dross Engineering)*

Para esos fundidores con un punto de purga central, la única forma de contener efectivamente las emisiones de gases durante la purga es encapsular todo el horno y tenerlo completamente sellado durante la purga.

Horno de rotario encapsulado (Cortesía de Gravita India)

El proceso de desulfurización que tiene lugar durante la fundición, es simplemente que añade chatarra ferrosa al material de carga, y también puede ser chatarra de acero, así como los tambores de aceite y los platos de acero.

Si el sulfuro no se remueve antes de la fundición, durante ésta el Sulfato de Plomo es reducido, por el carbono contenido en los finos del carbón añadidos a la carga del horno, para formar Sulfuro de Plomo y Dióxido de Carbono. El Sulfuro de Plomo reacciona entonces con el hierro para liberar el plomo metálico, y el sulfuro de hierro formado es capturado en la escoria.

La adición de Carbonato de Sodio en la carga del horno también ayuda con la captura de Sulfuro por medio de la reacción con el sulfato de Plomo, el Hierro y el Carbono para liberar el Plomo metálico formando un complejo compuesto de hierro, sodio y sulfuro que cuando se estabiliza es conocido como Escoria Erdite. Al mismo tiempo el monóxido de carbono y el dióxido de carbono se forman también. El monóxido de carbono es también consumido en la operación de fundición como un agente reductor como lo veremos a continuación.

El Dióxido de Plomo en la pasta es reducido a Monóxido de Plomo por el carbón a una temperatura relativamente baja, y puede ser reducido por sí mismo de monóxido de carbono a plomo metálico y dióxido de carbono, o el carbono a plomo metálico y monóxido de carbono.

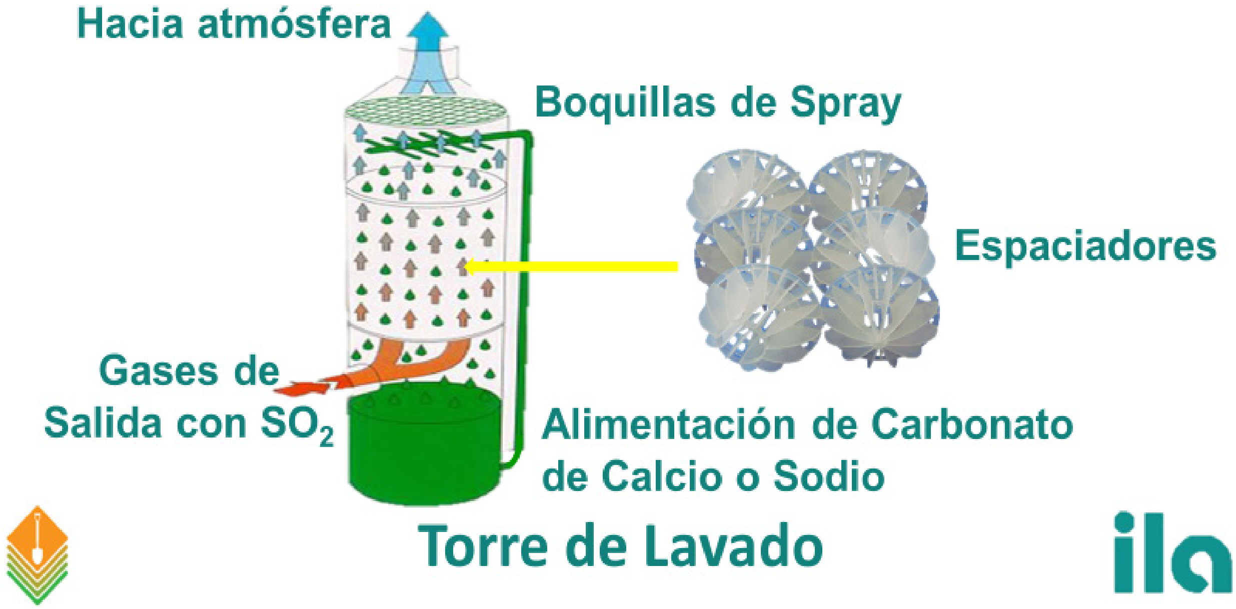
Este proceso simple y económico removerá hasta el 95% del sulfuro del material de carga.

Si el hierro y el Carbonato de Sodio no son añadidos a la mezcla fundidora, entonces el Sulfato de Plomo en la pasta sería reducido a Monóxido de Plomo, pero además liberaría Monóxido de Carbono y Dióxido de Azufre, los cuales entrarían a la atmósfera a menos que puedan ser confinados antes a través de una chimenea, y éste es el ejemplo para considerar desulfurización después de la fundición.

Hay varias opciones, pero se van a considerar las dos más comunes. Ambas opciones requieren del uso de la Torre Depuradora, la cual es esencialmente un tanque alto de acero que tiene una solución ya sea de carbonato de sodio o carbonato de calcio rociado dentro de la cámara desde la parte superior del tanque.

La solución alcalina pasa por miles de rellenos plásticos o separadores que incrementan efectivamente el área de superficie del líquido, de ese modo habilitando más oportunidades de contacto entre el gas de escape del horno que entra a la base de la torre y la solución alcalina.

Las reacciones son generalmente de absorción del dióxido de azufre ya sea por el sulfato de calcio o el sulfato de sodio, y la liberación del gas de dióxido de carbono. Los sulfatos de calcio y sodio estarán en solución, pero las sales pueden ser recuperadas en una manera similar a la descrita anteriormente para producir productos comercializables.



Una torre depuradora o de lavado bien manejada removerá el 99% de dióxido de azufre en el gas residual. Durante la pasada década, se han incrementado más y más operaciones que escogen dos de las tres opciones para asegurar que las emisiones de chimenea están libres de dióxido de azufre.

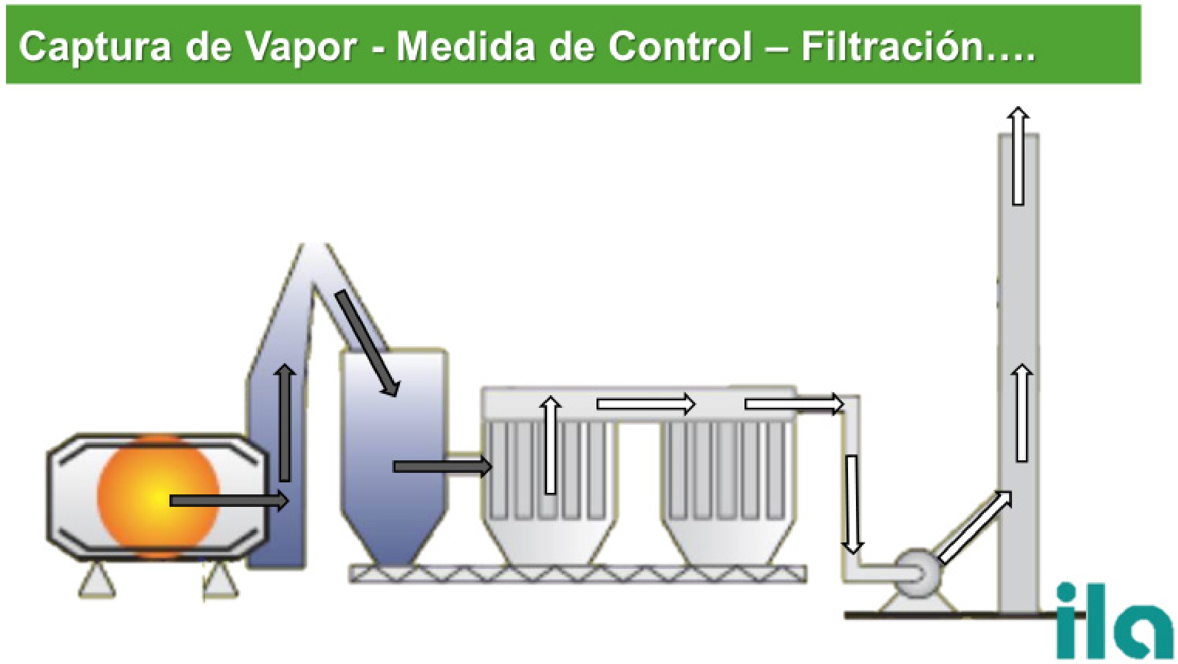
La cal es normalmente seleccionada para hacer un lavado alcalino y el Yeso producido puede ser vendido o usado en la producción de lozas de pavimento. Es más común encontrar que los fundidores modernos escojan las dos primeras opciones, o sea, antes y durante la fundición, en vez de depender de la tercera opción sola, porque si ésta falla, entonces no hay procesos posteriores para remover el dióxido de azufre.

3.1.5. Sistemas de Ventilación y Filtración

Los sistemas de Ventilación son un aspecto muy importante de la gestión de la planta y la salud ocupacional. Típicamente, en el frente del tambor del Horno Rotatorio Inclinado hay una Campana de Ventilación, y hay un ducto de Ventilación de Combustión en la parte posterior del tambor.

Sin embargo, para los hornos rotatorios con las purgas en el centro, es difícil de capturar todos los gases y polvos generados durante la purga porque las emisiones tienden a arrastrarse alrededor del tambor y se escapan a la captura y así la única solución efectiva es encajarlo en el horno completamente y ventilar la caja.

Está muy bien capturar los gases y polvos, pero ¿a dónde van estos?, ¿cómo es el polvo capturado y contenido?, ¿puede ser reciclado? Cualquier gas o polvo generado en cualquier etapa del proceso de reciclaje debe ser ventilado a través de ductos a una planta de filtrado, o filtro de mangas, donde el polvo es removido, recolectado, y los subproductos devueltos al horno con la siguiente carga.



El filtro de Mangas funciona de la siguiente manera: los gases residuales del horno salen de la parte posterior del tambor por el conducto de combustión y luego a una caja de eliminación, que efectivamente baja la velocidad del gas para permitir que partículas grandes literalmente “abandonen” y caigan al piso de la cámara. El polvo presente en los gases pasa entonces a través de la bolsa de filtro, con la forma de una media, donde las partículas de polvo se depositan en el interior de la “media”. Los gases limpios son liberados a la atmosfera.

Periódicamente, un compartimiento en el Filtro de Mangas será apagado para permitir que el polvo recolectado sea expulsado, por aire o por agitación, del revestimiento del filtro. Durante esta operación otro compartimiento en el filtro de mangas será abierto y se filtra el polvo de los gases residuales del horno.

Los polvos son sacados del filtro de mangas a través de una válvula no-retornable a un tambor de recolección y el material se retorna al horno para recuperar plomo.

3.1.6 Tratamiento de la Escoria

El otro factor que nosotros necesitamos direccionar es el residuo del horno o escoria.

Operaciones de reciclaje competentes serán logradas con muy bajos contenidos de plomo en la escoria del horno, menos del 1%, pero en varios países la escoria es aún clasificada como un residuo peligroso y se debe considerar opciones para su disposición o reuso que no serán afectados por las regulaciones de residuos peligrosos.

En Indonesia, una compañía ya está produciendo losas de pavimento decorativo en una escala comercial, desde la formulación que incluye en la mezcla 15% de escoria de plomo aproximadamente. Las losas de pavimento cumplen con las regulaciones de construcción y son muy estables.

3.1.7 Exposición Ocupacional al Plomo

Es importante mantener el sitio de trabajo limpio, ordenado, libre de polvo y residuos y mojado. De esta manera se reducirá el riesgo de polvo de plomo en el ambiente de trabajo y se mantiene el lugar seguro de trabajo.

Sin embargo, las siguientes Guías deberían ser adoptadas para minimizar los riesgos asociados a la exposición ocupacional al Plomo:

1. Siempre llevar el adecuado Equipo de Protección Personal (EPP) determinado para el trabajo.
2. Ventilar todos los cuartos de control con aire filtrado por filtros HEPA y mantener una presión positiva para asegurar que el polvo no entra al cuarto cuando el personal entra y sale del área de control.
3. Ropa limpia de trabajo debe ser usada cada día o cada turno.
4. Cada trabajador del área de fundición debe tomar una ducha antes de salir de la planta, al final del día laboral o del turno.
5. Debe proveerse de una cafetería limpia bajo presión positiva con aire filtrado por filtros HEPA.

Lo esencial para cualquier Fundidora de Plomo, como requerimiento mínimo, es que todos deben llevar un casco duro, gafas y mascarilla protectora contra polvo.

Si las mascarillas de polvo son entregadas en vez de respiradores de neopreno, entonces ellas deben ser máscaras con válvulas de escape porque ellas reducirán los problemas de condensación.

Lo más importante de todo con cualquier respirador es que se ajuste correctamente, el clip de la nariz esté puesto en el sitio para crear un sello entre la nariz y la máscara.

Aunque los respiradores de neopreno y las mascarillas de polvo serían suficientes para la mayoría de las tareas en la planta fundidora, hay ciertos trabajos que requiere un mayor nivel de EPP, por ejemplo, el trabajo en el filtro de mangas por cualquier razón.

Cuando se esté trabajando en el filtro de mangas, llevar una máscara para toda la cara y un overol, pero lo más importante es que cuando un operador o un instalador haya terminado el trabajo ellos deben tomar un baño y remover cualquier residuo de polvos ANTES de quitarse el equipo de protección.

Ahora existen más operaciones de purga del horno que están siendo controladas a control remoto, pero donde sea necesario purgar el horno manualmente, debe llevarse completo EPP que proteja contra el calor y el metal fundido, también como un visor de cara completa y guantes de cuero para horno.

No sobra decir que, habiéndose comprometido con suplir con el EPP apropiado y la ropa limpia de trabajo, también se debe hacer provisiones adecuadas de lavandería, así sea dentro o fuera de la planta, y los vestuarios deben estar limpios y libres de cualquier polvo.

Los vestuarios deben segregarse así la ropa de trabajo y la ropa limpia que se lleva a casa no deben estar mezcladas y todos los operarios deben ducharse al final del día o del turno.

De igual manera, las duchas deben ser aseadas regularmente y contar siempre con suministro de jabón.

Toda la ropa de trabajo debe quedarse en la planta y los operadores deben solo ponerse su propia ropa limpia cuando salgan del trabajo para regresar a casa.

Es también importante proveer de una cafetería acondicionada con aire limpio donde los trabajadores pueden disfrutar sus comidas sin riesgo de ingesta de plomo.

3.2. ¿Qué es la Herramienta para un Análisis Comparativo para la Recuperación y Reciclaje de BAPU?

Es importante tener las Guías para la recuperación de las Baterías de Acido-Plomo Usadas (BAPU), los estándares de seguridad, el desempeño de Salud Ocupacional y Ambiental, y los compromisos para el Desarrollo Sostenible. Sin embargo, sin una inspección, monitoreo, evaluación y verificación independientes, no hay garantía de conformidad con las Buenas Prácticas o cumplimiento con la legislación vigente.

Es igualmente importante que cualquier herramienta de monitoreo de un proceso de evaluación integral sea de fácil uso y consistente con las notas guía de la Asociación Internacional de Plomo (ILA), las guías técnicas de la Convención de Basilea, y la legislación nacional y regional Colombiana que incluya seguridad, higiene y sostenibilidad.

El Formulario para el Análisis Comparativo es un cuestionario que fue diseñado para asegurar que las preguntas den un enfoque aproximado de cada etapa a evaluar. También está diseñado para que el Análisis Comparativo puede ser realizado sin necesidad de ser un experto en las Guías Técnicas o las Mejores Prácticas para el reciclaje de BAPU.

Las preguntas están también diseñadas para que el cumplimiento o el incumplimiento de las buenas prácticas puedan ser identificadas dependiendo si las respuestas marcadas están en los recuadros verdes.

La herramienta de Análisis Comparativo es adecuada para la Evaluación del Desempeño Ambiental de cualquier etapa del ciclo de Vida de la Batería de Ácido-Plomo desde la consecución del mineral de plomo, a través de la fundición, el refinado de plomo, la fabricación de baterías, distribución, Recuperación y Reciclaje de BAPU. Este taller se enfoca en la Recuperación y Reciclaje de las BAPU.

3.2.1. Comparación entre la inspección regulatoria y la herramienta de Evaluación de la Gestión Ambientalmente Adecuada

En primer lugar, es un pre-requisito para cualquier Proceso de Evaluación que una Compañía, una Planta, una Fábrica, una Mina o un Centro de Recolección cumpla con los requerimientos de la regulación nacional y regional, y las convenciones internacionales que sean aplicables. Así, las inspecciones en sitio por parte de las Autoridades Ambientales, y las Agencias de Salud y Seguridad son una parte esencial e integral del proceso de ESM para la recuperación de BAPU.

Es importante considerar las diferencias entre una Inspección Reglamentaria por una entidad gubernamental y una Inspección usando la Herramienta de Análisis Comparativo.

Primero, la Inspección Reglamentaria está dirigida específicamente a un aspecto particular de la operación, como las emisiones de Plomo, los niveles de Plomo en sangre de los trabajadores, las descargas de efluentes o la disposición de Residuos Peligrosos, mientras que la Herramienta de Análisis Comparativo es Holístico en su alcance y examina el proceso de recuperación completo para asegurar que hay un mínimo de impactos al ambiente y a la salud durante las fases de recuperación incluyendo recolección, almacenamiento temporal, empaque y transporte.

Segundo, una Inspección Regulatoria normalmente será hecha en una planta, mientras que una Evaluación Comparativa revisará varios puntos asociados con la cadena de recuperación de BAPU para asegurar un enfoque consistente al ESM durante cada fase de recuperación o vinculo en la cadena de distribución.

Las autoridades ambientales tomarán muestras de emisiones y descargas para análisis cuantitativo para determinar el desempeño ambiental, mientras que la Evaluación Comparativa será cualitativa mediante la observación de las operaciones de reciclaje y las metodologías utilizadas.

Y finalmente, la Inspección Reglamentaria es reactiva, ya que está tomando muestras, revisando u observando los resultados y los eventos pasados, mientras que el Análisis Comparativo y el proceso se dirige hacia la prevención y el enfoque proactivo hacia el ESM para examinar los componentes del proceso, las operaciones y las medidas de control.

3.2.2. Caso de Estudio Comparativo

Estas son las preguntas que los evaluadores deberían preguntarse a sí mismos al realizar cualquier evaluación:

- ¿Es ésta una práctica aceptable?
- ¿Cómo podría el Gobierno monitorear esta situación?
- Es esta operación necesaria y si no, ¿por qué no?
- ¿Qué podría ser sugerido para mejorar las condiciones de trabajo o el desempeño ambiental?

3.2.3. Indicadores para la determinación del Desempeño Ambiental de las BAPU

Los Indicadores para la determinación del Desempeño Ambiental son establecidos para las siguientes etapas del Ciclo de Vida de Baterías de Ácido-Plomo:

- Recolección
- Almacenamiento Temporal
- Empaque
- Transporte
- Reciclaje

Teniendo identificado las cinco fases en el proceso de recuperación y reciclaje de BAPU, es muy importante tener en cuenta los Indicadores para cada fase en los procedimientos, procesos y metodologías que tienen una experiencia comprobada para la gestión ambientalmente adecuada, la salud ocupacional y la seguridad.

3.2.3.1 Indicadores para la Recolección de las BAPU

Examinando los criterios comparativos con mayor detalle para la Recolección de BAPU, es importante que:

- *La BAPU completa sea recogida – que no se haya drenado el electrolito.*
- *Las BAPU sean apiladas de manera vertical, e inspeccionar que los topes estén ajustados para evitar derrames.*
- *Hay un contenedor plástico por separado por si hay fuga en alguna BAPU.*
- *Los Operarios llevan Elementos de Protección Personal (EPP) – guantes de caucho y botas de seguridad como mínimo.*

3.2.3.2 Indicadores para el Almacenamiento Temporal de las BAPU

Para el Almacenamiento Temporal es esencial tener:

- *Un área cubierta para prevenir contaminación de agua superficial por lluvias fuertes*
- *Piso de Concreto con sumidero que retenga cualquier derrame*
- *Áreas de trabajo y pasos peatonales claramente delineados*
- *Estación de lavado de ojos para asegurar que ante cualquier salpicadura de electrolito a la cara sea removido con agua limpia y esterilizada*

3.2.3.3 Indicadores para el Empaque de las BAPU

El Empaque puede ser realizado en las Áreas de Almacenamiento temporal, o en un punto de venta, con tal que los Indicadores en cualquiera de los dos sean los mismos:

- *Las BAPU son medidas y clasificadas por tipo de batería así cuando ellas están organizadas en estibas las filas de BAPU son parejas y las estibas pueden ser apiladas de manera segura.*
- *Las BAPU son probadas para determinar si ellas están descargadas y gastadas, si no ellas pueden ser recargadas y vendidas como "batería recargada". Bajo NINGUNA circunstancia una BAPU debería ser reacondicionada – que es poner en servicio con celdas extraídas de otras BAPU.*
- *Al ser colocadas las BAPU en las estibas, debe ser realizado en filas ordenadas, un cartón grueso debe ser colocado entre cada capa de BAPU, para absorber cualquier fuga menor de electrolito.*
- *Las BAPU se envuelven con una película plástica y se sujeta en los 4 lados con plástico fuerte para mantener las BAPU en el sitio sin ningún movimiento durante el transporte a la fundidora.*

3.2.3.4 Indicadores para el Transporte de las BAPU

Ya que el transporte de las BAPU es normalmente realizado en las rutas públicas, su transporte adecuado es muy importante. Los indicadores claves son:

- *En muchos países, las BAPU están clasificados como un Residuo Peligroso, como ellos están bajo la Convención de Basilea, por ello las compañías que transportan BAPU desde los centros de* *recolección o distribuidores a las plantas recicladoras requieren una licencia o una autorización por parte de las autoridades locales. Se debe revisar la situación en las regiones de Colombia.*

- *Las BAPU deben estar ubicadas en estibas, envueltas en plástico y atadas de manera segura a la estiba, o en un contenedor plástico a prueba de fugas, debidamente asegurado en la parte trasera del vehículo para prevenir cualquier movimiento durante el transporte a la fundidora.*
- *En países donde las BAPU están clasificadas como un Residuo Peligroso, los vehículos transportadores de este tipo de materiales deben exhibir las señales de advertencia de Peligro en la parte externa del vehículo. En los países donde esto no sea un requerimiento legal, una señalización acorde debería estar exhibida así los servicios de emergencia sean notificados del contenido en caso de accidente.*
- *Finalmente, es importante que los vehículos transportadores de BAPU sean adecuados para esta tarea, preferiblemente encerrado o de paredes altas despegables, y que el conductor esté entrenado para tratar derrames menores durante el transporte o aplicar primeros auxilios si alguien es salpicado con electrolito.*

3.2.3.5. Indicadores para Reciclaje de las BAPU

Como el Reciclaje de BAPU es más complicado que la Recolección, Almacenamiento, Empaque y Transporte, es mejor separar las tareas de Análisis Comparativo en cuatro categorías diferentes y examinar cada una de ellas por partes. Y las categorías son:

- *Ambiente*
- *Seguridad*
- *Aseo*
- *Prácticas Operativas*

3.2.3.5.1 Indicadores para Reciclaje de las BAPU – Ambiente

Considerando las condiciones ideales para mantener las ESM de Reciclaje de BAPU los Indicadores para el Ambiente deberían incluir:

- *Los sistemas de filtro de mangas y de control de emisiones deben operar en una manera tal que las emisiones están dentro de los límites legales permitidos y no son contaminantes ni tóxicos. Las operaciones del alto horno deben incluir un depurador para remover el dióxido de azufre.*
- *Para evitar cualquier inconveniente con la descarga de efluentes, los efluentes de la planta deberían ser tratados y usados para producir sub-productos comercializables. El efluente que no es usado para producir sub-productos puede ser usado como agua de proceso o evaporado, ya sea naturalmente o por recirculación, a través de los intercambiadores de calor localizados en el sistema de gases residuales del horno.*
- *Los residuos del horno deberían inactivarse o dejarlos inactivos para que solo residuos sólidos no peligrosos sean dispuestos de la planta, o el residuo convertido en un producto comercializable como los ladrillos cerámicos.*
- *La política de la compañía y los procedimientos operativos deben ser diseñados e*

implementados para que así la Planta de Reciclaje permanezca libre de contaminantes y de reusables, en caso de que la fundidora cierre o se traslade a otro sitio, en otras palabras, debería haber un programa que siempre mantenga un Sitio Sostenible.

3.2.3.5.2 Indicadores para Reciclaje de las BAPU – Seguridad Industrial

Ahora está claro que es igualmente importante para una planta recicladora operar de una manera segura, así como que la operación sea ambientalmente adecuada. Hay varios aspectos de la Gestión de la Seguridad, pero el enfoque del Análisis Comparativo se enfoca en varios aspectos que pueden ser resumidos en 4 indicadores clave:

- *La Política de Seguridad de la Compañía debe tener un compromiso claro con los más altos estándares de seguridad para todo el personal de la planta y cualquier visitante o trabajador de la planta por un periodo corto. Además, esta política debe estar publicada en la página web de la compañía y disponible para inspección.*
- *Todos los trabajadores del sitio deben asistir a la Inducción sobre Seguridad Integral.*
- *Todo el personal que trabaja en las áreas de operación debe vestirse apropiadamente y llevar las EPP especificadas todo el tiempo*
- *Cualquier trabajo de mantenimiento o de ingeniería debe estar autorizado a través de un rígido procedimiento de "Permiso de Trabajo" para asegurar que las condiciones de seguridad apropiadas sean aplicadas y cualquier equipo de la planta esté "apagado" antes de empezar el trabajo.*

3.2.3.5.3 Indicadores para Reciclaje de BAPU – Limpieza

La Salud de los trabajadores y la población local son fundamentales si la Planta de Reciclaje opera en zonas urbanas. Así los indicadores para Salud Ocupacional son críticos y deberían incluir los siguientes elementos claves:

- *La Política de Salud Ocupacional Integral debe cubrir a los empleados, hombres y mujeres, y estipular las condiciones aplicables a las operaciones de la planta para minimizar cualquier riesgo adverso a la salud de los empleados y la población local.*
- *Todos los trabajadores del sitio deben llevar y usar correctamente los EPP apropiados para minimizar la exposición al Plomo en el área de operación.*
- *Debe haber un programa de vigilancia médica proactiva bajo la guía de un Médico cualificado para asesorar a la compañía y los trabajadores en temas relacionados a la Salud Ocupacional. El programa debe incluir chequeos periódicos de los niveles de plomo en sangre de los empleados.*
- *Todo el personal trabajando en áreas de exposición se le debe proveer cada día ropa de trabajo limpia y esta ropa debe ser mantenida separada de la ropa con la que llega de sus hogares. Además, a los trabajadores se les debe proporcionar una cafetería limpia para tomar sus alimentos mientras están en la planta.*

3.2.3.5.4. Indicadores para Reciclaje de las BAPU – Prácticas Operativas

Cuando consideramos las Prácticas de Operación, no es una tarea fácil la de identificar los cuatro indicadores claves y las listas de indicadores pueden variar, pero todas ellas son válidas. El desafío está en la selección de los indicadores que son vitales para el desarrollo de la Industria de Reciclaje en Colombia. Estos son los cuatro indicadores claves:

- *Primero, y principalmente en línea con los requisitos de la Gestión del Ciclo de Vida de Manera Ambientalmente Adecuada, es esencial que las BAPU provengan de un comercializador reconocido que trabaje de manera ambientalmente adecuada. Las visitas a los proveedores son esenciales en este aspecto.*
- *Las BAPU deben ser rotas mecánicamente usando una sierra o trituradora segura y aprobada. Es totalmente inaceptable que las BAPU sean rotas por los trabajadores con machetes, hachas o martillos.*
- *Las operaciones de fundición deben ser cerradas y los hornos deben tener sistemas de trabajo seguro, como detectores de fallas del quemador y otros, y un adecuado sistema de higiene y ventilación para preservar los sitios de trabajo libre de polvo y humos de plomo.*
- *Finalmente, es esencial que el ambiente de trabajo permanezca limpio, lo que significa, libre de polvo de plomo y cualquier residuo que contenga plomo proveniente de los sub-productos y que todos los sitios de trabajo estén organizados y libres de riesgos a la seguridad.*

3.3. Aplicación Práctica de la Herramienta de Análisis Comparativo

Cuando se usa la Herramienta de Evaluación en el campo se deben realizar los siguientes pasos:

- ✓ *Completar la sección relevante o las secciones del Formato de Evaluación para la tarea respectiva respondiendo las preguntas en la columna uno del formato.*
- ✓ *Identificar los Indicadores Claves para la Recolección, Almacenamiento Temporal, Empaque, Transporte y Recepción de BAPU.*
- ✓ *Determinar si la inspección muestra o no cumplimiento con los Indicadores claves y seleccionar la respuesta apropiada. Los recuadros verdes indican "Bueno" o "Mejor Práctica" y si todas las respuestas están en los recuadros verdes, entonces la planta de reciclaje es ambientalmente adecuada, segura y limpia.*
- ✓ *Repetir el proceso para cada pregunta y cada sección del formato.*
- ✓ *Preparar una serie de recomendaciones para implementar cualquier mejora necesaria para un cumplimiento completo.*

Siempre pensar en una manera proactiva para resolver las no– conformidades.

3.3.1. Uso de la Herramienta de Análisis Comparativo

En la teoría todo está muy bien, pero ¿cómo hacerlo funcionar en la práctica?

La Herramienta de Análisis Comparativo ha sido aplicada y probada en India, Costa Rica y más recientemente en China.

Durante la inducción a la Asociación de Desarrollo de Plomo Zinc en India y en conjunto con Pure Earth, la Herramienta de Análisis Comparativo fue usada en un proyecto piloto para resolver el problema local de exposición al plomo en Tamil Nadu, involucrando el Comité de Control de Contaminación del estado de Tamil-Nadu y una planta de reciclaje de BAPU.

Hubo una cooperación total entre el Comité Regional de Control de la Contaminación y la Compañía.

Para probar la facilidad del uso de la Herramienta, la mínima cantidad de instrucción fue dada por el Centro Internacional de Gestión de Plomo (ILMC, por su sigla en inglés) sobre como el formato debe ser diligenciado en cada sección.

La inspección de la planta comenzó con cada miembro del Equipo de Inspección, observando la operación de reciclaje y señalando los cuadros apropiados en cada sección del formato.

Cada aspecto de la operación fue inspeccionado y cuando se completó, los participantes regresaron a Chennai para revisar los resultados de la Evaluación.

En Chennai los participantes de la Compañía, el Comité de Control de Contaminación del Estado y Pure Earth analizaron los Formatos en dos grupos separados para comparar los resultados y además probar la aplicación del proceso.

3.3.2. El Resultado

Las discusiones fueron enfocadas, constructivas y sin enfrentamientos. Los resultados en el formato de recomendaciones cayeron en tres categorías:

- Mejoras a Corto Plazo – Sin costo y pueden ser implementadas inmediatamente
- Corto Plazo – Bajo costo, hasta US$ 2,000
- Largo Plazo – Donde el mayor capital de inversión requerido es de hasta US$1M.

En total, integrando las respuestas de todos los participantes, se dieron:

- 12 recomendaciones a Corto Plazo que podían ser implementadas inmediatamente
- 9 recomendaciones a Corto Plazo para mejoras por un costo de hasta US$2,000
- Y 4 Recomendaciones a Largo Plazo, donde el Capital de Inversión requerido es de hasta US$ 1 M

Los resultados de este ejercicio piloto formaron la base para un dialogo constructivo entre el Comité de Control de la Contaminación del Estado de Tamil Nadu y la compañía.

3.3.2.1 Casos de Aplicación de la Herramienta

Costa Rica

La Herramienta de Análisis Comparativo ha sido también usada recientemente en una fundidora de Costa Rica como requerimiento del gobierno y en conjunto con el Centro Regional para América Central y México del Convenio de Basilea.

Siguiendo el mismo proceso como en India, la inspección de la planta proporcionó suficiente información para la Evaluación Comparativa como el desempeño ambiental de la fundidora.

China

En China la Herramienta de Análisis Comparativo (BAT) está siendo aplicada en un esquema piloto como requerimiento de la Asociación de la Industria de Metales No Ferrosos de China (CNIA, por su sigla en inglés) en una de las fundidoras del Grupo Chunxing para comprobar si la Herramienta puede ser usada para animar al Gobierno a enfocarse más en los procedimientos y procesos adecuados de recuperación y reciclaje de BAPU, en vez de enfocarse solamente en la capacidad y la ubicación de la planta, o en la proximidad de la planta a la población.

3.3.2.2. Conclusiones de la Aplicación de la Herramienta

Las siguientes conclusiones resultaron de estos tres ejercicios sobre el uso de la Herramienta de Análisis Comparativo:

- ✓ La herramienta es fácil de usar y da una rápida evaluación de una operación en la planta.
- ✓ En los tres ejercicios piloto, la mayoría de los problemas fueron identificados.
- ✓ Los procesos fueron cualitativos, examinando las tecnologías empleadas, las prácticas de trabajo y los procedimientos de seguridad.
- ✓ Ya que el enfoque fue en la operación y las metodologías las discusiones fueron constructivas y sin enfrentamientos.
- ✓ Mientras no haya un sustituto para corroborar los datos de Buenas Prácticas, recoger todos los datos consume tiempo y es costoso, pero hay una razón para creer que la Herramienta de Análisis Comparativo para el reciclaje de BAPU puede ser un indicador útil costo-efectivo para la Gestión Ambientalmente Adecuada, el Trabajo Seguro y la buena Salud Ocupacional.

3.4. La Herramienta de Análisis Comparativo para la Recuperación y Reciclaje de BAPU

El Formato de Análisis Comparativo es fácil de usar y está en formato de cuestionario.

Este fue diseñado de ésta manera para dar un enfoque consistente a cada evaluación sin importar el sitio o el Evaluador. Esto también significa que la Evaluación comparativa puede ser realizada sin un experto en las Guías Técnicas de Basilea o en las Mejores Prácticas para la Recuperación y Reciclaje de BAPU.

Las preguntas también están diseñadas para que el cumplimiento o el no cumplimiento pueda ser identificado fácilmente dependiendo si las marcas están en los recuadros verdes.

La Herramienta de Análisis Comparativo es apropiado para la Evaluación de Desempeño Ambiental de alguna fase del Ciclo de Vida de la Batería de Acido-Plomo desde la obtención del concentrado de Plomo, a través de la fundición, el refinado de Plomo, la fabricación de la batería, la comercialización, el reciclaje y recuperación de las BAPU.

3.4.1. Diligenciamiento del Formato de Análisis Comparativo

En cada sección del formato:

- ✓ *Identificar los Indicadores Clave para la fase apropiada del Ciclo de Vida, que son Recolección de BAPU, Almacenamiento Temporal, Empaque, Transporte y Recolección, o Reciclaje.*
- ✓ *Determinar si la inspección muestra cumplimiento con los Indicadores Clave o no, y marcar la respuesta apropiada. Los recuadros verdes indican las "Buenas" o "Mejores Prácticas" y si todas las respuestas marcadas están en los recuadros verdes, entonces es probable que la planta de reciclaje tiene prácticas ambientalmente adecuadas, seguras e higiénicas. Pero por favor notar que la evaluación es cualitativa y por lo tanto es muy importante hacer seguimiento con monitoreo y pruebas cuantitativas.*
- ✓ *Repetir el proceso para cada pregunta y cada sección del Formato.*

Sección 1. Información General

La Sección 1 contiene la información acerca de la compañía, los datos de contacto de la organización, del representante de la compañía y del evaluador.

Es importante registrar los datos de contacto para que cualquier consulta pueda hacerse su seguimiento.

Sección 2 – Recolección de BAPU y puntos de suministro

Idealmente, los reguladores deberían visitar e inspeccionar los centros de recolección de BAPU, los patios de chatarrización de vehículos, los distribuidores de autos y baterías, pero tal vez solo es posible visitar una fundidora de plomo, en la cual el regulador podría inspeccionar el área de recepción y comprobar que tipo de BAPU son entregadas completas con el electrolito y por quien.

Segundo, es muy importante encontrar si las BAPU son drenadas del electrolito antes de ser entregadas al fundidor o si han sido entregadas completas con el ácido.

Las BAPU deben ser inspeccionadas para asegurar que ellas no tienen fugas y si hay alguna fuga – que estén siendo transportadas en un contenedor plástico separado a prueba de fugas.

En muchos países, los recolectores de BAPU y los distribuidores ganan un ingreso extra mediante la identificación de las baterías usadas que son desechadas, pero que solo necesitan ser recargadas. Así que probando todas las BAPU ellos pueden seleccionar esas que pueden ser recargadas y vendidas como batería recargada. Esto es perfectamente legal y maximiza la vida de la batería.

El almacenamiento es preferible que sea bajo techo porque hay menos riesgo para el ambiente si una batería está presentando fugas.

Finalmente verificar el método de transporte y cómo las BAPU son empacadas para entrega a la fundidora. Los vehículos transportadores de BAPU deben exhibir el signo de aviso de peligro de acuerdo a la legislación local o nacional, y las BAPU deben estar embaladas o empacadas, si hay alguna BAPU con fugas, ésta debería estar en un contenedor separado a prueba de fugas.

Sección 3 – Estado Ambiental

Primero es importante conocer cuáles son las autoridades gubernamentales nacionales o locales que son responsables de otorgar las licencias de operación, y recordar algunas veces que puede ser más que un ministerio, puede ser también la Agencia Ambiental y el Ministerio de Salud.

Es también importante conocer que tan lejos se encuentra la fundidora de las poblaciones y si la fundidora está ubicada en una zona destinada para uso industrial.

El regulador necesita entender que sucede con algún efluente del proceso. Idealmente los efluentes del proceso deberían ser descargados desde el sitio, pero si es así, hay que examinar el proceso de tratamiento, si hay una planta de tratamiento del efluente. En esta forma el regulador puede comprobar que pasa con el electrolito de la BAPU, si está siendo descargado sin tratamiento, o recolectado y procesado.

El siguiente ítem en la lista de chequeo en el sistema de control de emisiones y es importante encontrar que sucede con el polvo recolectado en el filtro de planta o filtro de mangas.

Es importante examinar los sistemas de control de contención de dióxido de azufre, producido desde los residuos de ácido sulfúrico en la BAPU. Añadiendo hierro al material de carga capturará el 95% del sulfuro en el horno rotatorio, pero los hornos altos necesitan un depurador para remover el dióxido de azufre.

Continuando con la lista de chequeo, el siguiente ítem es examinar que sucede con los residuos del horno o “escoria”. La escoria de plomo del horno puede ser tóxica y soluble en agua, pero ésta puede ser tratada y transformarla a un estado inerte, y también podría ser materia prima para la producción de ladrillos y baldosas.

Finalmente, el regulador debería examinar el sitio para comprobar si está limpio, organizado y libre de polvo.

Sección 4 – Exposición Ocupacional al Plomo

Es importante para los reguladores tener en mente cuando se considera los Indicadores de Exposición Ocupacional al Plomo que ellos examinen las políticas de la organización y los procedimientos que monitorean la salud ocupacional, y si reduce o controla los niveles de exposición al Plomo.

Así que la primera tarea que se requiere es ver si hay políticas de higiene y de uso de mascarilla.

Segundo, y esta es la tarea más importante, observar a los operarios en el trabajo y comprobar si ellos están llevando sus mascarillas correctamente y todo el tiempo en las áreas de exposición, tanto en la fundidora como en la refinadora.

Los reguladores deben preguntar si hay un médico oficial y/o un oficial en enfermería ocupacional señalado por la compañía para monitorear la salud ocupacional (mediciones de plomo en sangre), y dar tratamiento o terapia a los empleados si es necesario.

El personal médico no tiene que ser de tiempo completo, puede ser tiempo parcial siempre y cuando las visitas a las operaciones sean regulares y dentro de un tiempo razonable. Además, es esencial que los empleadores concienticen a sus empleados no solamente sobre el riesgo potencial asociado a la exposición al plomo, sino también sobre las precauciones personales que se deben tomar para reducir o minimizar los riesgos.

Los reguladores deberían encontrar si los operarios están usando ropa de trabajo adecuada y observar cual es la frecuencia de cambio y lavado. Ellos deberían también encontrar si la cafetería está separada de las áreas de fundición y de producción. Notar que no es suficiente con avisar que comer en el sitio de trabajo no está permitido. Es importante que los operarios se presenten al trabajo cuando han comido, porque si ellos no comen antes del trabajo, el riesgo de ingestión de Plomo se incrementa.

Finalmente, examinar el cuarto de lavado y la ducha, si hay una, y determinar si los operarios en las áreas expuestas, particularmente la fundición, se bañan y se cambian a ropa limpia antes de regresar a casa.

Sección 5 – Seguridad

El enfoque de Seguridad de la Compañía es el tema de la Sección 5 y es esencial encontrar si hay una Política de Seguridad escrita y creíble, o si está disponible para los operarios en los tableros de anuncios o en un manual, o si ha sido distribuida por vía electrónica.

El regulador debería encontrar si hay inspecciones regulares de seguridad o auditorias, o ambas. Él o ella debe determinar si cada empleado, contratista o visitante ha recibido una apropiada inducción de seguridad. Las compañías que han adoptado mejores prácticas darán una inducción a cada persona que visita o trabaja en el sitio.

Seguido, el evaluador necesita encontrar si se han realizado evaluaciones de riesgo para cada trabajo o posición dentro de la planta. Si una operación tiene ISO 9001, entonces cada tarea asociada con la certificación tendrá una evaluación de riesgo, pero hay que tener en mente que la ISO 9001 no significa que cada aspecto de la operación se ha incluido, porque la ISO 9001 puede ser para una parte del proceso solamente, como la fundición.

El siguiente asunto para el evaluador es comprobar si hay un libro de accidentes y encontrar si todos los accidentes no están solamente registrados, sino también que se hayan sido investigados y quien lo ha realizado. Idealmente, todos los accidentes deberían ser investigados por un equipo que incluya especialistas en seguridad, gestores y representantes de los operarios.

Es muy importante que cualquier elemento de la planta o equipo este aislado cuando se vaya a realizar mantenimiento, modificación o limpieza. No solamente que esté apagado, sino también éste DEBE estar bloqueado del sistema de distribución eléctrica y de energía y debe haber una autorización escrita para el trabajo que se va a realizar.

Finalmente, debe hacerse una inspección de las precauciones de incendio. Idealmente debe haber extinguidores de espuma y sacos o baldes (cubos) de arena. Los extinguidores de fuego deben estar vigentes, y todos deben estar accesibles a los trabajadores.

Una vez el formato está diligenciado completamente, el evaluador tiene que estudiar las notas realizadas en el formato de BAT y:

- ✓ *Preparar una serie de recomendaciones que serán para apoyar a los procedimientos y las prácticas en la planta, los cuales deberán ser para dar un cumplimiento total de las prácticas en los recuadros verdes, o una lista de mejoras requeridas para alcanzar la conformidad.*

Siempre pensar en una manera proactiva para resolver las no-conformidades.

El Resultado

Los resultados en el formato de recomendaciones normalmente se organizan en tres categorías:

- Mejoras a Corto Plazo – Sin costo y pueden ser implementadas inmediatamente
- Corto Plazo – Bajo costo, hasta US$ 2,000
- Largo Plazo – Donde el mayor capital de inversión requerido es de hasta US$ 1 M.

PURE EARTH
BLACKSMITH INSTITUTE

Con financiación de ....

USAID
FROM THE AMERICAN PEOPLE

En alianza con.....................

Asociación Internacional de Plomo

ila

Soluciones a la Gestión del Plomo Sostenibles y Ambientalmente Seguras

Brenda Natalia Lopez, Pure Earth

ila

Parte 1. Recolección, Almacenamiento y Transporte de BAPU; Evaluación y Controles, Seguridad, Salud Ocupacional y Medio Ambiente

Estado – Factores y Oportunidades

- ✓ El valor económico de las BAPU es un factor clave para el reciclaje.
- ✓ La recolección informal de BAPU y la cadena de suministro son muy eficientes.
- ✓ Las tasas de reciclaje son altas, pero las tasas de recuperación pueden ser bajas.
- ✓ La generación de energía renovable está creciendo rápidamente
- ✓ Las baterías de plomo son el principal sistema de almacenamiento de energía.
- ✓ La gran mayoría de los países ratificó el Convenio de Basilea
- ✓ Ante la ausencia de leyes específicas, prevalecerán las directrices técnicas del CB.
- ✓ La falta de sitios de eliminación de desechos peligrosos promueve el desarrollo de productos

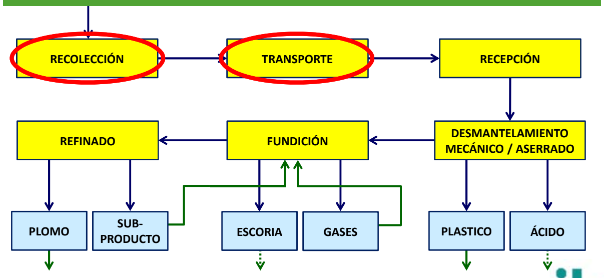
Barreras a la Gestión Ambientalmente Segura de BAPU Reciclaje …

- ESM de BAPU: El reciclaje no es prioridad de la agenda política
- Recicladores informales y comercializadores de chatarra (exportación) ofrecen los precios más altos
- Los costos de transporte pueden ser altos y los tiempos de viaje pueden ser largos
- Los costos de reciclaje informal son bajos debido a la falta de sistemas de control
- Las autoridades ambientales no siempre son conscientes de los riesgos del reciclaje informal del plomo
- Falta una base técnica / de ingeniería: esencial para las operaciones de la planta
- El desempleo es alto y los trabajadores son reemplazados fácilmente

Matriz GAR para el Reciclaje de BAPU

La actividad	El proceso	GAR/ESM
Recolección	Circuito cerrado	BAPU no drenado
Transporte	Contenedor plástico	Prueba de fugas
Almacenamiento	Protegido	Sin fugas de ácido
Desmantelamiento	Aserradero/Mecánico	No Manualmente
Electrólito	Neutralización	Sin descarga
Reciclaje	Fundición ventilada	Control de emisiones
Subproductos	Productos inertes	Sin residuos peligrosos

Reciclaje de BAPU : Procesos Importantes …



Recolección BAPU: Riesgos de Seguridad y Salud

Contenido BAPU	Clasificación	Exposición	EPP
Plomo y Ácido		Ingestión Derrame y Salpicaduras	
Plomo es Pesado			

Recolección BAPU: Riesgos de Seguridad y Salud

¿ Qué Pasa con Tus Ojos?

Recolección BAPU: Riesgos de Seguridad y Salud

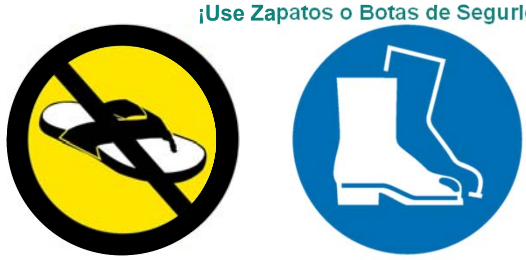
Tenga Siempre un Lavado de Ojos (colirio) Disponible

Recolección BAPU: Riesgos de Seguridad y Salud

¿ Qué pasa con tus pies?

Recolección BAPU: Riesgos de Seguridad y Salud

¡Use Zapatos o Botas de Segurldad!



Las Baterías de Plomo son Pesadas y Pueden llegar a Pesar 1 t

Recolección BAPU: Riesgos de Seguridad y Salud

Las Baterías de Plomo son Pesadas y Pueden llegar a Pesar 1 t

Recolección BAPU: Riesgos de Seguridad y Salud

Las Baterías de Plomo son Pesadas y Pueden llegar a Pesar 1 t

Embalaje y Almacenamiento: Riesgos - Fuga de Ácido

Clasifique las Baterías por Tamaño y Apílelas Uniformemente

Embalaje y Almacenamiento: Riesgos - Fuga de Ácido

Clasifique las Baterías por Tamaño y Apílelas Uniformemente

Embalaje y Almacenamiento: Riesgos - Fuga de Ácido

Un Buen Diseño de la Batería Reduce el Riesgo

Recolección BAPU: Riesgos Ambientales – Vertido de Ácido

¿Qué Cantidad de Ácido Sulfúrico se Vierte?

Un ejemplo:

20,000 t de BAPU drenadas = 12,000 t de Plomo refinado

= 2,600 t de Ácido

¡No vacíe el electrolito de la batería!

Recolección BAPU: Riesgos Ambientales – Vertido de Ácido

El electrolito de la batería es ácido sulfúrico y es:

- Clasificado como un desecho peligroso
- Un irritante para la piel y los órganos internos
- Si se salpica en la cara, puede causar ceguera
- Es un carcinógeno
- Es tan corrosivo que disolverá el hormigón

¡No vacíe el electrolito de la batería!

Recolección BAPU: Riesgos Ambientales – Vertido de Ácido

Evite el Movimiento: Empaque las BAPU Ajustadamente

Recolección BAPU: Riesgos Ambientales – Vertido de Ácido

Clasifique las Baterías por Tamaño y Apílelas Uniformemente

ila

Recolección BAPU: Riesgos Ambientales

Una BAPU con Fugas Dañará al Medio Ambiente

ila

Transporte: Contenedor a Prueba de Fugas

Beneficios 2.

- ✓ Úselo en cualquier vehículo
- ✓ Liviano
- ✓ Fácil de usar en la carretilla elevadora
- ✓ Se puede apilar

Certificado por la ONU

ila

Transporte: Un Contenedor a Prueba de Fugas

Beneficio 3.

- ✓ Puede ser reutilizado

Certificado por la ONU

ila

Almacenamiento temporal: al aire libre no es ideal …

El Suelo Estaría Contaminado por Ácido

ila

Almacenamiento Temporal: Bajo Techo es Perfecto…

Tanzania

ila

Almacenamiento Temporal: Bajo Techo es Perfecto…

Revestimiento de Resina Impermeable

ila

Almacenamiento Temporal: Bajo Techo es Perfecto…

Estanterías de Acero para Almacenamiento

ila

Almacenamiento: Instalación de Sumidero y Bomba

Captura de Cualquier Derrame de Ácido

ila

Almacenamiento: Contenedor Resistente a la Intemperie

Imágenes cortesía de estibas UNISEG

ila

Transporte: Vehículo con Licencia Especializada

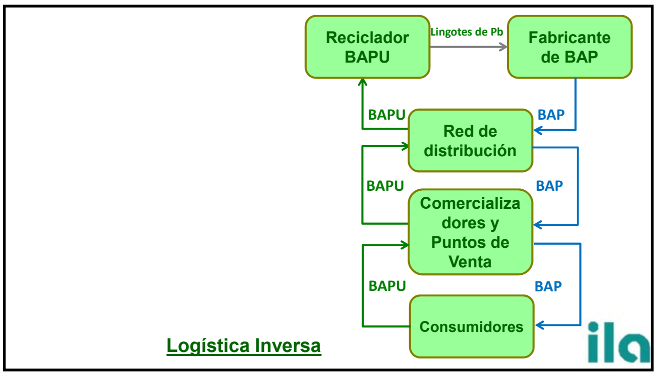
Vehículo cerrado con señales de advertencia de peligro

ila

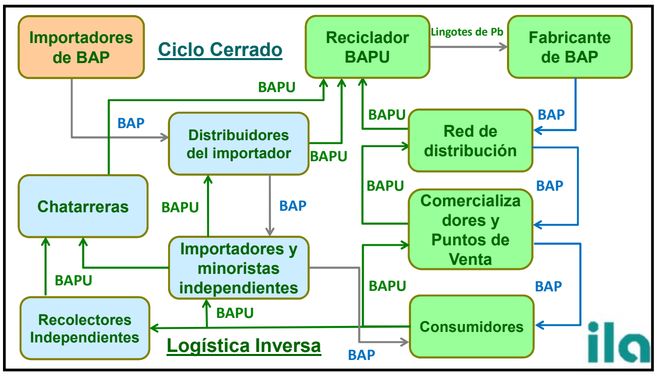
Ciclo cerrado y logística inversa…

El Más Efectivo para Controlar el Reciclaje de BAPU

ila



Reciclador BAPU
Lingotes de Pb
Fabricante de BAP
BAPU
BAP
Red de distribución
BAPU
BAP
Comercializadores y Puntos de Venta
BAPU
BAP
Consumidores
Logística Inversa



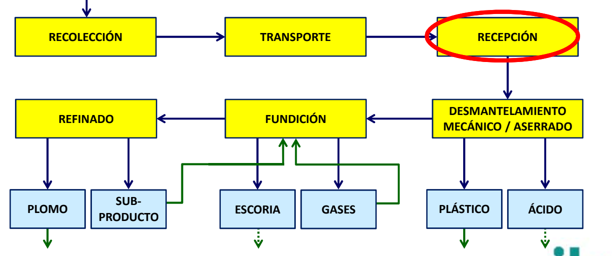
Importadores de BAP
Ciclo Cerrado
Reciclador BAPU
Lingotes de Pb
Fabricante de BAP
BAPU
BAP
Distribuidores del importador
BAPU
BAPU
BAP
Red de distribución
Chatarreras
BAPU
BAP
BAPU
BAP
Comercializadores y Puntos de Venta
Importadores y minoristas independientes
BAPU
BAPU
BAPU
BAP
Recolectores Independientes
Logística Inversa
BAP
Consumidores

Gracias

Part 2. ULAB Breaking: Risk Assessment and Controls - Safety, Occupational Health and the Environment

ila

Reciclaje de BAPU : Procesos Importantes …



ila

Recepción BAPU: Riesgos de Seguridad y Salud

Contenido BAPU	Clasificación	Exposición	EPP
Plomo Metálico		Ingestión	
Óxidos de Plomo y Sulfatos		Ingestión	
Ácido sulfúrico diluído		Derrame y Salpicaduras	
Separadores	Seguro si están limpios	Ingestión	
Peso		Manos y Pies	

Recepción BAPU: Inspección y Selección …

Verificar el estado de la batería

En este ejemplo, la batería está muerta y debe ser reemplazada

Identificar baterías que solo necesitan recargarse.

ila

Recepción BAPU: Seleccionar y Recargar …

A veces, una BAPU se puede recargar

y se puede vender como una batería recargada

Vender las Baterías Recargadas

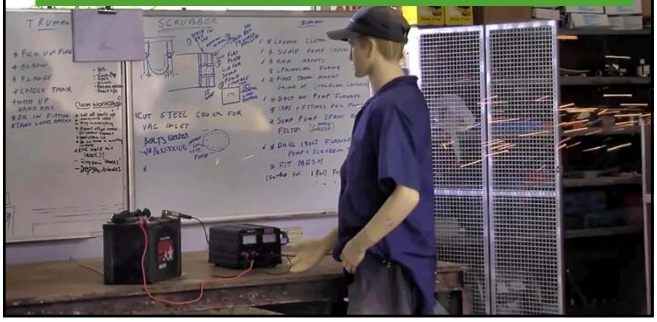
ila

Recepción BAPU: Recargar y Vender…

Vender las Baterías Recargadas

ila

Recepción BAPU: Riesgos de Seguridad y Salud



Recepción BAPU: Riesgos de Seguridad y Salud

ila

Recepción BAPU: Inspección y Selección …

Inspección de baterías:

Retire cualquier batería que no sea una batería de plomo, especialmente baterías de litio………. ¿Por qué?

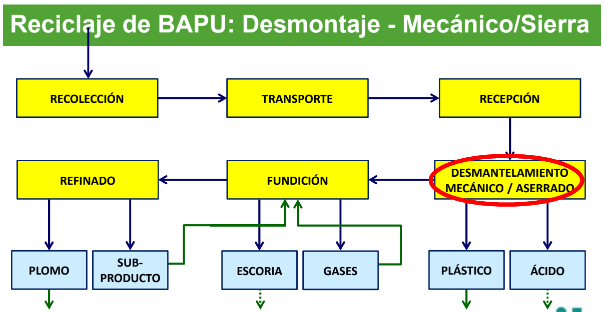
ila

Recepción BAPU: Inspección y Selección …

Esta es la razón por la que las baterías de litio deben eliminarse del reciclaje de BAPU

ila

Reciclaje de BAPU: Desmontaje - Mecánico/Sierra



ila

Desmantelamiento de Baterías: Manual

Inseguro

Manual

Tegal - Indonesia

ila

Desmantelamiento de Baterías: Sierra de Batería

Seguro

Ajuste la sierra a la altura de la BAPU

El electrolito debe drenarse a la planta de tratamiento de efluentes antes del desmantelamiento

ila

Serrado de Batería: Riesgos de Salud y Seguridad

Contenido BAPU	Clasificación	Exposición	EPP
Plomo Metálico		Ingestión	
Óxidos de Plomo y Sulfatos		Ingestión Inhalación	
Ácido Sulfúrico Diluido		Derrame y Salpicaduras	
Niebla Ácida		Ingestión Inhalación	
Ruido		Orejas	

Serrado de Batería: Riesgos de Salud y Seguridad

¡Use Zapatos o Botas de Seguridad!

Las Baterías de Plomo son Pesadas y Pueden Pesar 1 t

ila

Trituración de Baterías : Trituradora Mecánica

Seguro

El electrolito no se debe drenar de la BAPU antes de la trituración

ila

Trituración de Baterías : Trituradora Mecánica

Rejillas de batería

ila

Trituración de Baterías : Trituradora Mecánica

Separación de los Plásticos

ila

Trituradora: Riesgos de Salud y Seguridad

Contenido BAPU	Clasificación	Exposición	EPP
Plomo Metálico		Ingestión	
Óxidos de Plomo y Sulfatos		Ingestión Inhalación	
Ácido Sulfúrico Diluido		Derrame y Salpicaduras	
Niebla Ácida		Ingestión Inhalación	
Ruido		Orejas	

Trituradora: Riesgos de Salud y Seguridad

¡Use Zapatos o Botas de Seguridad!

Las Baterías de Plomo son Pesadas y Pueden Pesar 1 t

Trituradora: Batería de Litio: Riesgo de Explosión

Esto es lo que sucede cuando una batería de litio entra en una trituradora

Riesgo Ambiental: Electrolito de la Batería

El electrolito de la batería es ácido sulfúrico diluido

Es corrosivo y destruye los ecosistemas

Pure Earth - India

Electrolito: Neutralización – Evitar descarga

Tratamiento de Efluente - Ciclo Cerrado

Tratamiento de Efluente: Electrolito de la Batería

Proceso GAR y sin descargas

El electrolito debe procesarse en una planta de tratamiento de efluentes para producir subproductos vendibles

Manejo de Condiciones Climáticas Tropicales…

¿Cómo podemos mitigar los problemas asociados con las tormentas?

ila

Manejo de Condiciones Climáticas Tropicales…

Los tanques de proceso deben estar por encima del nivel de cualquier agua de inundación

ila

Electrolito de la Batería: Subproductos vendibles …

PTAR: Electrólito/Neutralización Ácida:- Agregar +

$$H_2SO_4 + 2NaOH = Na_2SO_4 + 2H_2O$$

$$H_2SO_4 + Na_2CO_3 = Na_2SO_4 + H_2O + CO_2$$

$$H_2SO_4 + Ca(OH)_2 = CaSO_4.2\ H_2O$$

$$H_2SO_4 + (NH_4)_2CO_3 = (NH_4)_2SO_4 + CO_2 + H_2O$$

ila

Opciones de Venta de Subproductos…

Sulfato de Sodio	• Fabricación de vidrio • Fabricación de papel
Yeso	• Industria del Cemento • Materiales de Construcción
Sulfato de Amonio	• Fertilizante

MARKET RESEARCH

ila

Opciones para el uso de Efluentes Procesados…

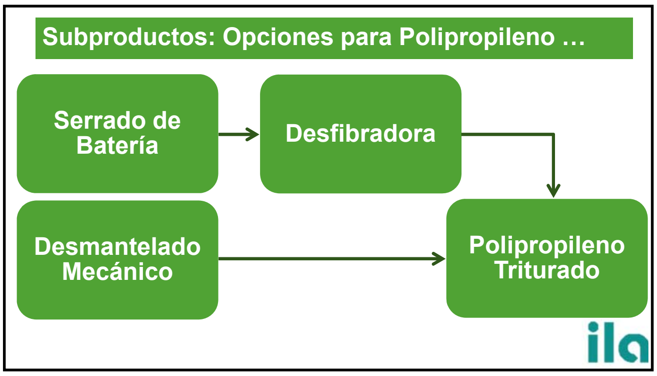
Un refrigerante para la fundición de lingotes de plomo

Para reducir los niveles de polvo

ila

TAR : Riesgos de Salud y Seguridad

Contenido BAPU	Clasificación	Exposición	EPP
Ácido Sulfúrico Diluido		Derrame y Salpicaduras	

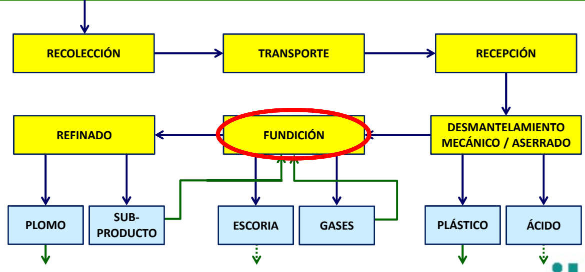

Subproductos: Opciones para Polipropileno …
Serrado de Batería
Desfibradora
Desmantelado Mecánico
Polipropileno Triturado
ila


Subproductos: Opciones para Polipropileno …
Polipropileno Triturado
• USD $ 500 / t
Bolitas de Polipropileno
• USD $ 800 / t
ila

Parte 3. Operaciones de fundición de plomo: Evaluación y Control de Riesgos – Seguridad, Salud Ocupacional y Medio Ambiente

ila

Fundición de BAPU: Operación de Alimentación Única



ila

Fundición…

Separación de los Componentes de Batería:

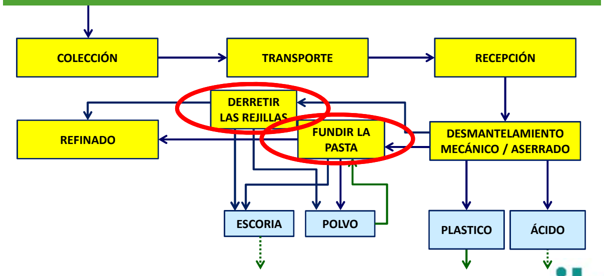
- Rejillas de Batería
- Pasta de la Batería

Operaciones:

¿Qué es Mejor, Uno o Dos Hornos?

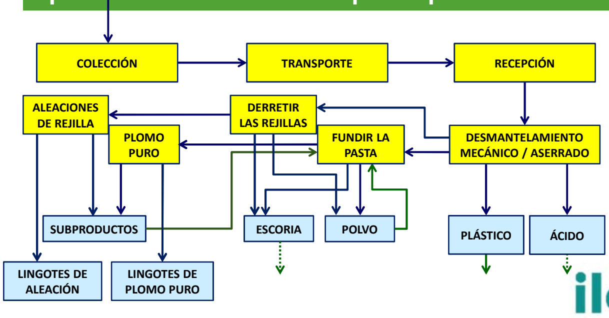
ila

Operación de Alimentación por Separado …..



ila

Operación de Alimentación por Separado …..



ila

Operación de Alimentación por Separado …..

Beneficios Ambientales y de Costos

- ✓ La fundición de las rejillas consume ~ 70% menos de energía
- ✓ La fundición de las rejillas no requiere fundentes, agentes reductores o reactivos
- ✓ Refinación del metal de la rejilla del horno para aleaciones ahorra energía y metales de aleación
- ✓ La refinación del metal de la pasta del horno al plomo puro utiliza menos energía y reactivos

ila

Operación de Alimentación por Separado …..

Beneficios Ambientales y de Costos

- ✓ Las operaciones de horno doble ofrecen flexibilidad para el mantenimiento planificado
- ✓ La operación de horno doble proporciona una mayor continuidad de producción
- ✓ Los costos de operación y mantenimiento son aproximadamente un 13% inferior a los costos de un horno sencillo

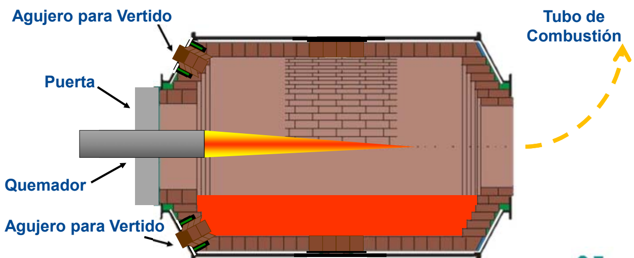
ila

Operación de Horno Eficiente de Energía …

Horno Rotatorio - Pb Metales - Costa Rica

ila

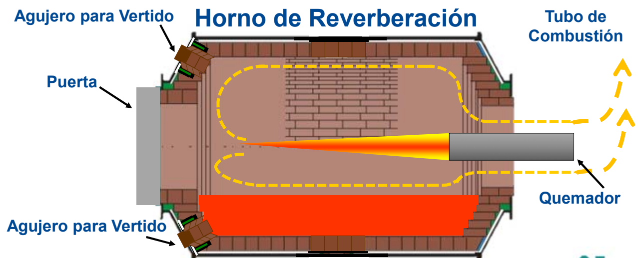
Operación de Horno Eficiente de Energía …



Quemador Montado en la Puerta

ila

Operación de Horno Eficiente de Energía …



Montaje Trasero del Quemador

ila

Operación de Horno Eficiente de Energía …

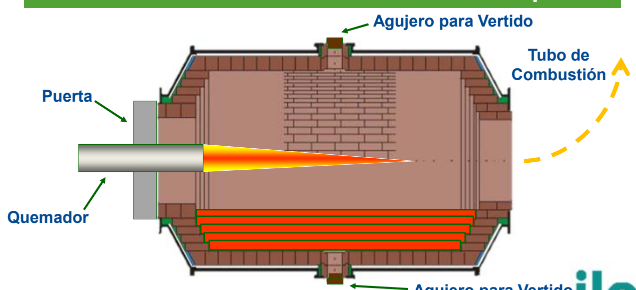
Beneficios Ambientales y de Costos

- ✓ El doble paso a través del horno hace el mejor uso de la energía
- ✓ Los tiempos de proceso se reducen y el consumo de energía
- ✓ La reducción de los tiempos de proceso aumenta la producción
- ✓ La reducción del consumo de energía reduce las emisiones de GEI
- ✓ La reducción del consumo de energía reduce el costo del combustible
- ✓ El quemador trasero reduce el riesgo de daños durante la carga

Horno de Reverberación

ila

Fundición: Amenaza Ambiental: Polvo – Captura?



Agujero para Vertido en el Centro

ila

Fundición: Polvo - Captura por Encapsulación …

Ventilación Encajada de Horno Rotativo

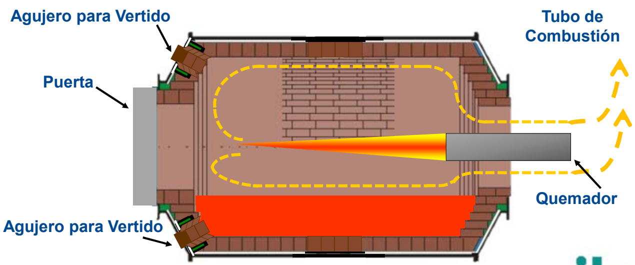
ila

Fundición: Polvo - Captura por Encapsulación …

EcoGlobal – Filipinas

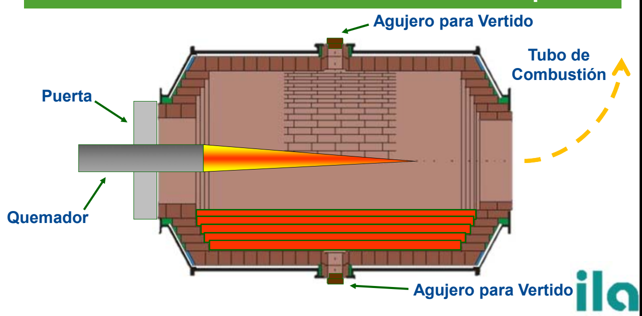
ila

Fundición: Amenaza Ambiental: Polvo – Captura?



ila

Fundición: Amenaza Ambiental: Polvo – Captura?



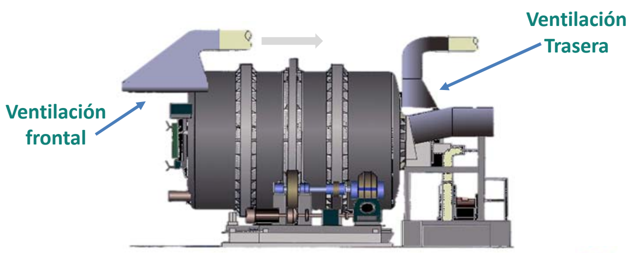
ila

Fundición: Amenaza Ambiental: Captura de Polvo

Campana de Ventilación - Horno Rotativo Vertido Frontal

ila

Fundición: Amenaza Ambiental: Captura de Polvo



Campana de Ventilación - Horno Rotativo Vertido Frontal

ila

Fundición: Amenaza Ambiental: Captura de Polvo

Campana de Ventilación - Horno Rotativo Vertido Frontal

ila

Fundición: Amenazas a la Salud Ocupacional

Amenazas de Salud Ocupacional por el Polvo y el Vapor del Plomo

⚠ Inhalación y digestión: el resultado es plomo elevado en la sangre

⚠ Exposición elevada: puede causar:

- Cansancio, irritabilidad, estreñimiento, daño de órgano interno
- Dolor abdominal, estreñimiento, dolor articular y muscular,
- Dolor de cabeza, disminución en el razonamiento cognitivo

⚠ En casos extremos, la exposición aguda puede causar la muerte

⚠ Emisiones no controladas resultan en la exposición de la población

Por qué el Polvo y el Vapor deben ser Capturados?

ila

Fundición: Amenazas a la Salud Ocupacional

El tamaño de partícula del polvo de plomo y el vapor

Vapor de plomo: 0.1 a 0.7 micras

Polvo de plomo: hasta 500 micras

Protección de un respirador: una máscara de polvo N95 filtrará…

✓ 95% del polvo sobre 0.3 micras

Por qué el Polvo y el Vapor deben ser Capturados?

ila

Fundición: Amenazas a la Salud Ocupacional

El Tamaño de Partícula del Polvo y Vapor de Plomo

Vapor de plomo: 0.1 a 0.7 micras

Polvo de plomo: hasta 500 micras

¿Que puedes ver?

El tamaño de las partículas en micrones

ila

Fundición: Amenazas a la Salud Ocupacional

¿Hay alguna ventilación de extracción?

ila

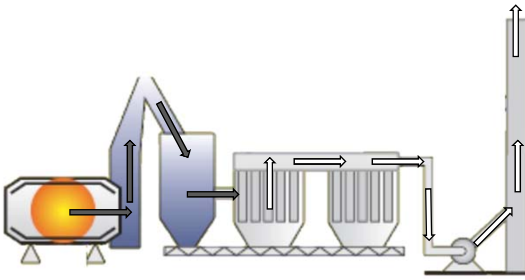
Fundición: Amenaza a la Salud de la Población!

Controlar las Emisiones es Esencial

ila

NL6

Captura de Vapor - Medida de Control – Filtración….



ila

Captura de Vapor - Medida de Control – Filtración….

Normalmente los Filtros Capturan Partículas de Polvo de Más de 25 micras

ila

Captura de Vapor - Medida de Control – Filtración….

Se requieren conductos largos para enfriar el vapor

No se permite agregar aire para enfriar el gas de combustión

Enfriamiento del gas de combustión es esencial para formar partículas de polvo de más de 25 micras

ila

Captura de Vapor - Medida de Control – Filtración….

Capture el polvo en un contenedor de acero sellado

Cierre el contenedor y póngalo en el horno

Zhejiang Changxing Jintaiyang Power Co., Ltd

ila

Fundición: Captura de Polvo - el Costo Financiero

<u>Reciclaje Artesanal :</u>

Pérdidas de Polvo ~ 2%

24,000 t of BAPU =

~ 14,100 t de Plomo +

~ 300 t Pérdidas de Pb

= USD $ 600,000

¿Es Económico Instalar una Planta de Filtro? - SÍ

ila

Fundición: Amenaza Ambiental: Emisiones de SO_2

SO_2 también es tan tóxico como el gas de cianuro

ila

Fundición: Medidas de Control para el Dióxido de Azufre

Tres Opciones:

- Previo a la Fundición
- Durante la Fundición
- Después de la Fundición

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Dos Opciones: 1

$PbSO_4$ + Na_2CO_3 = $PbCO_3$ + Na_2SO_4

Sulfato de Plomo + Carbonato de Sodio = Carbonato de Plomo + Sulfato de Sodio

Otros Compuestos: $Pb_3(CO_3)_2(OH)_2$, $NaPb_2(CO_3)_2OH$

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Producción de papel: Proceso Kraft

Fundición: Medidas de Control para el Dióxido de Azufre

Dos Opciones: 2

$PbSO_4$ + $(NH_4)_2CO_3$ = $PbCO_3$ + $(NH_4)_2SO_4$

Sulfato de Plomo + Carbonato de amonio = Carbonato de Plomo + Sulfato de amonio

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Tres Opciones:

- Previo a la Fundición
- Durante la Fundición
- Después de la Fundición

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Ecuaciones Metalúrgicas para la Captura de Azufre:

$$PbSO_4 + C \rightarrow PbS + CO_2$$

$$PbS + Fe \rightarrow Pb + FeS$$

$$PbSO_4 + Na_2CO_3 + Fe + C \rightarrow Pb + \text{“}FeS.Na_2S\text{”} + CO/CO_2$$

Escoria

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Agregue chatarra al horno

El hierro puede eliminar hasta el 95% del azufre

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Ecuaciones Metalúrgicas para la Producción de Plomo:

$PbO_2 + Calor + C \rightarrow PbO\ (315^0) + CO$

$PbO + CO \rightarrow Pb + CO_2$

$2PbO + C \rightarrow Pb + CO$

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre

Ecuaciones para la Producción de Dióxido de Azufre :

$PbSO_4 + Calor + C \rightarrow PbO + CO + SO_2$

$PbO + CO \rightarrow Pb + CO_2$

$2PbO + C \rightarrow Pb + CO$

Desulfurización de la Pasta

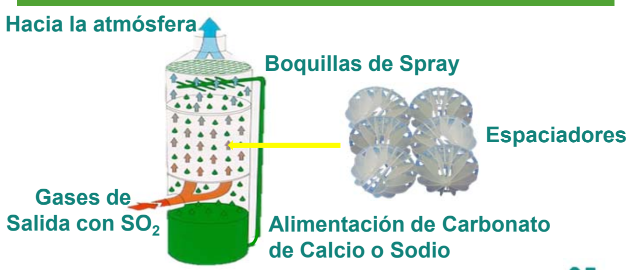
Fundición: Medidas de Control para el Dióxido de Azufre

Tres Opciones:

- Previo a la Fundición
- Durante la Fundición
- Después de la Fundición

Desulfurización de la Pasta

Fundición: Medidas de Control para el Dióxido de Azufre



Torre de Lavado

Fundición: Medidas de Control para el Dióxido de Azufre

Dos opciones:

$2CaCO_3$	+	$2SO_2$	+	O_2	=	$2CaSO_4$	+	$2CO_2$
Carbonato de Calcio	+	Dióxido de Azufre	+	Oxígeno	=	Sulfato de Calcio	+	Dióxido de Carbono
$2Na_2CO_3$	+	$2SO_2$	+	O_2	=	$2Na_2SO_4$	+	$2CO_2$
Carbonato de Sodio	+	Dióxido de Azufre	+	Oxígeno	=	Sulfato de Sodio	+	Dióxido de Carbono

Desulfuración del Gas de Combustión

Fundición: Medidas de Control para el Dióxido de Azufre

Torre de Lavado

ila

Reciclaje de BAPU: Amenaza Ambiental - Escoria ...

Amenazas para la salud y el medio ambiente:

- ⚠ Puede contener gránulos de plomo y compuestos de plomo
- ⚠ Es higroscópico y se desintegrará al exponerse al aire
- ⚠ Es irritante para los ojos, la piel y los pulmones
- ⚠ Tóxico

¿Cómo Podemos Deshacernos de la Escoria?

ila

Reciclaje de BAPU: Amenaza Ambiental - Escoria ...

¿Cómo Podemos Deshacernos de la Escoria?

ila

Reciclaje de BAPU: Amenaza Ambiental - Escoria ...

Una empresa con una licencia para el tratamiento de residuos

El problema es que el proceso es costoso

Una Planta de Tratamiento y Eliminación de Residuos Peligrosos

ila

Reciclaje de BAPU: Amenaza Ambiental - Escoria ...

¿Qué puedo hacer?

¿Cómo Podemos Deshacernos de la Escoria?

ila

La Escoria se Puede Convertir en Adoquines…..

Calle de la Cumbre

Nepal

Es Muy Importante Investigar el Mercado

ila

La Escoria se Puede Convertir en Adoquines…..

Tegal

Indonesia

Máquina para hacer Adoquines

La Escoria se Puede Convertir en Adoquines…..

Tegal

Indonesia

Adoquines Hexagonales

Fundición: Riesgos de Seguridad y Salud

Riesgos	Clasificación	Exposición	EPP
Polvo de Plomo		Ingestión Inhalación	
Vapor de Plomo		Inhalación	Ventilación de Extracción Efectiva
Metal Caliente y Escoria		Piel, Ojos y Boca	
Ruido		Orejas	
Mantenimiento de la Planta de Filtrado		Ingestión Inhalación	

Fundición: Medidas de Control

Mantenga las Áreas de Trabajo Limpias y Ordenadas

Fundición: Medidas de Control

Mantenga las Áreas de Trabajo Húmedas y/o Mojadas

Fundición: Medidas de Control

Engitec

Siempre Use el EPP Correcto

Fundición: Medidas de Control

Seleccione máscaras que tengan válvulas de escape

Respiradores Desechables

ila

Fundición: Medidas de Control

¡Importante! Utilice la banda de metal para obtener un buen ajuste alrededor de la nariz

Respiradores Desechables

ila

Fundición: Medidas de Control

¡Más Importante!
Use respiradores de cara completa cuando trabaje en una planta de filtro

Respirador Cara Completa

ila

Fundición: Medidas de Control

¡Más Importante!

Y Overoles de Pies a Cabeza

Respirador Cara Completa y Overoles

ila

Fundición: Medidas de Control

¡Más Importante!

Use Respiradores de Cara Completa
Y Overoles de Pies a Cabeza cuando trabaje en una planta de filtro

Respirador Cara Completa y Overoles

ila

Fundición: Medidas de Control

¡Más importante!

Cuando el trabajo está terminado. Ducharse con un respirador y los overoles para quitar el polvo; luego quítelos y vuelva a ducharse.

Respirador Cara Completa y Overoles

ila

Fundición: Medidas de Control

Operations en el Horno

Usar casco, protección para la cara, botas, mascarilla, guantes, bata de protección o escudo

Vertiendo el Plomo

Fundición: Medidas de Control

1. Vestuarios separados para ropa limpia y de trabajo
2. Todo el personal se duchará al final de cada día
3. Solo use ropa limpia cuando salga de la planta
4. La cafetería debe estar limpia con un filtro de aire absoluto (HEPA)

Fundición: Medidas de Control

Limpie la Ropa de Trabajo Todos los Días

Fundición: Medidas de Control

Limpie la Ropa de Trabajo Todos los Días

Fundición: Medidas de Control

Vestuarios Separados

Fundición: Medidas de Control

Limpio vestidor y duchas

Dong Mai Vietnam

Vestuarios Separados

Fundición: Medidas de Control

Guatemala: La Cafetería con un Filtro Absoluto

ila

Gracias

ila

El Uso y la Aplicación de la Herramienta de Evaluación Comparativa

Brenda Natalia Lopez, Pure Earth

ila

GAR/ESM Matrix para Reciclar BAPU…

Actividad	Proceso	GAR/ESM
Recolección	Bucle cerrado	No Drenado
Transporte	Contenedor	A Prueba de Fugas
Almacenamiento	Protegido	Sin fugas
Desmantelamiento	Sierra o Mecánico	No manualmente
Electrólito	Neutralización	Sin descargas
Reciclaje	Ventilación	Control de Emisiones
Subproductos	Productos Inertes	Sin residuos peligrosos

ila

Observación y Medición

¿Un regulador solo observa y mide?

ila

Evaluar GAR/ESM

Las preguntas para los reguladores son:

- ¿Puedes evaluar el rendimiento?
- ¿Puedes identificar problemas?
- ¿Puede hacer recomendaciones para mejorar la GAR/ESM de BAPU?

ila

Observación y Medición

¿Un regulador solo observa y mide?

¿Qué pasa si el regulador puede identificar problemas y ayudar a resolverlos?

ila

Herramienta de Evaluación Comparativa

- ✓ Es exhaustivo y fácil de usar
- ✓ De acuerdo con las Pautas Técnicas de Basilea
- ✓ Está en la forma de un cuestionario
- ✓ Identifica buenas y malas prácticas
- ✓ Aplicable a todo el ciclo de la vida

ila

Herramienta de Evaluación Comparativa

Estas son las únicas ayudas requeridas para la evaluación

Un kit de prueba de pH

y un anemómetro

ila

Convenio de Basilea

BASEL CONVENTION

Directrices Técnicas

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contenedor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Cielo abierto	Embalado a cielo abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contenedor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Cielo abierto	Embalado a cielo abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Comparando Inspecciones

Regulatoria	vs	Evaluación Comparativa
Específico	-	Holístico
Un sitio	-	Cadena de Suministro
Cuantitativo	-	Cualitativo
Reactivo	-	Proactivo

ila

Herramienta de Evaluación Comparativa

Preguntas

1. ¿Es esta una práctica aceptable?
2. ¿Cómo controlarías esa situación?
3. ¿Es la tarea o la operación necesaria?
4. ¿Qué recomendaciones mejorarían el rendimiento?

ila

Herramienta de Evaluación Comparativa

Evaluación Comparativa de Secciones para Reciclaje

- Recolección de BAPU
- Almacenamiento
- Embalaje
- Transporte
- Reciclaje

Herramienta de Evaluación Comparativa

Cómo Utilizar la Herramienta de Evaluación Comparativa

- ✓ Completar el formulario de evaluación

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contenedor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

Herramienta de Evaluación Comparativa

Cómo Utilizar la Herramienta de Evaluación Comparativa

- ✓ Completar el formulario de evaluación
- ✓ Identificar los puntos de referencia importantes

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contendor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?				
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

Herramienta de Evaluación Comparativa

Cómo Utilizar la Herramienta de Evaluación Comparativa

- ✓ Completar el formulario de evaluación
- ✓ Identificar los puntos de referencia importantes
- ✓ Evaluar el cumplimiento con los puntos de referencia

ila

Herramienta de Evaluación Comparativa

Drenado	Mayoría	Algunos	Completo

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
5	prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contenedor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican los BAPU?	Tamaño	Contendor plastico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

8	¿Cómo se transportan las BAPU a la planta de reciclaje?

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican los BAPU?	Tamaño	Contendor plastico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
9	a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	separado

Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican los BAPU?	Tamaño	Contendor plastico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

Cómo Utilizar la Herramienta de Evaluación Comparativa

- ✓ Completar el formulario de evaluación
- ✓ Identificar los puntos de referencia importantes
- ✓ Evaluar el cumplimiento con los puntos de referencia
- ✓ Repetir el proceso para cada sección del formulario

Herramienta de Evaluación Comparativa

No.	Estado Ambiental	A	B	C	D
1	¿Qué agencias emiten licencias de operación?	Salud	Medio Ambiente	Empresa	Otras
2	¿Qué tan cerca está la población de la Planta de Reciclaje?	Adyacente	1 kilómetro	5 kilómetros	Zona industrial
3	¿El efluente del proceso es descargado del sitio?	Siempre y sin tratamiento	A veces sin tratamiento	Después del tratamiento	Nunca
4	¿Qué le sucede al electrolito de la batería?	Descargado	Tratado y descargado	Recogido, tratado y utilizado en el proceso	Recolectado para producir yeso
5	¿Cómo se controlan las emisiones del horno?	Sin controles	Ventilado a una planta de filtro	Todos los procesos son ventilados	C con todo el polvo reciclado
6	Si hay un alto horno, ¿hay un Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Qué pasa con los residuos del horno?	Dispuesto en el basurero local	Tratado y enviado al basurero local	Tratado y vendido como material de construcción	Tratado y utilizado para hacer ladrillos
9	¿El sitio está limpio, ordenado y sin escoria ni residuos de ácido?	No	Sólo polvo y escoria	Solo residuos de ácido	Sí

3 de 5 – Estado Ambiental

Herramienta de Evaluación Comparativa

No.	Estado Ambiental	A	B	C	D
1	¿Qué agencias emiten licencias de operación?	Salud	Medio Ambiente	Empresa	Otras
2	¿Qué tan cerca está la población de la Planta de Reciclaje?	Adyacente	1 kilómetro	5 kilómetros	Zona industrial
3	¿El efluente del proceso es descargado del sitio?	Siempre y sin tratamiento	A veces sin tratamiento	Después del tratamiento	Nunca
4	¿Qué le sucede al electrolito de la batería?	Descargado	Tratado y descargado	Recogido, tratado y utilizado en el proceso	Recolectado para producir yeso
5	¿Cómo se controlan las emisiones del horno?	Sin controles	Ventilado a una planta de filtro	Todos los procesos son ventilados	C con todo el polvo reciclado
6	Si hay un alto horno, ¿hay un Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Qué pasa con los residuos del horno?	Dispuesto en el basurero local	Tratado y enviado al basurero local	Tratado y vendido como material de construcción	Tratado y utilizado para hacer ladrillos
9	¿El sitio está limpio, ordenado y sin escoria	No	Sólo polvo y	Solo residuos de	Sí

3	¿El Efluente del Proceso es Descargado del Sitio?

Herramienta de Evaluación Comparativa

No.	Estado Ambiental	A	B	C	D
1	¿Qué agencias emiten licencias de operación?	Salud	Medio Ambiente	Empresa	Otras

Siempre y sin tratamiento	A veces sin tratamiento	Después del tratamiento	Nunca

No.	Estado Ambiental	A	B	C	D
5	¿Cómo se controlan las emisiones del horno?	Sin controles	Ventilado a una planta de filtro	Todos los procesos son ventilados	C con todo el polvo reciclado
6	Si hay un alto horno, ¿hay un Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Qué pasa con los residuos del horno?	Dispuesto en el basurero local	Tratado y enviado al basurero local	Tratado y vendido como material de construcción	Tratado y utilizado para hacer ladrillos
9	¿El sitio está limpio, ordenado y sin escoria ni residuos de ácido?	No	Sólo polvo y escoria	Solo residuos de ácido	Sí

3 de 5 – Estado Ambiental

Herramienta de Evaluación Comparativa

No.	Estado Ambiental	A	B	C	D
1	¿Qué agencias emiten licencias de operación?	Salud	Medio Ambiente	Empresa	Otras
2	¿Qué tan cerca está la población de la Planta de Reciclaje?	Adyacente	1 kilómetro	5 kilómetros	Zona industrial
3	¿El efluente del proceso es descargado del sitio?	Siempre y sin tratamiento	A veces sin tratamiento	Después del tratamiento	Nunca
4	¿Qué le sucede al electrolito de la batería?	Descargado	Tratado y descargado	Recogido, tratado y utilizado en el proceso	Recolectado para producir yeso
5	¿Cómo se controlan las emisiones del horno?	Sin controles	Ventilado a una planta de filtro	Todos los procesos son ventilados	C con todo el polvo reciclado
6	Si hay un alto horno, ¿hay un Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Qué pasa con los residuos del horno?	Dispuesto en el basurero local	Tratado y enviado al basurero local	Tratado y vendido como material de construcción	Tratado y utilizado para hacer ladrillos
9	¿El sitio está limpio, ordenado y sin escoria ni residuos de ácido?	No	Sólo polvo y escoria	Solo residuos de ácido	Sí

3 de 5 – Estado Ambiental

Herramienta de Evaluación Comparativa

No.	Exposición Ocupacional al Plomo	A	B	C	D
1	¿Hay una política de higiene y respirador?	No	Solo para respiradores	Solo para higiene	Sí
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos	Solo empleados en operación	Todos los empleados
3	¿Es un médico o enfermera empleada para controlar la salud de los empleados?	No	Si hay una solicitud	Solo una enfermera	Sí
4	¿Se monitorean los niveles ocupacionales de plomo en la sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud se explican a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
6	¿Los empleados reciben ropa de trabajo?	No	Overoles	Overoles y sombrero	C + botas y guantes
7	¿Con qué frecuencia se lavan y cambian las prendas?	Nunca	Una vez al mes	Cada semana	Cada semana
8	¿La Cafetería está separada de la fundición?	No	Comer en el sitio no está permitido	Sí, pero no ventilado	Sí con filtración absoluta (HEPA)
9	¿Hay duchas en el lugar para los empleados?	No, pero hay un baño	Sí, una ducha	Sí, pero la ducha no es obligatoria	Sí y ducharse es obligatorio

4 de 5 – Exposición Ocupacional al Plomo

Herramienta de Evaluación Comparativa

No.	Exposición Ocupacional al Plomo	A	B	C	D
1	¿Hay una política de higiene y respirador?	No	Solo para respiradores	Solo para higiene	Sí
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos	Solo empleados en operación	Todos los empleados
3	¿Es un médico o enfermera empleada para controlar la salud de los empleados?	No	Si hay una solicitud	Solo una enfermera	Sí
4	¿Se monitorean los niveles ocupacionales de plomo en la sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud se explican a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
6	¿Los empleados reciben ropa de trabajo?	No	Overoles	Overoles y sombrero	C + botas y guantes
9	empleados?	baño	Sí, una ducha	no es obligatoria	obligatorio

8 ¿La Cafetería está separada de la fundición?

4 de 5 – Exposición Ocupacional al Plomo

Herramienta de Evaluación Comparativa

No.	Exposición Ocupacional al Plomo	A	B	C	D
1	¿Hay una política de higiene y respirador?	No	Solo para respiradores	Solo para higiene	Sí
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos	Solo empleados en operación	Todos los empleados
3	¿Es un médico o enfermera empleada para controlar la salud de los empleados?	No	Si hay una solicitud	Solo una enfermera	Sí
4	¿Se monitorean los niveles ocupacionales de plomo en la sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud se explican a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
9	¿Hay duchas en el lugar para los empleados?	No, pero hay un baño	Sí, una ducha	Sí, pero la ducha no es obligatoria	Sí y ducharse es obligatorio

No	Comer en el sitio no está permitido	Sí, pero no ventilado	Sí con filtración absoluta

4 de 5 – Exposición Ocupacional al Plomo

Herramienta de Evaluación Comparativa

No.	Exposición Ocupacional al Plomo	A	B	C	D
1	¿Hay una política de higiene y respirador?	No	Solo para respiradores	Solo para higiene	Sí
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos	Solo empleados en operación	Todos los empleados
3	¿Es un médico o enfermera empleada para controlar la salud de los empleados?	No	Si hay una solicitud	Solo una enfermera	Sí
4	¿Se monitorean los niveles ocupacionales de plomo en la sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud se explican a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
6	¿Los empleados reciben ropa de trabajo?	No	Overoles	Overoles y sombrero	C + botas y guantes
7	¿Con qué frecuencia se lavan y cambian las prendas?	Nunca	Una vez al mes	Cada semana	Cada semana
8	¿La Cafetería está separada de la fundición?	No	Comer en el sitio no está permitido	Sí, pero no ventilado	Sí con filtración absoluta (HEPA)
9	¿Hay duchas en el lugar para los empleados?	No, pero hay un baño	Sí, una ducha	Sí, pero la ducha no es obligatoria	Sí y ducharse es obligatorio

4 de 5 – Exposición Ocupacional al Plomo

Herramienta de Evaluación Comparativa

No.	Seguridad	A	B	C	D
1	¿Hay una política de seguridad disponible para la inspección?	No	En el archivo de seguridad	En el tablón de anuncios del sitio	En exhibición y en Internet
2	¿Hay inspecciones de seguridad y auditorías regulares?	No	A veces si hay un accidente	Inspecciones - sin auditorías	Anualmente
3	¿Todos los empleados, contratistas y visitantes se someten a una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Cada persona en la planta
4	¿Se han llevado a cabo evaluaciones de riesgos para cada operación?	No	Solo para la licencia	Solo para ISO 9001	Sí
5	¿Hay un registro de cada accidente en el sitio?	No	Hay un libro de accidentes	Algunos se registran	Sí en el libro de accidentes
6	¿Se investiga cada accidente?	No	Sí, por el gerente	Por la compañía de seguros	Por el gerente y un trabajador
7	¿Hay un permiso para trabajar y un proceso de aislamiento para el mantenimiento?	No	Solo un "permiso para trabajar"	Solo para aislamiento	Sí, cerraduras y llaves
8	¿Cuáles son las precauciones de incendio y los procedimientos de emergencia?	Ninguna	Extintores de incendios	Extinguidores y cubos de arena	Extintores y procedimientos de evacuación
9	¿Cómo se desmantela o tritura las BAPU?	No lo sé	Desmantelado manual	Sierra de batería ventilada	Trituradora mecánica

5 de 5 – Seguridad

Herramienta de Evaluación Comparativa

No.	Seguridad	A	B	C	D
1	¿Hay una política de seguridad disponible para la inspección?	No	En el archivo de seguridad	En el tablón de anuncios del sitio	En exhibición y en Internet
2	¿Hay inspecciones de seguridad y auditorías regulares?	No	A veces si hay un accidente	Inspecciones - sin auditorías	Anualmente
3	¿Todos los empleados, contratistas y visitantes se someten a una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Cada persona en la planta
4	¿Se han llevado a cabo evaluaciones de riesgos para cada operación?	No	Solo para la licencia	Solo para ISO 9001	Sí
5	¿Hay un registro de cada accidente en el sitio?	No	Hay un libro de accidentes	Algunos se registran	Sí en el libro de accidentes
8	¿Cuáles son las precauciones de incendio y los procedimientos de emergencia?	Ninguna	Extintores de incendios	Extinguidores y cubos de arena	procedimientos de evacuación
9	¿Cómo se desmantela o tritura las BAPU?	No lo sé	Desmantelado manual	Sierra de batería ventilada	Trituradora mecánica

7 ¿Hay un permiso para trabajar y un proceso de aislamiento para el mantenimiento?

5 de 5 – Seguridad

Herramienta de Evaluación Comparativa

No.	Seguridad	A	B	C	D
1	¿Hay una política de seguridad disponible para la inspección?	No	En el archivo de seguridad	En el tablón de anuncios del sitio	En exhibición y en Internet
2	¿Hay inspecciones de seguridad y auditorías regulares?	No	A veces si hay un accidente	Inspecciones - sin auditorías	Anualmente
3	¿Todos los empleados, contratistas y visitantes se someten a una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Cada persona en la planta
4	¿Se han llevado a cabo evaluaciones de riesgos para cada operación?	No	Solo para la licencia	Solo para ISO 9001	Sí
5	¿Hay un registro de cada accidente en el sitio?	No	Hay un libro de accidentes	Algunos se registran	Sí en el libro de accidentes
8	los procedimientos de emergencia?		incendios	cubos de arena	de evacuación
9	¿Cómo se desmantela o tritura las BAPU?	No lo sé	Desmantelado manual	Sierra de batería ventilada	Trituradora mecánica

No	Solo un "permiso para trabajar"	Solo para aislamiento	Sí, con cerraduras y llaves

5 de 5 – Seguridad

Herramienta de Evaluación Comparativa

No.	Seguridad	A	B	C	D
1	¿Hay una política de seguridad disponible para la inspección?	No	En el archivo de seguridad	En el tablón de anuncios del sitio	En exhibición y en Internet
2	¿Hay inspecciones de seguridad y auditorías regulares?	No	A veces si hay un accidente	Inspecciones - sin auditorías	Anualmente
3	¿Todos los empleados, contratistas y visitantes se someten a una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Cada persona en la planta
4	¿Se han llevado a cabo evaluaciones de riesgos para cada operación?	No	Solo para la licencia	Solo para ISO 9001	Sí
5	¿Hay un registro de cada accidente en el sitio?	No	Hay un libro de accidentes	Algunos se registran	Sí en el libro de accidentes
6	¿Se investiga cada accidente?	No	Sí, por el gerente	Por la compañía de seguros	Por el gerente y un trabajador
7	¿Hay un permiso para trabajar y un proceso de aislamiento para el mantenimiento?	No	Solo un "permiso para trabajar"	Solo para aislamiento	Sí, cerraduras y llaves
8	¿Cuáles son las precauciones de incendio y los procedimientos de emergencia?	Ninguna	Extintores de incendios	Extinguidores y cubos de arena	Extintores y procedimientos de evacuación
9	¿Cómo se desmantela o tritura las BAPU?	No lo sé	Desmantelado manual	Sierra de batería ventilada	Trituradora mecánica

5 de 5 – Seguridad

ila

Benchmarking Assessment Tool

Cómo Utilizar la Herramienta de Evaluación Comparativa

- ✓ Completar el formulario de evaluación
- ✓ Identificar los puntos de referencia importantes
- ✓ Evaluar el cumplimiento con los puntos de referencia
- ✓ Repetir el proceso para cada sección del formulario
- ✓ Hacer recomendaciones para mejorar el SSA

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3					
4					
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Cielo abierto	Embalado a cielo abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

3 ¿Cómo se entregan las BAPU, drenado o completo?

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial

Drenado	Mayoría	Algunos	Completo

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contenedor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
7	¿Cómo se almacenan las BAPU antes del transporte?	Campo abierto	Embalado en el abierto	Bajo cubierta	Embalado en un almacén
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Suelto	Suelto pero vertical	Paletizado y envuelto	C + las BAPU con fugas están en un contenedor separado

8 ¿Cómo se transportan las BAPU a la planta de reciclaje?

2 de 5 – Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Recolección de BAPU y Sitios de Suministro	A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	SEI/Seguridad	Industrial
2	¿Cómo se recogen las BAPU?	Ciudadanos	Minoristas	Garajes	Chatarrero
3	¿Cómo se entregan las BAPU, drenado o completo?	Drenado	Mayoría	Algunos	Completo
4	¿Cómo se clasifican las BAPU?	Tamaño	Contenedor plástico	Automóvil	Industrial
5	¿Están las BAPU con fugas empacadas en contenedores a prueba de fugas?	No	A veces	No - drenado	Siempre
6	¿Qué sucede con las BAPU que se recolectan?	Probado y Recargado	Reacondicionado	Vendido	Embalado y transportado
9	a la planta de reciclaje?	Suelto	Suelto pero vertical	envuelto	un contenedor separado

Bicicleta o carro	Camioneta	Camiones cerrados	Camión con licencia

2 de 5 - Recolección de BAPU y Sitios de Suministro

ila

Herramienta de Evaluación Comparativa

No.	Estado Ambiental	A	B	C	D
1	¿Qué agencias emiten licencias de operación?	Salud	Medio Ambiente	Empresa	Otras
2	¿Qué tan cerca está la población de la Planta				
5	¿Cómo se controlan las emisiones del horno?	Sin controles	Ventilado a una planta de filtro	Todos los procesos son ventilados	C con todo el polvo reciclado
6	Si hay un alto horno, ¿hay un Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Qué pasa con los residuos del horno?	Dispuesto en el basurero local	Tratado y enviado al basurero local	Tratado y vendido como material de construcción	Tratado y utilizado para hacer ladrillos
9	¿El sitio está limpio, ordenado y sin escoria ni residuos de ácido?	No	Sólo polvo y escoria	Solo residuos de ácido	Sí

3	¿El Efluente del Proceso es Descargado del Sitio?

3 de 5 – Estado Ambiental

Herramienta de Evaluación Comparativa

No.	Estado Ambiental	A	B	C	D
1	¿Qué agencias emiten licencias de operación?	Salud	Medio Ambiente	Empresa	Otras
5	¿Cómo se controlan las emisiones del horno?	Sin controles	Ventilado a una planta de filtro	Todos los procesos son ventilados	C con todo el polvo reciclado
6	Si hay un alto horno, ¿hay un Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Qué pasa con los residuos del horno?	Dispuesto en el basurero local	Tratado y enviado al basurero local	Tratado y vendido como material de construcción	Tratado y utilizado para hacer ladrillos
9	¿El sitio está limpio, ordenado y sin escoria ni residuos de ácido?	No	Sólo polvo y escoria	Solo residuos de ácido	Sí

Siempre y sin tratamiento	A veces sin tratamiento	Después del tratamiento	Nunca

3 de 5 – Estado Ambiental

Herramienta de Evaluación Comparativa

No.	Exposición Ocupacional al Plomo	A	B	C	D
1	¿Hay una política de higiene y respirador?	No	Solo para respiradores	Solo para higiene	Sí
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos	Solo empleados en operación	Todos los empleados
3	¿Es un médico o enfermera contratado para controlar la salud de los empleados?	No	Si hay una solicitud	Solo una enfermera	Sí
4	¿Se monitorean los niveles ocupacionales de plomo en la sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud se explican a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
6	¿Los empleados reciben ropa de trabajo?	No	Overoles	Overoles y sombrero	C + botas y guantes
9	empleados?	baño	Sí, una ducha	no es obligatoria	obligatorio

8	¿La Cafetería está separada de la fundición?

4 de 5 – Exposición Ocupacional al Plomo

Herramienta de Evaluación Comparativa

No.	Exposición Ocupacional al Plomo	A	B	C	D
1	¿Hay una política de higiene y respirador?	No	Solo para respiradores	Solo para higiene	Sí
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos	Solo empleados en operación	Todos los empleados
3	¿Es un médico o enfermera contratado para controlar la salud de los empleados?	No	Si hay una solicitud	Solo una enfermera	Sí
4	¿Se monitorean los niveles ocupacionales de plomo en la sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud se explican a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
9	empleados?	baño	Sí, una ducha	no es obligatoria	obligatorio

No	Comer en el sitio no está permitido	Sí, pero no ventilado	Sí con filtración absoluta

4 de 5 – Exposición Ocupacional al Plomo

Herramienta de Evaluación Comparativa

No.	Seguridad	A	B	C	D
1	¿Hay una política de seguridad disponible para la inspección?	No	En el archivo de seguridad	En el tablero de anuncios del sitio	En exhibición y en Internet
2	¿Hay inspecciones de seguridad y auditorías regulares?	No	A veces si hay un accidente	Inspecciones - sin auditorías	Anualmente
3	¿Todos los empleados, contratistas y visitantes se someten a una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Cada persona en la planta
4	¿Se han llevado a cabo evaluaciones de riesgos para cada operación?	No	Solo para la licencia	Solo para ISO 9001	Sí
5	¿Hay un registro de cada accidente en el sitio?	No	Hay un libro de accidentes	Algunos se registran	Sí en el libro de accidentes
8	los procedimientos de emergencia?	Ninguna	incendios	cubos de arena	procedimientos de evacuación
9	¿Cómo se desmantela o tritura las BAPU?	No lo sé	Desmantelado manual	Sierra de batería ventilada	Trituradora mecánica

7	¿Hay un permiso para trabajar y un proceso de aislamiento para el mantenimiento?

5 de 5 – Seguridad

Herramienta de Evaluación Comparativa

No.	Seguridad	A	B	C	D
1	¿Hay una política de seguridad disponible para la inspección?	No	En el archivo de seguridad	En el tablón de anuncios del sitio	En exhibición y en Internet
2	¿Hay inspecciones de seguridad y auditorías regulares?	No	A veces si hay un accidente	Inspecciones - sin auditorías	Anualmente
3	¿Todos los empleados, contratistas y visitantes se someten a una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Cada persona en la planta
4	¿Se han llevado a cabo evaluaciones de riesgos para cada operación?	No	Solo para la licencia	Solo para ISO 9001	Sí
5	¿Hay un registro de cada accidente en el sitio?	No	Hay un libro de accidentes	Algunos se registran	Sí en el libro de accidentes
9	¿Cómo se desmantela o tritura las BAPU?	No lo sé	Desmantelado manual	Sierra de batería ventilada	Trituradora mecánica

No	Solo un "permiso para trabajar"	Solo para aislamiento	Sí, con cerraduras y llaves

5 de 5 – Seguridad

Recomendaciones

1. Corto plazo: costo mínimo o sin costo
   - *Solo compre BAPU con electrolito*
   - *Licencia el camión de recolección BAPU*
2. Medio plazo y bajo costo
   - *Neutralice y filtre el electrolito antes de la descarga*
   - *Instale un sistema de filtro absoluto para el casino*
   - *Presente un procedimiento de aislamiento*
3. Largo plazo: requiere inversión
   - *Construya una PTE y opere un circuito cerrado*

ila

Herramienta de Evaluación Comparativa

- **Conclusiones*:***
  - ***Fácil de usar, rápido y proactivo***
  - ***Puede identificar problemas de SSE***
  - ***El proceso es cualitativo y se basa en la observación***
  - ***No es conflictivo y promueve GAR/ESM***
  - ***Puede proporcionar una indicación útil de GAR/ESM***

ila

Gracias

ila

Formulario
Herramienta de Evaluación Comparativa

Recolección y Reciclaje de Baterías de Ácido-Plomo Usada (BAPU)

1. Información General

Nombre de la empresa	
Ubicación	
Tipo de Proceso realizado en la empresa	
Fecha de Inspección	
Dirección de la empresa	
Representante de la empresa	
Cargo	
Número de teléfono	
Dirección de correo electrónico	
Sitio web de la empresa	
Tamaño del área de proceso en la empresa (metros cuadrados)	
Nombre del Evaluador	
Número de teléfono	
Dirección de correo electrónico	
Número de empleados	
Promedio de edad de los empleados y años de antigüedad	

2. **Recolección BAPU y Sitios de Suministro – Comerciantes, distribuidores, talleres de reparación, chatarreros, serviteca y centros de recolección**

No.		A	B	C	D
1	¿Qué tipo de BAPU se están recolectando?	Automóvil	Motocicleta	Sistema de Alimentación Ininterrumpida (UPS)	Industrial
2	¿Cómo se recogen las BAPU?	Usuarios (individuos)	Comerciantes	Distribuidores / Talleres	Chatarreros
3	¿Cómo se entregan las BAPU? Están drenadas o sin drenar?	Drenadas	Mayoría Drenadas	Algunas Drenadas	Todas sin drenar
4	¿Cómo se clasifican los BAPU?	Por Tamaño	Por Tipo de Carcaza	Por uso en Automóvil	Por uso Industrial / UPS
5	¿Las BAPU con fugas están separadas y embaladas en contenedores plásticos?	No	No, y son drenadas primero antes de ser transportadas	A veces	Siempre
6	¿Qué sucede con las BAPU recolectadas?	Son reacondicionadas	Son revendidas	Son probadas y recargadas	Son embaladas y transportadas
7	¿Cómo se almacenan las BAPU antes de ser transportadas a la planta de reciclaje?	A campo abierto	Embaladas a campo abierto	Bajo cubierta	Embaladas en un almacén
8	¿Cómo se transportan las BAPU a la planta de reciclaje?	Bicicleta o carreta	Camioneta pick-up	Camión (furgón)	Camión con licencia
9	¿Cómo se empacan las BAPU en el vehículo para su transporte a la planta de reciclaje?	Sueltas	Sueltas y de manera vertical	Organizadas en estibas y empacadas	Las BAPU con fugas están separadas en un contenedor a prueba de fugas

3. **Situación Ambiental**

No.		A	B	C	D
1	¿Qué agencias emiten las licencias ambientales y de operación?	Salud	Medio Ambiente	Cámara de Comercio	Otras
2	¿Qué tan cerca está la población de la Planta de Reciclaje?	Al lado de la planta	1 kilómetro	5 kilómetros	En la Zona Industrial
3	¿El efluente (vertimiento) del proceso es descargado fuera de la planta (por ejemplo al sistema de alcantarillado?	Siempre y sin tratamiento	A veces sin tratamiento	Después del tratamiento	Nunca
4	¿Qué se hace con el electrolito (líquido) de la batería?	Es vertido	Es tratado y luego vertido	Es recogido, tratado y utilizado en el proceso	Es recolectado para producir yeso
5	¿Cómo se controlan las emisiones del horno y del proceso de refinación?	No existen equipos de control	Las emisiones del horno son ventiladas a los equipos de control	Todos los procesos son ventilados a los equipos de control	Todo el polvo recolectado en los equipos de control es reciclado
6	Si hay un alto horno, ¿hay una Torre de Lavado?	No	Sí		
7	Si hay un horno rotatorio, ¿se agrega hierro a la fundición?	No	Sí		
8	¿Cómo se manejan los residuos del horno?	Dispuesto en relleno sanitario o basurero	Tratado y dispuesto en relleno de seguridad	Tratado y vendido como material para vías	Tratado y utilizado para hacer ladrillos/tejas
9	¿El sitio está limpio, ordenado y sin polvo, escoria y/o residuos de ácido?	No está limpio ni ordenado, y tiene polvo, escoria y residuos de ácido	Sólo polvo y escoria	Solo residuos de ácido	Sí está limpio y ordenado, y no tiene polvo, escoria ni residuos de ácido

4. **Exposición Ocupacional al Plomo**

No.		A	B	C	D
1	¿Hay una política de higiene y de uso de respirador?	No	Solo para uso de respiradores	Solo para higiene	Sí, ambas
2	¿Todos los trabajadores usan respiradores en las áreas operativas?	No	Algunos trabajadores	Solo trabajadores en el área de operación	Todos los trabajadores
3	¿Hay un médico/a y/o enfermero/a ocupacional contratado para examinar la salud de los empleados?	No	A solicitud	Solo una enfermera	Sí, ambos
4	¿Se monitorean los niveles ocupacionales de plomo en sangre?	Nunca	Anualmente	Dos veces al año	Cada 3 meses
5	¿Los riesgos de salud son explicados a los empleados?	Nunca	Si hay una solicitud	Durante la inducción	Regularmente
6	¿Los empleados reciben ropa de trabajo?	No	Overoles	Overoles y casco	Overoles, casco, botas y guantes
7	¿Con qué frecuencia se lava y cambia la ropa de trabajo?	Nunca	Una vez al mes	Cada semana	Cada turno
8	¿Se encuentran separadas la cafetería y el área de proceso?	No	Comer en el área de trabajo no está permitido	Sí, pero la cafetería no está aislada/ventilada	Sí, con filtración absoluta (filtros HEPA) y con aire acondicionado
9	¿Hay duchas en el área de proceso para los trabajadores?	No, pero hay un baño	Sí, hay una ducha	Sí, pero ducharse no es obligatorio	Sí, y ducharse es obligatorio

5. **Seguridad**

No.		A	B	C	D
1	¿Hay una política de seguridad publicada y disponible para la inspección?	No	En el archivo de seguridad	En el tablero de anuncios del área de proceso	En el tablero de anuncios del área de proceso y en el sitio web de la empresa
2	¿Hay inspecciones regulares de seguridad o auditorías?	No	A veces, después de un accidente	Solo Inspecciones	Sí, ambas anualmente
3	¿Todos los empleados, contratistas y visitantes reciben una inducción de seguridad?	No	Solo empleados	Solo contratistas y visitantes	Sí, todos los empleados, contratistas y visitantes
4	¿Se han realizado evaluaciones de riesgos para cada operación?	No	Solo para la licencia ambiental	Solo para la ISO 9001	Sí
5	¿Hay un registro de cada accidente en el área de proceso?	No	Hay un libro de accidentes, pero no es obligatorio realizar el registro	Hay un libro de accidentes, y algunos accidentes se registran	Sí, hay un libro de accidentes y todos los accidentes se registran
6	¿Se investiga cada accidente?	No	Sí, por el gerente de planta	Sí, por la compañía de seguros	Sí, en forma conjunta por la dirección general y el equipo de trabajo del área
7	¿Hay un sistema de permiso de trabajo y un proceso de bloqueo y etiquetado para el proceso de mantenimiento?	No	Solo se requiere un permiso de trabajo durante el	Solo se requiere el proceso de bloqueo y etiquetado durante	Sí hay un sistema de permiso de trabajo y un proceso de

			proceso de mantenimiento	el proceso de mantenimiento	bloqueo y etiquetado para el proceso de mantenimiento, y hay candados y llaves para realizar el bloqueo
8	¿Cuáles son las precauciones de incendio y los procedimientos de emergencia?	Ninguna	Hay extintores de incendios	Hay baldes o cubos de arena	Hay extintores y baldes o cubos de arena
9	¿La Planta tiene un Seguro de Responsabilidad para Accidentes e Incidentes (incendio y/o robo)?	No	Hay una póliza de responsabilidad civil para incidentes (incendio y/o robo)	Sí, la Planta tiene un seguro para accidentes solamente	Si, la planta tiene un seguro de cubrimiento total en caso de accidentes e incidentes (incendio y/o robo)

GAHP
GLOBAL ALLIANCE ON HEALTH AND POLLUTION

Health and Pollution Action Plans

Accelerating National Actions To Address Pollution-Related Illness

TABLE OF CONTENTS

This document was produced with the financial assistance of the European Union and USAID. The views expressed herein can in no way be taken to reflect the official opinion of the European Union or USAID.

Executive Summary

The Health and Pollution Action Plan (HPAP) program is designed to assist governments of low- and middle-income countries to develop and implement solutions to pollution-related health challenges. The HPAP program is facilitated by the Global Alliance on Health and Pollution (GHAP), which is a consortium of national ministries of health and environment, international development banks, United Nations agencies, bilateral development agencies, NGOs and other actors working on pollution (www.ghap.net). The HPAP program brings together national Ministries of Environment, Health, Production/Industry, Transport, Energy, Mining, Agriculture and others to advance concrete pollution actions.

The goals of the HPAP program are:

1. Assist governments to identify, evaluate and prioritize existing pollution challenges based on health impacts
2. Establish pollution as a priority for action within national agencies and development plans
3. Define and advance concrete interventions to reduce pollution exposures and related illnesses

The Health and Pollution Action Plan process is driven by national agencies, with facilitation and support by GAHP members. The HPAP differs from other planning process because it is intentionally structured to bring together different agencies and parties who usually do not work closely together. It is intended to promote collaboration, and have well-defined and practical outcomes, including commitments by all the participants, including international partners and donors, to undertake specific short- and medium-term actions for improved environmental health.

Depending on the national context, the scope of the HPAP may include indoor and outdoor air pollution, unsafe water and inadequate sanitation, chemical contamination of soil, and occupational exposures to pollutants. The HPAP process is flexible and tailored to the needs of each country, but generally includes the following steps:

PHASE 1. Collection, compilation and analysis of available information on health impacts from pollution and existing pollution management programs by the Ministries of Health, Environment and Industry/Production, with assistance of the GAHP Secretariat.

PHASE 2. Inception meeting to prioritize pollution issues, define next steps, including roles and responsibilities of stakeholders through a participatory process.

PHASE 3. Preparation of a draft Health and Pollution Action Plan describing priority pollutants, pollution sources, health impacts, cost-effective interventions to reduce exposures, resources needed and potential sources of funding by a joint National Working Group with participants from the Ministries of Health, Environment, Transportation, Agriculture, Energy, Industry, Mining and with support from the GAHP Secretariat.

PHASE 4. A draft Action Plan is circulated to national and international stakeholders, which are invited to provide comments. The National Working Group integrates stakeholder comments and a final Health and Pollution Action Plan is created. Stakeholders reconvene to officially endorse and validate the Action Plan and discuss next steps toward implementing suggested actions.

PHASE 5. Dissemination, promotion, fund raising, implementation, monitoring and review of the HPAP through domestic and international initiatives, in collaboration with GAHP members, under the guidance of a joint coordinating team between the Ministries of Health and Environment.

About the Global Alliance on Health and Pollution

The Health and Pollution Action Plan (HPAP) program is an initiative of the Global Alliance on Health and Pollution (GAHP). GAHP is a global collaborative body that assists low- and middle-income countries to take concrete action to reduce the impacts of pollution on health. GAHP members include more than 40 national ministries of health and environment, development banks, United Nations organizations, other bilateral and multilateral groups, universities and non-governmental organizations. The current GAHP Secretariat is the New York-based non-profit organization, Pure Earth (formerly Blacksmith Institute).

More information about GAHP is available at www.GAHP.net.

Background on Health and Pollution Prioritization

Pollution is the leading cause of preventable, premature death in the world. In 2015, pollution-related illnesses killed approximately nine million people. The overwhelming majority—92%—of the burden of disease from pollution falls on people in low- and middle-income countries. Pollution's impacts are felt most acutely by communities that are poorly equipped to address the problem and recover from its impacts. Pollution has severe implications for sustainable development, exacerbates the poverty cycle, harms the environment and biodiversity, causes lifelong disability, and stagnates economic growth.

There is also strong evidence that pollution is not an inevitable outcome of development. New, cost-effective and alternative technologies and well-tested solutions can prevent, mitigate and remediate pollution problems and reduce toxic exposures. Many middle-and high-income countries and industrial sectors have successful experiences and expertise with best available technologies and best environmental practices aimed at preventing and combatting air, water and soil pollution. Countries can take decisive action to prevent and clean up pollution, without sacrificing economic growth, saving thousands of lives in the process and improving sustainable development.

GAHP has received requests from a number of low- and middle-income country governments to facilitate research, prioritization, planning, project selection and design, and the development of funding strategies to address pollution challenges. Although GAHP is not a funding agency, the expertise and experience of its member organizations can be highly valuable for countries where national institutions face limitations related to funding and technical capacity.

In response to these requests, the GAHP Secretariat has developed the HPAP program—a process that can be tailored to the needs of an individual country, and aims to identify, prioritize and accelerate national interventions to reduce pollution-related illness.

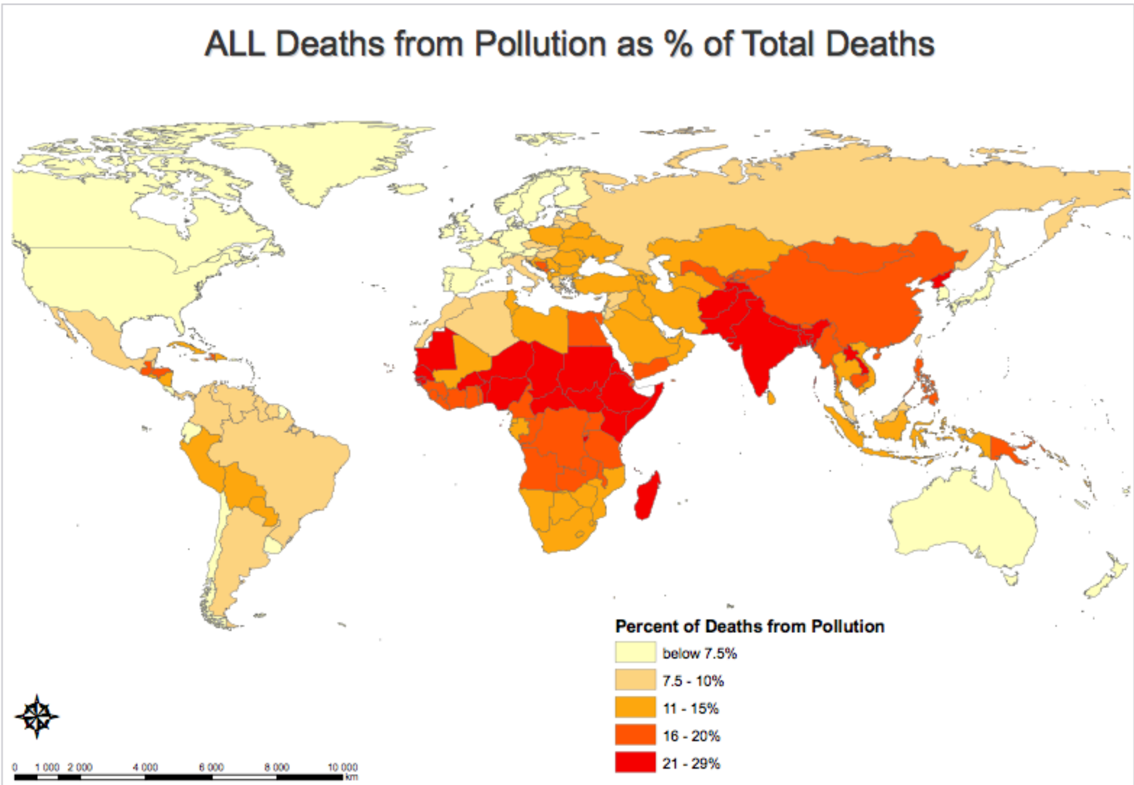


Figure 1. Percentage of all deaths in 2015 that were caused by pollution Source:

Goals and Scope of the HPAP Program

Data related to health impacts from pollution in low- and middle-income countries is often incomplete, making it difficult to analyze and estimate the true scope and severity of pollution's health burden. Such data gaps limit the ability of governments to assess the full impacts from pollution, prioritize future actions and monitor outcomes of interventions based on health impacts and potential gains. Recognizing this reality, the HPAP program aims to identify all available data related to the burden of disease from pollution, identify data gaps, and create a strategy to prioritize and accelerate cost-effective actions to fill gaps and reduce pollution-related illness.

The Health and Pollution Action Plan (HPAP) program is a collaborative process that aims to assist governments to:

1. Identify, evaluate and prioritize existing pollution issues based on health impacts

2. Establish pollution as a priority for action within national agencies and development plans
3. Define and advance concrete interventions to reduce pollution exposures and related illnesses

The scope of the HPAP program is limited to pollutants that cause a direct impact to human health. Depending on the particular challenges in a given country, the program may analyze the following pollution risk factors:

1. **Exposures to ambient (outdoor) air pollution (AAP)** - AAP is a relatively modern form of pollution and is largely associated with industrial production, urbanization and the increasing use of motor vehicles. AAP is produced by stationary sources - industrial, chemical production plants, large-scale agricultural operations, feedlots, power plants, and diesel generators - and also by mobile sources - cars, trucks and buses.

2. **Exposures to household (indoor) air pollution (HAP)** - HAP is the predominant form of air pollution in much of the developing world. An estimated 2.8 billion people globally use biomass for cooking and heating. Particulates, carbon monoxide (CO), formaldehyde, benzene and polycyclic aromatic hydrocarbons (PAHs) are the principal pollutants in HAP. HAP increases risks of acute lower respiratory infections in children under 5 years of age and of stroke, ischemic heart disease, chronic obstructive pulmonary disease, lung cancer, and cataracts in adults. HAP has also been linked to preterm birth, low birth weight, tuberculosis, neurodevelopmental disorders and leukemia. The health impacts of HAP mirror those of tobacco smoke and risk levels are intermediate between those of active and passive smoking.

3. **Unsafe water and inadequate sanitation** - many parts of the world still lack acceptable water supplies and many people, particularly in precarious urban settlements and rural areas, lack adequate sewer systems and urban waste collection, despite decades of effort under successive international programs. Relevant prevention technologies and systems exist, but poverty, lack of knowledge and other priorities at the local level all constrain the adoption of improvements, despite their proven benefits for public health and the high cost of inaction.

4. **Exposures to soil pollution from heavy metals and toxic chemicals** - Polluted soil from active and abandoned mines, smelters, industrial facilities and hazardous waste sites threatens the environment and human health in communities worldwide. Most contaminated sites tend to be relatively small, but the aggregate number of people impacted by the many thousands of these sites worldwide is large. Pollution at contaminated sites can spread into the surrounding environment through leaching of toxic chemicals into lakes, rivers and groundwater as well as

through airborne spread of contaminated dusts, especially in dry, desert climates. Poor communities tend to occupy polluted lands or live close to them putting them in high risk. Polluted sites are most commonly contaminated by informal, small-scale, unregulated local industry or artisanal activity in urban or suburban areas exposing low-income communities (e.g. by the informal production and recycling of lead-acid batteries or small-scale gold mining using mercury).

5. **Occupational exposures to pollution** - Occupational pollution has become highly prevalent in recent years in low- and middle-income countries. Much of the global manufacture and use of toxic chemicals and pesticides has shifted to low- and middle-income countries. Examples includes the ongoing exposure of more than 1 million workers in Asia and sub-Saharan Africa to chrysotile asbestos, usually with little or no respiratory protection; occupational exposure to lead in informal recycling of car batteries; mercury exposure in artisanal gold mining; occupational exposure to chromium in tanneries; and exposures related to e-waste dismantling. The worst of these exposures tend to occur in informal, small-scale, locally owned establishments. Occupational exposures are frequently passed on to family members through the transfer of pollution on clothing, increasing the burden of disease to children at home.

The HPAP program is not designed to analyze or address the following types of pollution:

- Non-toxic urban waste
- Non-toxic plastic waste on land or at sea
- Naturally occurring substances released into air, water or soil through natural processes (e.g., naturally occurring arsenic in groundwater)
- Greenhouse gasses
- Tobacco smoke
- Noise pollution
- Light pollution

Description of the HPAP Process

The Health and Pollution Action Plan process aims to establish pollution as a priority within national agencies and agendas, and to define a roadmap for action that is coordinated among, and supported by the international community.

The HPAP process is led by relevant national agencies, and is facilitated and supported by the GAHP Secretariat and other GAHP members. The HPAP program is not conducted *for* a country *by* GAHP, but rather is a locally driven process with input and facilitation by the GAHP Secretariat, with support from its members.

The HPAP process will give governments (at local and national levels) a clear picture of where control of pollution will produce the greatest health benefits, allowing them to target efforts and resources and provide international donors with defined priority areas for support.

The process begins with meetings to gain the commitment from key agencies, including ministries of environment, health, production/industry, agriculture, mining, finance, development, transport and others. International agencies may also be included, appropriate to the country or region, such as the World Bank, UNEP, UNDP, UNIDO, regional Development Banks (e.g. Asian, African, Inter-American), and others.

The success of the HPAP process depends on the interest and commitment of the leaders and staff of relevant national ministries and agencies. It is an ongoing effort, with the steps outlined below as the start of a process that integrates agency activities under a common goal of reducing the health impacts of pollution.

Summary Of Initial HPAP Process Steps

Phase 1
Data Collection and Analysis
GAHP members and key partners in Ministries of Health and Environment identify and analyze data on health impacts from relevant pollution issues, begin dialogues with key stakeholders, set timelines and an agenda for HPAP program, prepare for consultations on setting priorities

↓

Phase 2
Set health based priorities for action on pollution
With facilitation by GAHP Secretariat, senior representatives from relevant national and international agencies review health impacts and set health-based priorities for action on pollution

↓

Phase 3
Draft the Health and Pollution Action Plan
National ministries and GAHP members identify and outline potential actions and interventions to reduce pollution impacts on health in a draft Action Plan.

↓

Phase 4
Stakeholder Inputs, Final Draft and Validation
Participating Ministries, development partners and donors provide inputs on the draft Action Plan. A Final Action Plan is presented for validation by participating national ministries or other agencies.

↓

Phase 5
Follow Up Actions: Support for Mainstreaming and Implementation
The GAHP Secretariat and members work with national agencies to integrate the Health and Pollution Action Plan and its Actions into domestic and international development plans, raise additional funding and coordinate/collaborate during implementation, monitoring and review

Phase 1. Data Collection

The HPAP process begins with data collection to assemble and analyze all available baseline data on pollution concentrations, exposures, sources and associated health impacts. A National Working Group led by key partners in the Ministries of Environment and Health provide locally generated data from national agencies, while the GAHP Secretariat provides data from the World Health Organization (WHO) and the Institute for Health Metrics and Evaluation (IHME) on the annual deaths and disability adjusted life-years (DALYs) associated with relevant national pollution challenges. A review of known exposure pathways is conducted for pollution risk factors with significant impacts on health. Any existing pollution source-apportionment studies are reviewed and integrated in the analyses.

The National Working Group makes a particular effort to investigate pollution issues that are often understudied, and therefore may have a higher associated burden of disease than previously estimated. These include:

- **Household air**, especially with respect to enhancing fuel types, such as support for alternative energies or available technologies (bottled gas, sun ovens, better ventilation and smoke extraction, others) instead of open burning of dung, wood or charcoal.

- **Contaminated sites**, not just those communities settled near large industries, but also a focus on toxins from smaller or informal urban industries, especially in high-density areas or poor settlements on polluted sites. These may include mercury contamination from artisanal small-scale gold mining and lead contamination from informal lead-acid battery recycling.

- **Distributed lead exposure issues**, which include lead in pottery glazes, lead in paint, informal car battery and cable recycling and other pathways that may be specific to a particular culture or community.

- **Occupational risks**, including those of asbestos.

During the data collection period, the GAHP Secretariat and key national agency representatives identify other relevant stakeholders, begin dialogues about planning and coordination, develop agendas and presentations, and invite national and international leaders and organizations to the HPAP consultations on priority setting in Phase 2.

Phase 2. Setting Health-Based Priorities For Action On Pollution

The first open and inclusive step of the HPAP process is an Inception Meeting of senior staff from relevant agencies, including ministries of environment, health, production/industry, finance, mining, transport and others, as well as relevant international agencies such as development banks, United Nations agencies, and other regionally significant groups. The aim of the Inception Meeting is to analyze available pollution-related health data, communicate existing pollution programs between agencies, and establish a common approach to prioritizing future actions.

Main elements for setting priorities include:

- Existing data and information on health impacts from risk factors such as exposures to outdoor and indoor air pollution, unsafe water and inadequate sanitation, exposures to chemicals in soil, occupational exposures to contaminants, and others.

- Existing successes, gaps and lessons learned from current or past pollution control efforts.

- Willingness and abilities of participating national and international stakeholders to contribute to the next steps and potential programs and interventions.

The output from the prioritization exercise is a brief summary describing existing pollution challenges, approximate health impacts of each (measured in annual deaths, disability adjusted life years (DALYs)), and selected priorities. The summary report serves as the foundation for an ongoing process of identification and further prioritization of cost-effective actions based on exposure and health impacts and potential improvements to health outcomes from various actions and interventions.

Phase 3. Drafting the Health and Pollution Action Plan

Based on the outcome of Phase 2, the National Working Group and GAHP facilitators conduct a deeper review of relevant sources of pollution, routes of exposure and potential interventions to be described in a draft Health and Pollution Action Plan. The draft Action Plan may contain the following types of analysis for each priority pollution area:

- Analyze current national policies, regulations, capacities and programs related to each of the identified priority pollution areas.

- Review and analyze potential solutions and interventions for each high priority pollution type, considering the political will to implement effective solutions, the capacity available, and the potential effect on public health indicators/metrics.

- Explore the practical effectiveness of potential interventions, measured against costs, and begin to identify funding sources, both national and international. Utilize GAHP members with significant expertise to aid in determining which solutions are right for which problem.

- Create a road map for implementation to address the top priorities selected, for each pollution area, taking into account the political realities and sources of funding. The ideal outcome is a roadmap of action, with timetables, and an investment map prioritizing vulnerable and at risk populations that can save lives. This roadmap should estimate the health outcomes if investments are effective.

- Identify, for each intervention:
    - Monitoring systems that are robust, transparent, and credible.
    - Targets for achievement that have reasonable timeframes.
    - Key challenges and responses, taking into account feasibility, visibility and replicability.
    - Agreed agency responsibilities.
    - Expected improvements in health outcomes.

The final recommendations are selected taking into account local economic, political, and social realities. The roadmap will describe priority pollutants and sources, vulnerable and at risk populations, recommendations for effective actions and interventions, potential improvements to health outcomes from recommended actions, and potential sources of funding.

Phase 4. Stakeholder Inputs, Final Draft and Validation

Once a complete draft Action Plan has be created by the National Working Group, the draft is circulated among participants of the Inception Meeting and other national and international stakeholders, including development partners. Stakeholders are invited to provide comments on the draft. All comments are considered by the National Working Group and incorporated into the final Action Plan where there is general consensus.

Once the final Action Plan document is complete, it is circulated back to the relevant national ministries or agencies in preparation for validation. In most cases, the National Working Group and GAHP facilitators will convene a final Validation Meeting to officially endorse the Health and Pollution Action Plan and discuss next steps toward implementing actions and interventions.

Phase 5. Accelerating Pollution Actions and Interventions

Post-Workshop, there will be a wide range of actions that need to be undertaken for successful implementation of the Action Plan. GAHP can assist the country with the follow up that will be necessary to ensure that progress is being made against the targets and goals outlined in the implementation plan. The range of actions could include:

1. Implementation of the detailed programs.

2. Monitoring and Evaluation. Regular follow up of progress against the goals and targets in the intervention plan will be necessary to ensure the plan outlined in the workshop is implemented.

3. Continue to convene. Challenges will likely come up with the implementation of the plan that requires a coordinated agency effort to resolve. The workshop members should continue to convene to address these challenges, outline solutions and adapt the plan if necessary.

4. Hold responsible agencies accountable for delivery of agreed actions assigned to them in the implementation plan.

5. Monitor impact and successes. It is important to identify and make known the achievements and successes in reducing pollution and its impact on local communities. Therefore, it is important to be able to monitor results, as well as to understand where and why results may take longer to achieve.

6. Share successful experiences. Governments undertaking the HPAP process will be among the first to develop a country-driven process/plan to prioritize and tackle pollution using health metrics. This experience can be showcased by GAHP and used to create a template for other countries to follow and replicate.

Image:CECoD

Preliminary Survey Report

Initial Draft Submitted: March 25, 2017

Project: “Reducing the Threats of Toxic Chemical Pollution to Human Health in Low- and Middle-Income Countries”

Award Number: AID-OAA-A-16-00019

USAID FROM THE AMERICAN PEOPLE

PURE EARTH BLACKSMITH INSTITUTE

CECoD TRUNG TÂM MÔI TRƯỜNG VÀ PHÁT TRIỂN CỘNG ĐỒNG

Table of Contents

LIST OF ANNEXES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CECoD Center for Environment and Community Development, Pure Earth’s partner in Vietnam

FDI Foreign Direct Investment

MoNRE Ministry of Natural Resources and Environment, Vietnam, part of the research team

MPI Ministry of Planning and Investment

Pb Symbol for Lead

USAID United States Agency for International Development, funder of the project

VASI Vietnam Administration of Sea and Islands, part of the research team

VND Vietnamese Dong, the Vietnamese currency

VN-GSO Vietnam General Statistics Office

Zn Symbol for Zinc

Project Overview

1 As part a Cooperative Agreement (no. AID-OAA-A-16-00019) with the United States Agency for International Development (USAID), Pure Earth and the US Mission in Hanoi, agreed to support the Ministry of Natural Resources and Environment (MoNRE) of the government of Vietnam at their request in a project focused on monitoring, assessment, and response to unplanned releases in marine environments.

2 This project encompasses three key outputs:

Output 1: Rapid Gap and Training Needs Assessment

Output 2: Capacity Building Workshop

Output 3: Study Tour

3 The enclosed Preliminary Survey Report is part of Output 1. As part of this output, Pure Earth, through its partner organization, the Center for Environment and Community Development (CECoD), is conducting the following activities:

- Stakeholder interviews
- Identification of system and procedure gaps
- Identification of training, skill, and knowledge gaps
- Identification of coordination gaps
- Development of recommendations

4 The Preliminary Survey Report is based on the stakeholder feedback and research completed by a team comprised of 3 experts from CECoD, and officials from MONRE. The team drafted this report to inform the government of the current industry that is located along waterways, the types of pollution likely to be found in those areas, the current capacity and practice for oversight, and initial observations of training that could be provided to strengthen the oversight, assessment, and response to unplanned releases in marine environments.

Executive Summary

5 This report summarizes the findings of a survey and series of interviews conducted among 32 central and provincial government authorities during December 2016. Interviewees were asked about current major industry in each province, environmental problems they are aware of, and the current institutional arrangements for marine environmental risk and unplanned release management and response.

6 The government of Vietnam is concerned about protecting water quality and has enacted environmental projection activities particularly focused on preventing any negative impacts of industry on health and the environment, particularly in coastal areas and along waterways. Of the 64 provinces in Vietnam, 28 are coastal. Industry in these coastal areas has increased steadily year over year and now accounts for about half of the industrial output of the entire country. The majority of the industrial clusters operating in coastal provinces are small- and medium-scale, low-technology operations making oversight and management more complicated.

7 The interview responses indicate that the main water pollution concerns among the local officials are:

- Mining and Mineral Processing run-off and sludge
- Agricultural run-off including pesticides
- Textile/garment factories and dye industries
- Oil spillage/petrochemical waste
- Chemicals/pharmaceutical/rubber/plastics manufacture
- Metal smelting, steel, and metallurgy waste
- Sewage and domestic wastewater
- Food processing and manufacture particularly seafood processing

8 Interviewees were asked to detail the institutional arrangements for monitoring marine environment pollution. The findings indicate that while there are specific inspection and monitoring activities required under current legislation, there are at least twelve different oversight bodies responsible for the activities that must be coordinated and whose activities

must be standardized so that data remains comparable. Additionally, the human resources capacity and technical skills available within each province vary widely and no central training mechanism exists for the more than 750 people employed at the central and provincial authorities and the additional 800 people working within the industrial zones.

9 The results from the surveys and interviews will inform the recommendations for the government and the design of the Capacity Building Workshop to include relevant training topics. The initial outline of the requirements for effective monitoring, assessment, and response to unplanned releases to the environment is below and will be further developed for the final report to the government.

	Factor	Comment
1	Public concern and desire to address unplanned releases	Without a general public concern about unplanned releases and a desire to address them, no system will be effective - people and industry would not report releases, and there would be opposition to the costs and disruptions resulting from releases response.
2	Government authority	Government must have clear authority to require reporting, response to and remediation of releases. This may include authority for cost recovery from parties responsible for releases.
3	Clear regulatory definitions of regulated unplanned releases	Clear definitions of what is and is not and unplanned release are essential to establish the scope of regulations and control, and to allow planning for the level of resources required.
4	Unplanned release risk evaluation	Evaluation must be done of the types, levels and geographic dispersion of unplanned release risks likely present in the jurisdiction of concern.
5	Government funding	Funding of response reporting and remediation must be adequate. Level of funding is the best indicator of government priority on this issue. Funding must include regular funding and emergency funding to address large incidents.
6	Public education	Public education is essential regarding what is a regulated unplanned release, why these are of concern, how to report, etc. This notably includes targeted education of likely sectors responsible for releases, such as petroleum and chemical industries, transport companies (truck, rail and water), mining companies, and pesticide application firms.

7	Government organization - release observation, notification and reporting systems	Clear systems to detect and report releases are essential - by whom, to whom, how fast after a release occurs or is found, what information is desire, etc. - A central body to receive and then act on the information is necessary. - A network or organization of inspectors looking for unplanned releases is important for the detection and reporting of releases. These inspectors can be government environment agency personnel, or can (more cost-effectively) incorporate local government agents, non-government organizations, public utility workers and others as appropriate, providing training and coordination is provided. In addition, voluntary reporting by (non-network) citizens, NGO's, local government representatives or companies is also important.
8	Environmental Monitoring Systems	A network of monitoring systems is important to detect unplanned releases or their environmental impact. Typically, for rivers and seas, this means monitoring stations at key locations that are continuously or periodically sampled for key environmental indicator parameters such as pH, suspended solids, COD, oils, VOCs, coliform, metals, chlorophyll (an indicator of algae blooms), etc. Monitoring is important both to augment release observation and reporting by inspectors and to understand what are "normal" conditions versus conditions that may indicate an unplanned release.
9	Laboratories	High quality laboratories are needed to analyze both routine and one-off environmental samples - notably water samples but also soil and air samples. Capability to do forensic analysis is important, such as gas or liquid chromatography coupled with mass spectrometry, especially for forensic analysis of suspected organic chemical releases. Biological analysis capability can also be important, such as for forensic tissue analysis to determine what is impacting fish, birds or marine life.
9	Government organization - command structures and responsibility clarification	Need a structure in the government to decide on actions necessary in response to a release, then manage necessary communications and response actions. Actions include both remediation measures and measures to protect the public and the environment such as evacuations, alternate water supply provision, fishing prohibitions, etc.
10	Government organization - communication methods and capability	Methods to communicate concerns and response measures to the public are essential. This includes effective communication of public protection measures, responses to press or public questions, call out or commandeering of response capabilities, coordination with medical establishments, etc.
11	Command and communication training	Trained commanders for release response are needed, of adequate number and geographic dispersion to meet likely needs. Commanders need to be able to make strategic decisions about response strategies, resource needs, communication needs. They also must handle public, private sector and the government interactions typically involved in a release response. This is a notably different skill set than hands-on response work.
12	Responder organizations	Need to have a corps of trained responders of adequate number and geographic dispersion to handle likely releases. Training must factor in the various types of releases, response measures and technologies likely to be needed. Response organization may be in government or in private organizations.

13	Responder training	The corps of trained responders needs high quality training programs, including regular refresher training.
14	Supplies and equipment	Need to have adequate supplies and equipment to respond to likely releases, of types and quantities likely to be needed in view of release risks, and strategically placed to be available when needed, and maintained in good condition
15	Government organization - monitoring, follow up and post-remediation action management	An organization and system to follow up on release responses in necessary. This includes evaluation to assure the response was effective and complete; sharing learning from responses and incorporating them in future plans and resources; putting in place and managing any long term environmental monitoring needed; following up with and if appropriate reimbursing people impacted by releases; and following up on any legal actions or cost recovery actions resulting from the release.

10 Based on the requirements above as well as the results from the interviews held with local officials, the following training topics are being considered for the Capacity Building Workshops:

- Forensic assessment
- Testing and monitoring of sediments, soil, water, and biota
- Modelling and mapping for planning and risk evaluation
- Emergency response and prevention protocols
- Clean-up and remediation options
- Communicating about environmental risks and emergencies
- Best Practices in environmental management policy
- Evaluating laboratory capacity for analysis

11 The information presented in this report will be shared with participating stakeholders for additional feedback and will be included along with the materials and trainings included in the Capacity Building Workshop, the recommendations and references for future action, and any other relevant materials in the final report of the project. Please submit any comments or questions by email to Madame To Thi Duong (to.duong@cecod.org.vn) and Lara Crampe (Lara@PureEarth.org).

Survey Design and Implementation

Objectives

12 The survey undertaken for this project was designed to assess and identify knowledge gaps and determine capacity building and training needs related to regulatory responses to unplanned releases into the marine environment. The original survey plan is included in Annex 1. Specifically, the survey aimed to:

a) Detail the level of awareness and perceptions of local government officials with regard to the management of unplanned releases into the marine environment;

b) Determine the existing capacity of regulatory agencies to monitor and assess the impact of industries on the marine environment and human health; and

c) Develop a list of training needs of government entities to improve capacity in responding to (assessing, managing and monitoring) unplanned releases in the marine environment.

Methodology

13 The investigation team was comprised of 3 experts from CECoD, and officials from ICD/MoNRE. The team met face to face with 13 officials from central authorities and 36 officials from local authorities in 6 coastal provinces during December 2016 as indicated in the table below. The Department of Natural Resources and Environment from 3 other coastal provinces, Ninh Thuan, Nam Dinh and Thanh Hoa, responded to email questionnaires.

Administrative level	Number of Offices Visited	Number of Interviewees
Central Government	11	13
Provincial Government	21	36

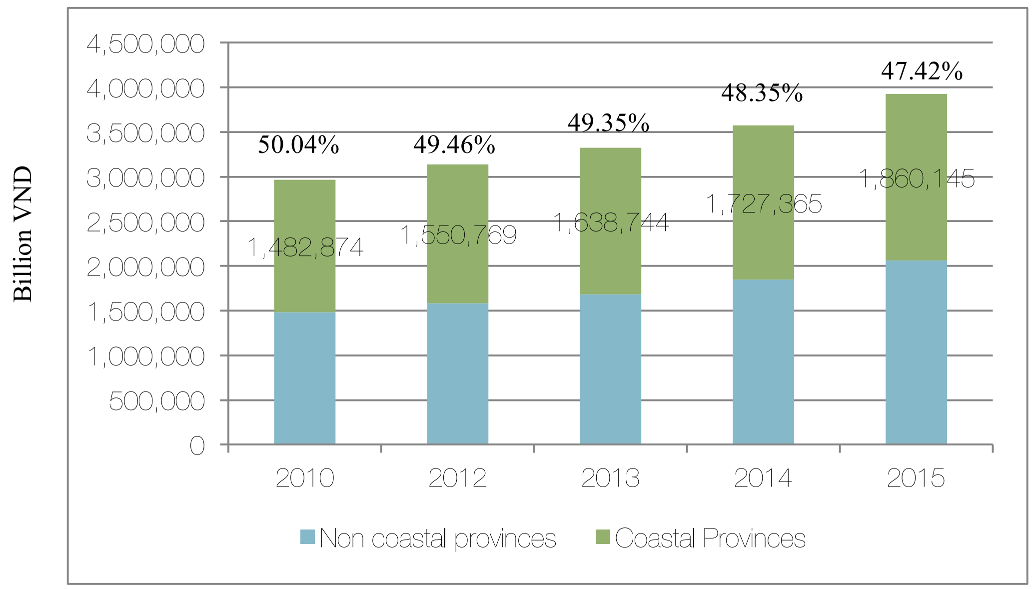
14 The details of the officials who were interviewed are included in Annex 2. The minutes of the meetings organized by the investigation team and related authorities are presented in Annex 3. The key facts and findings derived from the interviews as well as review of current legislation and available environment reports are summarized below.

Summary of Facts and Findings

Industrial Development in Coastal Provinces

15 Vietnam has 28 coastal provinces among its 64 provinces. According to the industrial development statistical data presented by Vietnam General Statistics Office (VN-GSO), the total industrial output value produced by the 28 coastal provinces has been continuously increasing and contributes about 50% of the overall national industrial output value as shown in Figure 1.

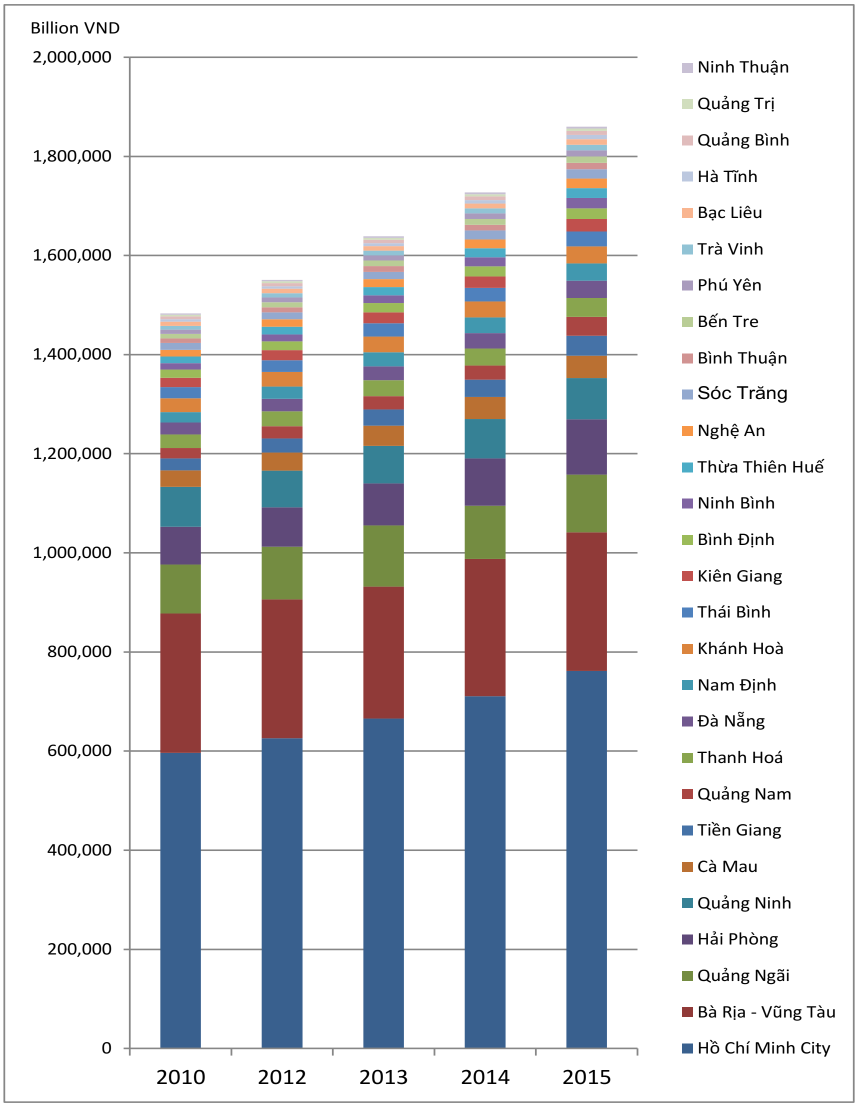
Figure 1: Contribution of Coastal Provinces to National Industrial Output Value



Source: Calculation based on Vietnam VN-GSO database (http://www.gso.gov.vn)

16 Figure 2 below presents the ranking of annual industrial output of the 28 coastal provinces between 2010 and 2015. Hochiminh City, Ba Ria Vung Tau, Quang Ngai, Hai Phong, and Quang Ninh have been the biggest contributors, producing 72-76% of total industrial output value of all coastal provinces annually until 2015. However, recently, industry has been rapidly developing in other coastal provinces, especially in the central key economic coastal region including Ha Tinh, Nghe An, Thua Thien Hue, Da Nang and Quang Nam. These provinces with growing industry sectors must increase oversight of industry waste streams, hazardous materials usage and disposal, and must prepare for potential environmental or health impacts.

Figure 2: Industrial Output Value of Coastal Provinces (2010-2015)



Source: Calculation based on VN-GSO database (http://www.gso.gov.vn)

17 Industry is growing steadily in Vietnam, particularly in coastal areas. As of December 2015, there were 304 industrial parks nationwide covering an area of about 85,000 hectares. Approximately 164 of the industrial parks are located in coastal areas occupying an area of 68,000 hectares, about 80% of total land area of industrial parks nationwide as indicated in Figure 3 below.[1]

[1] Calculations based on data provided by Provincial Departments of Industry and Trade in coastal provinces and Ministry of Industry and Trade's official portal

18 The industrial sector is an important contributor to the economy. The total Foreign Direct Investment (FDI) capital attracted by the 28 coastal provinces was estimated at about US$151.8 billion, accounting for more than half of all FDI as of 31st of December 2015. The industrial sector is a key stakeholder therefore and must be included in efforts to improve oversight and prevention of water pollution.

Figure 3. Industrial Development of Coastal Provinces (2010-2015)

Provinces	Ranking by provincial industrial output value (2015)	Industrial Output Value of 2015 (Billion VND)	FDI by 31st Dec 2015 (Million USD)	Industrial Parks in operation by 31st Dec 2015		Industrial Development Index (%)			
				#	Total area (ha)	2012	2013	2014	2015
Hồ Chí Minh City	1	761,915	42,366.8	21	7,463.19	105	106.3	106.8	107.2
Bà Rịa – Vũng Tàu	2	279,312	27,766.4	11	7,510.87	99.5	95.1	103.9	100.9
Quảng Ngãi	3	116,696	4,27.5	6	13,033.04	107.7	116.6	86.9	108.6
Hải Phòng	4	111,483	11,651.3	5	2,629.32	103.9	106.5	112.9	116.6
Quảng Ninh	5	83,291	5,380.7	4	960.92	92	102.3	104.7	105.2
Cà Mau	6	45,058	789.5	4	1,477.00	109.9	112.4	109.1	100.8
Tiền Giang	7	40,405	1,532.5	5	1,726.47	118.9	112.1	108.1	115.2
Quảng Nam	8	38,009	5,525.8	8	3,193.26	118.2	109.6	105.3	135
Thanh Hoá	9	37,987	10,409.1	8	4,160.94	107.9	108.2	106.9	109.8
Đà Nẵng	10	35,207	4,023.5	6	1,514.81	106	110.5	111	113.1
Nam Định	11	34,729	679.0	7	1,200.00	116.4	116.1	110.6	110.3
Khánh Hoà	12	34,467	2,349.4	5	877.32	106.8	104.5	103.1	106.8
Thái Bình	13	29,742	472.5	9	2,557.00	106.5	114.1	101.8	108.3
Kiên Giang	14	25,181	2,957.6	6	4,298.09	105.8	108.9	106.2	108.6
Bình Định	15	21,807	1,761.8	7	2,433.00	106.8	107	105.7	108.5
Ninh Bình	16	20,783	1,206.5	4		111.6	111.4	117.4	112.3
Thừa Thiên Huế	17	20,026	2,591.2	4	1,683	112.6	108.1	111.2	109.4
Nghệ An	18	19,162	1,640.6	4		109.7	106	110	109
Sóc Trăng	19	19,054	118.6	4	1,438.13	102	104.7	125.4	103.5
Bình Thuận	20	12,863	3,527.9	6	2,843.98	107.8	114.9	98	113.3
Bến Tre	21	12,827	591.1	2	173.47	114.8	111.9	102.7	108.5
Phú Yên	22	12,091	4,764.9	4	1,204	113.4	106.2	107.3	109.3
Trà Vinh	23	11,454	2,684.1	1	106.60	116.2	106.3	110.4	112.6
Bạc Liêu	24	11,288	94.2	5	555.84	103.8	105.3	105.2	114.1
Hà Tĩnh	25	8,282	11,265.0	4		107	113.1	119.1	120.3
Quảng Bình	26	8,061	109.1	9	4,773.39	108.5	108.7	106.6	109.3
Quảng Trị	27	4,942	85.6	2	546.00	113	109.2	104.8	113.6
Ninh Thuận	28	4,020	949.6	3	855.19	110.9	112.1	125.2	109.1
Whole country		3,922,845	281,882.5	304	85,200.00	105.8	105.9	107.6	109.8

Calculation based on VN-GSO database (http://www.gso.gov.vn) and Ministry of Planning and Investment (MPI) database

Increasing Concerns about Pollution

19 According to the National Report on the State of Environment from 2011-2015 published by MoNRE in October 2016, the monitoring data shows that marine water quality of coastal areas is within acceptable limits in accordance with the National Technical Norms No. QCVN10-MT:2015/BTNMT. However, due to the impacts of waste discharged from development activities in coastal areas, coastal waters have been polluted with organic matter. Chemical Oxygen Demand (COD) and Ammonium (NH_4^+) have been observed at levels higher than the acceptable limits in many areas (particularly in the northern and southern coastal provinces). Oil has also been found at levels higher than the acceptable limits in the areas near sea ports or harbors.

20 Additional pollution issues identified by MoNRE and indicated by local officials include:

- Improper treatment of domestic wastewater from urban areas and industrial wastewater from industrial parks polluting main river basin areas
- Increased frequency and severity of flooding in urban areas, particularly in Hanoi and Hochiminh City
- Transportation sources and concentrated industrial activities increasing air pollution and dust concentration in urban areas
- Industrial pollution from activities in craft villages, industrial parks and industrial clusters
- Mismanagement of solid wastes and hazardous wastes generated by industrial activities. Presently, only approximate 80% of industrial parks in operation have been equipped with central wastewater treatment systems
- Misuse and abuse of pesticides and chemical fertilizers causing soil and water pollution

21 In addition to the identified causes of pollution, there have been increasing incidences of environmental accidents. For example, oil spills have occurred in coastal areas of Vietnam at a rate of about 5-6 recorded cases per annum. There was leakage of phosphorous wastes from an incinerator operated by Lao Cai Phosphorous Joint Stock Company in February 2012. Chemical leakage caused a severe explosion in October 2014 at Dang Huynh Commerce Service

and Manufacturing Company in Hochiminh City. Lead-containing sludge and wastewater leaked from broken tanks at CKC Company Limited in Lang Ca village in Cao Bang Province in January 2016.Finally, the occurrence of a massive fishkill in April 2016 affected four provinces and was attributed to industrial waste discharged by the Formosa steel plant. All of these accidents are examples of the types of unplanned releases that can and do occur. Oversight systems and response planning are necessary for all provinces where industrial activities are occurring.

22 Among the industrial clusters established nationwide, more than half are small- or medium-scale industrial facilities applying low technologies and operating in coastal areas. The table below presents the current industry and key environmental problems in the coastal provinces as described in provincial reports and revealed during interviews with local officials. The data indicates that water pollution is of increasing concern to the provinces, particularly related to industrial wastes. Most of industrial operators are in the following key sectors: food and beverage processing (including seafood processing), garment and textile factories (including dyeing), pulp and paper manufacture, mechanical processing, manufacture of electronics, metallurgy, mining, and manufacture of building materials (including cement, tiles, and ceramics).

Figure 4. Major Industries and Environmental Problems in Coastal Provinces

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
A	Northern Vietnam					
1	Quảng Ninh	Share of provincial industrial output value in 2016 as follows: Mining (coal): 41.6% Manufacture: 37.3% Power generation:20.5% Water supply, waste treatment: 0.6% Key sub-sectors: agricultural products, sea food processing, coal mining, building material manufacture, textile and garment. Since 2012,manufacture of	Air pollution has increased from building material manufacture, construction sites, and power generation factories. Air quality in rural and tourism areas is still very good.	Some areas have been affected by coal mining activities (Vang Danh river). Coastal water is polluted by oil in the harbors or ports, organics and Ammonium (NH4+) has increased. Surface (inland) and underground	Soil acidification is increasing caused by mining activities.	Air pollution (dusts and noise) from transportation has increased in some areas.

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
		electronics has been a priority		water quality is still rather good.		
2	Hải Phòng	Industry in 2015 as follows: Metallurgy: 13.7% Mechanics: 31.08% Electronics: 9.53% Chemicals, rubbers, and plastics: 13.23% Power and water generation: 3.92% Agricultural product and sea food processing: 9.05% Building material manufacture: 7.06% Garment and textile: 11.88%	Air pollution is caused by waste treatment facilities. Some seriously polluting facilities have been improved although the number of air pollution sources has increased.	Surface water quality and coastal water quality is decreasing due to pollution. Underground water quality is still good.	Soil pollution risks have increased as industrial activities in craft villages, industrial zones and waste treatment activities have increased	Noise pollution caused from transportation and industrial activities has increased.
3	Thái Bình	Industrial activities in Thai Binh province has not been developed yet.	Air pollution from activities in industrial areas and craft villages concerns the population. Air pollution from transportation has increased.	Surface water quality has deteriorated in some rivers due to rapid development. Underground water has been polluted by organic pollutants in some locations. Coastal water has been polluted with high oil concentration and potentially with Lead(Pb) and Zinc (Zn).	Soil quality is still good according to the monitoring data	
4	Nam Định	There are more than 1,650 industrial enterprises operating in the province, mostly in mechanical processing, textile and dyeing, paper & pulp, the manufacture of building materials and food processing.	Air quality is still good	Surface water quality has deteriorated		

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
5	Ninh Bình	Most of industrial facilities in the province are small and medium scale using outdated technologies. This has increased potential hazards to the environment and health. Major industrial sectors are manufacture of building materials, food processing, garment and textile, craft and art products	Air pollution in urban and industrial areas has increased from dusts, and toxic emissions	Surface water has been polluted with organic pollutants and has bad odor. Water pollution has increased.		Noise pollution has increased
C	Central Vietnam					
6	Thanh Hóa	Share of industrial wastewater volume (totaling 293,072 m3 per day in 2015) by sectors as follows: Mining: 18.39% Food and beverage processing: 3.08% Pulp & paper: 75.72% Chemicals: 0.16% Oil refinery: 1.49% Metallurgy: 1.15%	Air pollution in the areas surrounding industrial zones and busy transportation areas has increased (dusts).	Surface water quality monitoring shows increased organic pollutants at most observed sites. Organic pollutants, Total Suspended Solids (TSS) and Iron (Fe) are above acceptable limits at coastal sites.	Soil quality has still been good (all observed sites have been found within acceptable limits)	Noise pollution in high populated residential areas has been slightly higher than acceptable limits.
7	Nghệ An	Key industrial sectors include food and beverage processing, mechanics and electronics, manufacture of building materials, chemicals, textile and garment, mining,	Air pollution from industrial facilities has increased and concerns the population	Water pollution from industrial activities has increased.	Soil pollution from misuse of pesticides	Not yet polluted
8	Hà Tĩnh	Industrial output value has dramatically increased after the opening of Vung Ang economic zone. Steel manufacture (Formosa) plays an important role in provincial industrial output value.	Air pollution by dusts and noise has increased in busy transportation and industrial areas	Surface water quality is still good. Monitoring of coastal water quality have shown that the concentration of oil, TSS and coliform are higher than acceptable limits in many observed sites.	Soil quality is still good	

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
9	Quảng Bình	Share of provincial industrial output value in 2016 as follows: Mining: 3.5% Manufacture: 93.8% Power-energy generation: 2% Water supply, waste treatment: 0.7% Key sectors include manufacture of building materials , garment and textile	Good	Good	Good	Good
10	Quảng Trị	By the end of 2014, there were more than 420 industrial establishments. The following sectors have high potential risk to the environment: rubber processing, sea food processing and mining.	Air quality is still good. However, pollution from transportation (dusts) has increased along some busy roads.	Surface water quality has been rather good and stable. Coastal water has been polluted with high concentration of oil at many observed sites.	Lack monitoring data on soil environment quality	Noise pollution from transportation has increased
11	Thừa Thiên Huế	Most industrial facilities have been small scale and located outside the industrial parks/clusters. The impacts of industrial activities on environment quality of the province have not been severe yet.	Ambient air environment quality is still rather good	Surface water quality is still rather good and being improved in comparison to previous time. Coastal water quality has been rather good.	Good	Good
12	Đà Nẵng	There are about 17,000 enterprises of which, 97% are small and medium enterprises.	Air pollution index has been stable under 100	Water pollution has been improved		
13	Quảng Nam	Priority has been given to develop the sectors of mechanical processing, electronics, textile and garment, food processing and manufacture of building materials		Surface water quality has deteriorated due to poor management of industrial wastewater discharged from industrial parks/clusters		
14	Quảng Ngãi	There are 3,000+ operators, 3 industrial parks, 11 industrial clusters and 22 craft villages)		Water has been polluted by industrial sources		

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
15	Bình Định	Key industrial sectors include food and beverage processing, paper manufacture and wood processing, textile and garment, mining (granite stones, gold and aluminum bauxite mining), manufacture of building materials, oil refinery and petro chemicals.		Coastal water quality has been impacted by industry and tourism		
16	Phú Yên	Key industrial sectors include seafood processing, wood processing, textile and garment, mining (gold and bauxite ferrous), rubber processing and chemicals, oil refinery and petrochemicals	Ammonia (NH3), Hydrogen Fluoride (HF), and Sulfur Oxide (SOx) are higher than acceptable limits in a few observed sites	Water quality has deteriorated due to industrial and development activities	Heavy metal concentration has been found at high level in a few observed sites	Noise pollution has been slightly higher than acceptable in a few observed sites
17	Khánh Hòa	Key sectors include seafood and beverage processing	Air quality has been improved in comparison to the previous period of 2006-2010.	Surface water quality has been stable and still good (just a few observed sites have been found with the pesticide concentrations higher than acceptable limits. Underground water quality is still good. Coastal water quality is still good (oil concentration slightly higher than acceptable limits)		
18	Ninh Thuận	Manufacturing industries account for 85% of provincial industrial output value with the following key sectors:	Air quality is good	Surface water quality has been stable and still good (high BOD found at a few observed sites).	Soil quality has deteriorated slightly	

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
		Key sectors: food processing, paper and plastic containers, cement		Coastal water has been polluted with high concentration of Iron (Fe), coliform, organics and TSS, especially near aqua-cultural farms		
19	Bình Thuận	Environmental risks are mostly from titanium mining, seafood processing and poor management of both solid waste and wastewater	Air pollution caused from Thermo power generation (Vinh Tan factory) was very serious, leading to demonstrations by surrounding communities Ambient air quality is generally good	Surface water quality has deteriorated with high concentration of organics and TSS. Coastal water quality is still good. Underground water is polluted in a few observed sites.	Soil quality is still good.	
C	Southern Vietnam and Mekong region					
20	Bà Rịa Vũng Tàu	Key environmental problem is pollution caused from steel manufacture (sludge) and wastewater from dyeing facilities, leather tannery		Water pollution has increased due to rapid urbanization and industrial development		
21	Hochiminh City	Environmental risks derive mostly from textile and garment, paper, chemicals, small scale petrochemicals, and steel.	Air pollution from transportation has been serious	Water quality has deteriorated due to rapid urbanization and industrial development		
22	Tiền Giang	Seafood processing				
23	Bến Tre	Seafood processing				
24	Trà Vinh	Seafood processing				
25	Sóc Trăng	Seafood processing	Air pollution (dusts) caused from industrial and	Surface water slightly polluted due to rapid	Soil quality of 8 monitored sites is good	Noise pollution from transportation

No	Province	Major industries	Environmental Problems			
			Air Pollution	Water Pollution	Soil Pollution	Noise Pollution
			transportation activities has increased based on the monitoring of 28 observed sites	urbanization and industrial dev. Monitoring data of coastal water shows high concentrations organics, TSS, coliform and heavy metals		and industrial activities
26	Bạc Liêu	Seafood processing				
27	Cá Mau	Seafood processing				
28	Kiên Giang	Seafood processing				

Sources: interviews, available reports collected during site visits, and open sources online

23 In addition to data on industry and current environmental concerns, the investigation team asked each interviewed official to rank the environmental risks of the various sector operating in their province. The compiled answers are included in Figure 5.

Figure 5: Rating of Environmental Risks by Sectors

Source	Risk ranking			Reasons (To Be Completed))
	High	Medium	Low	
Domestic wastewater without treatment or improper treatment	x			
Municipal solid waste		x		
Coal mining		x		
Oil and natural gas mining		x		
Other mining activities				
Food processing/manufacture	x			
Beverage manufacture				
Tobacco manufacture				
Textile, dying and garment	x			
Paper and pulp				
Chemical manufacture	x			
Pharmaceutical manufacture	x			
Rubber and plastics manufacture	x			
Nonmetallic mineral processing	x			
Metal product manufacture	x			
Electrical and electronic appliances, home appliances				
Furniture manufacture				
Vehicle, machinery manufacture				
Waste treatment, recycling and disposal		x		
Water treatment for various purposes		x		
Others (please specify) (*)				

24 There are many types of potential pollutant releases that can impact the environment from various industrial sources. The chart in Figure 6 outlines the different potential pollutant sources and their impacts in air, water, and on or below the ground. These are the risks that must be planned for by government institutional arrangements and regulatory systems.

Figure 6. Types of Unplanned Releases to the Environment

Media Released To	Type of Release	Typical Sources	Potential Impacts
Air	Toxic chemical gas cloud	Chemical factories, storage tanks, tank trucks, rail cars	Human and animal deaths and injuries, long term health impacts, ecological impacts
	Flammable gas clouds	Refineries, storage tanks, tank trucks, rail cars, gas well blowouts, gas pipeline leaks	Explosions leading to deaths and injuries
	Pesticides	Pesticide formulation, spraying	Human and animal deaths and injuries, long term health impacts, ecological impacts
	Metals and ores	Smelters	Contamination of downwind lands, health impact to people breathing fumes
	Chemical weapons	Weapons depots and waste dumps, production sites, tanks	Deaths and injuries, long term health impacts, ecological impacts
Water	Crude oil	Oil well blowouts, tanker ships, tank trucks, rail cars, pipeline ruptures	Death of fish and aquatic life, contamination of water supplies, fouled shorelines
	Refined fuels, petrol	Refineries, tanker ships, tank trucks, rail cars, pipeline ruptures	Death of fish and aquatic life, contamination of water supplies, loss of water body use
	Toxic chemicals	Chemical factories, storage tanks, tank trucks, rail cars	Human death or health impacts if exposed, death of fish and aquatic life, contamination of water supplies, making fish and shellfish unsafe to eat, loss of water body use, ecological impacts
	High organic loads	Untreated sewage releases, sewer pipe breaks, septic pumping trucks, improper septage disposal, sludge barges, concentrated livestock feedlots, feedlot lagoon failures, milk spills from dairies or trucks, etc.	Anoxic zones in water bodies leading to fish kills and damage to aquatic life, contamination of water supplies, making fish and shellfish unsafe to eat, loss of water body use, fouled shorelines

	Pesticides	Pesticide formulation, spraying, tank trucks, lorries	Death of fish/aquatic life, water supply contaminated, fish, shellfish unsafe to eat, loss of water use
	Metals and ores	Mining, mine tailing piles, barges, rail cars, smelters	Death of fish and aquatic life, contamination of water supplies, making fish and shellfish unsafe to eat, loss of water body use
	Hazardous wastes	Dumping of wastes illegally, factories, transport spills	Human death or health impacts if exposed, death of fish and aquatic life due to toxic effects or development of anoxic zones, contamination of water supplies, making fish and shellfish unsafe to eat, loss of water body use, ecological impacts
	Domestic & urban waste	Dumping of waste in or near water bodies, storm runoff and floods carrying dumped waste to water, litter	Discharge of high organic loads during storm events or floods with effects as above; impact on fish, birds and biota due to plastics or disease organisms; contamination of water supplies; making fish and shellfish unsafe to eat; loss of water body use, unsightly litter and water conditions.
Land Surface	Crude oil	Oil wells, refineries, pipeline ruptures, rail cars	Fouled land, ecological impacts, possible release to surface and ground water
	Refined fuels, petrol	Refineries, pipeline ruptures, rail cars, tank trucks, petrol stations	Fouled land, ecological impacts, possible release to surface and ground water
	Toxic chemicals	Chemical factories, storage tanks, tank trucks, rail cars, chemical use sites	Human and animal deaths and injuries, long term health impacts, ecological impacts, loss of land use, possible release to surface and ground water
	Pesticides	Pesticide formulation, spraying and other applications, tank trucks, lorries	Human and animal deaths and injuries, long term health impacts, ecological impacts, loss of land use, possible release to surface and ground water
	Metals and ores	Mines, tailing piles, smelters, recycling operations, rail cars, lorries	Human and animal deaths and injuries, long term health impacts, ecological impacts, loss of land use, possible release to surface and ground water

	Hazardous wastes	Dump sites, informal disposal activities	Human and animal death/injuries, long term health impact, ecological impact, loss of land use, possible release to surface / ground water
Underground	Crude oil	Underground tanks, pipelines	Contamination of water supplies, possible release to surface waters
	Refined fuels, VOCs	Underground tanks, pipelines	Contamination of water supplies, possible release to surface waters
	Toxic chemicals	Chemical factories, underground tanks, pipelines, waste dumps	Contamination of water supplies, possible release to surface waters
	Pesticides	Waste pesticide dumps, formulation and storage sites, application areas	Contamination of water supplies, possible release to surface waters

Institutional Arrangements and Regulatory System Review

25 Interviewees were asked to detail the institutional arrangements for monitoring marine environment pollution. The findings indicate that while there are specific inspection and monitoring activities required under current legislation, there are at least twelve different oversight bodies responsible for the activities that must be coordinated and whose activities must be standardized so that data remains comparable. The key working areas that must be coordinated include:

- Pollution Control (Oversight, Monitoring, Enforcement)
- Environmental Accident Preparedness
- Environmental Accident Response
- Pollution Remediation and Clean-up

Figure 7. Coordination Mechanisms among Relevant Authorities

Organization Name	Working areas that should be collaborated (*)				Specific Activities
	(1)	(2)	(3)	(4)	
Central Government Level					
MoNRE	Lead	Lead	Lead	Lead	See annex 2
VASI	x	x	x		Inspection/check of the applications/activities to explore/use marine resources and to protect the marine environment
VEA	x	x	x	x	Preside over the implementation of EIA/SEA tools for the management of environmental risks Inspection/check of the applications/activities for socio-economic and industrial development

					Develop plans, policies and guidelines for the management of environmental risks, environmental accident preparedness and responses, the remediation of polluted areas Preside over the implementation of the plans and projects focusing on the management of environmental risks, environmental accident preparedness and responses, the remediation of polluted areas in various locations (especially those implemented at inter-regional/provincial scale) Implementation of environmental monitoring to observe/supervise environmental quality
Environmental Police Dept.	x	x			Inspection/check of the applications/activities for socio-economic and industrial development to ensure the full compliance with environmental legislation
Vietnam Coast Guard	x		x		Supporting relevant authorities when requested
Vietnam National Search &Rescue Committee			x		Supporting relevant authorities when requested
Provincial Government Level					
DoNRE	Lead	Lead	Lead	Lead	
EPA	x	x	x	x	Preside over the implementation of EIA/SEA tools for the management of environmental risks under its provincial jurisdiction Inspection/check of the applications/activities for socio-economic and industrial development within the province Develop plans, policies and guidelines for the management of environmental risks, environmental accident preparedness and responses, the remediation of polluted areas within the province Preside over the implementation of the plans and projects focusing on the management of environmental risks, environmental accident preparedness and responses, the remediation of polluted areas within the province
Provincial Centre for Environmental Monitoring (PCEM)	x	x	x		Implementation of environmental monitoring to observe/supervise environmental quality and environmental performances by various entities within the province
Provincial Agency for Sea & Islands (PASI)	x	x	x	X	Inspection/check of the applications/activities to explore/use marine resources and to protect the marine environment within the province Conduct survey/researches to determine marine pollution levels and warning necessary measures to improve marine environment quality within the province
Provincial Environmental Police Force	x	X			Control against environmental crimes within the province
Provincial Authority for Industrial Zone Management	x	x	x	x	Inspection/checking of environmental performances of the industrial facilities locating inside industrial zones to ensure that the operation of the industrial zones will fully comply with environmental legislation system

Figure 7 Note: (*) Working Areas to be Coordinated (1): Pollution Control; (2): Environmental Accident Preparedness; (3) Response to Environmental Accident; (4) Pollution Remediation and Clean up

Human Resources Capacity

26 Interviewees were also asked about the human resources capacity and technical skills available within each province. The results are presented in Figure 7. The staffing, skill level, and budgets vary widely between provinces. Additionally, there is no central training mechanism for the more than 750 people employed at the central and provincial authorities or for the additional 800+ people working within the industrial zones.

Figure 8. Human Resources Capacity by Province

No	Province	Related organizations	Department of Natural Resources and Environment			Environmental Police
			EPA	PCEM	PASI	
A	Northern Vietnam					
1	Quảng Ninh					
2	Hải Phòng	In 2015, total budget allocated for environment protection activities was estimated at US$19 million (including US$3 million from international donors)	74 staff			95 staff
3	Thái Bình			20 staff (3 master degree holders, 15 university degree holders and 1 technician)		
4	Nam Định			39 staff	7 staff	
5	Ninh Bình			11 staff	21 staff	
C	Central Vietnam					
6	Thanh Hóa	7 Environmental Inspectors	16 staff	49 staff	17 staff	
7	Nghệ An		15 staff	44 staff (5 master degree holders)		
8	Hà Tĩnh		15 staff		5 staff	
9	Quảng Bình					
10	Quảng Trị		10 staff	20 staff		
11	Thừa Thiên Huế			20 staff		

No	Province	Related organizations	Department of Natural Resources and Environment			Environmental Police
			EPA	PCEM	PASI	
12	Đà Nẵng					
13	Quảng Nam		12 staff Established in 2008	35 staff Established in 2005	Not yet established	
14	Quảng Ngãi		13	84		
15	Bình Định		18	19		
16	Phú Yên	Environmental Division under Provincial Authority of Industrial Park Management has 5 staff (2 master degree holders and 3 university degree holders), established in 2010 In 2015, the province budget allocated for environmental protection activities was of VND33.87billion (approximately US$1.6 million)	15 staff, established in 2013			20 staff, established in 2010
17	Khánh Hòa	PEPF was established in 2013. In 2014, the province budget allocated for environmental protection activities was VND142.61 billion (approximately US$7.1 million)	16 staff (established in 2008)	18 staff (established in 2007)	Not yet established	25 staff (established in 2007)
18	Ninh Thuận		11 staff	27 staff	2 staff	
19	Bình Thuận		20 staff	27 staff Established in 2015 (upgraded from CEM under EPA)		
C	Southern Vietnam and Mekong region					
20	Bà Rịa Vũng Tàu		21 staff	39 staff		
21	Hochiminh City					
22	Tiền Giang		12 staff	13 staff		
23	Bến Tre		20 staff	27 staff		
24	Trà Vinh		14 staff	44 staff		
25	Sóc Trăng		14 staff	12 staff		
26	Bạc Liêu		10 staff	21 staff		
27	Cà Mau		11 staff	92 staff		
28	Kiên Giang		13 staff	25 staff		

Figure 8 Sources: Interviews, reports collected during site visits, and other open sources online

Current Monitoring System

27 While current monitoring systems are in place, there are needs for improvement. The following charts outline the current system and the requirements to be outlined for system improvements.

Figure 9. Environmental Monitoring System (as of 2015)

No	Province	Air pollution	Water Pollution			Soil Pollution
			Surface water	Underground water	Coastal water	
A	Northern Vietnam					
1	Quảng Ninh	41 observed sites	64 observed sites			
2	Hải Phòng	9 observed sites for ambient air at the frequency of 6 times per year	22 observed sites at the frequency of 4 times per year	11 observed sites at the frequency of 2 times per year	4 observed sites at the frequency of 4 times per year	10 observed sites at the frequency of 2 times per year
3	Thái Bình					
4	Nam Định					
5	Ninh Bình					
C	Central Vietnam					
6	Thanh Hóa					
7	Nghệ An	23 observed sites at the frequency of 4 times per year	43 observed sites at the frequency of 4 times per year	13 observed sites at the frequency of 4 times per year	14 observed sites at the frequency of 4 times per year	
8	Hà Tĩnh	30 observed sites in Vung Ang and Cau Treo economic zones and 40 other observed sites at the frequency of 4 times per year	25 observed sites in Vung Ang and Cau Treo economic zones and 46 other observed sites at the frequency of 4 times per year	20 observed sites in Vung Ang and Cau Treo economic zones and other 36 observed sites at the frequency of 4 times per year	4 observed sites in Vung Ang and Cau Treo economic zones and other 13 observed sites at the frequency of 4 times per year	20 observed sites at the frequency of 4 times per year
9	Quảng Bình					
10	Quảng Trị					

No	Province	Air pollution	Water Pollution			Soil Pollution
			Surface water	Underground water	Coastal water	
11	Thừa Thiên Huế	15 observed sites at the frequency of 4 times per year	48 observed sites at the frequency of 4 times per year	20 observed sites at the frequency of 4 times per year		
12	Đà Nẵng					
13	Quảng Nam					
14	Quảng Ngãi					
15	Bình Định	92 observed sites	130 observed sites	126 observed sites		62 observed sites
16	Phú Yên	38 observed sites for ambient air at the frequency of 6 times per year	32 observed sites at the frequency of 6 times per year	21 observed sites at the frequency of 6 times per year	20 observed sites at the frequency of 6 times per year	18 observed sites at the frequency of 6 times per year
17	Khánh Hòa	15 observed sites at the frequency of 12 times per year	19 observed sites at the frequency of 12 times per year			
18	Ninh Thuận	74 observed sites at the frequency of 12 times per year	58 observed sites at the frequency of 4 times per year	73 observed sites at the frequency of 2 times per year	28 observed sites at the frequency of 4 times per year	30 observed sites at the frequency of once per year
19	Bình Thuận	45 observed sites at the frequency of 6 times per year	34 observed sites at the frequency of 4 times per year (including 10 observed sites of La Ngà river at the frequency of 8 times per year)	29 observed sites at the frequency of 4 times per year	14 observed sites at the frequency of 4 times per year	26 observed sites at the frequency of once per year
C	Southern Vietnam and Mekong region					
20	Bà Rịa Vũng Tàu					
21	Hochiminh City					
22	Tiền Giang					
23	Bến Tre					
24	Trà Vinh					
25	Sóc Trăng					

No	Province	Air pollution	Water Pollution			Soil Pollution
			Surface water	Underground water	Coastal water	
26	Bạc Liêu					
27	Cá Mau	5observed sites at the frequency of 4 times per year	51 observed sites at the frequency of 4 times per year	38 observed sites at the frequency of 4 times per year	11 observed sites at the frequency of 4 times per year	9 observed sites at the frequency of once per year
28	Kiên Giang					

Sources for Figure 9: Compilation from the interviews made during the meetings organized by the investigation team and the available reports collected during site visits and other open sources of internet

Figure 10. Requirements for Organized Governmental Response to Unplanned Releases

	Factor	Comment	Vietnam Agency With Responsibility	Current Status
1	Public concern and desire to address unplanned releases	Without a general public concern about unplanned releases and a desire to address them, no system will be effective - people and industry would not report releases, and there would be opposition to the costs and disruptions resulting from releases response.		
2	Government authority	Government must have clear authority to require reporting, response to and remediation of releases. This may include authority for cost recovery from parties responsible for releases.		
3	Clear regulatory definitions of regulated unplanned releases	Clear definitions of what is and is not and unplanned release are essential to establish the scope of regulations and control, and to allow planning for the level of resources required. Not every drop of anything spilled can be included else the program becomes unworkable and ignored, so definitions and thresholds are critical.		
4	Unplanned release risk evaluation	Evaluation must be done of the types, levels and geographic dispersion of unplanned release risks likely present in the jurisdiction of concern. This is essential to determine organizational and funding needs for the items further down this list. Types of releases and impacts are listed on the "Types of Releases" table.		
5	Government funding	Funding of response reporting and remediation must be adequate. Level of funding is the best indicator of government priority on this issue. Funding must include both regular funding for the items further below on this list, and ability to obtain emergency funding to address large incidents.		
6	Public education	Public education is essential regarding what is a regulated unplanned release, why these are of concern, how to report, etc. This notably includes targeted education of likely sectors responsible for releases, such as petroleum and chemical industries, transport companies (truck, rail and water), mining companies, and pesticide application firms.		

7	Government organization - release observation, notification and reporting systems	Clear systems to detect and report releases are essential - by whom, to whom, how fast after a release occurs or is found, what information is desire, etc. A central body to receive and then act on the information is necessary. A network or organization of inspectors looking for unplanned releases is important for the detection and reporting of releases. These inspectors can be government environment agency personnel, or can (more cost-effectively) incorporate local government agents, non-government organizations, public utility workers and others as appropriate, providing training and coordination is provided. In addition, voluntary reporting by (non-network) citizens, NGO's, local government representatives or companies is also important.		
8	Environmental Monitoring Systems	A network of monitoring systems is important to detect unplanned releases or their environmental impact. Typically, for rivers and seas, this means monitoring stations at key locations that are continuously or periodically sampled for key environmental indicator parameters such as pH, suspended solids, COD, oils, VOCs, coliform, metals, chlorophyll (an indicator of algae blooms), etc. Monitoring is important both to augment release observation and reporting by the "network" discussed above (which relies to some extent on having the right people at the right place to observe a problem), and to understand what are "normal" conditions versus conditions that may indicate an unplanned release.		
9	Laboratories	High quality laboratories are needed to analyze both routine and one-off environmental samples - notably water samples but also soil and air samples. Capability to do forensic analysis is important, such as gas or liquid chromatography coupled with mass spectrometry is important, especially for forensic analysis of suspected organic chemical releases. Biological analysis capability can also be important, such as for forensic tissue analysis to determine what is impacting fish, birds or marine life.		
9	Government organization - command structures and responsibility clarification	Need a structure in the government to decide on actions necessary in response to a release, then manage necessary communications and response actions. Actions include both remediation measures and measures to protect the public and the environment such as evacuations, alternate water supply provision, fishing prohibitions, etc.		
10	Government organization - communication methods and capability	Methods to communicate concerns and response measures to the public are essential. This includes effective communication of public protection measures, responses to press or public questions, call out or commandeering of response capabilities, coordination with medical establishments, etc.		
11	Command and communication training	Trained commanders for release response are needed, of adequate number and geographic dispersion to meet likely needs. Commanders need to be able to make strategic decisions about response strategies, resource needs, communication needs. They also must handle public, private sector and the government interactions typically involved in a release response. This is a notably different skill set than actual response work.		

12	Responder organizations	Need to have a corps of trained responders of adequate number and geographic dispersion to handle likely releases. Training must factor in the various types of releases, response measures and technologies likely to be needed. Response organization may be in government or in private organizations.		
13	Responder training	The corps of trained responders needs high quality training programs, including regular refresher training.		
14	Supplies and equipment	Need to have adequate supplies and equipment to respond to likely releases, of types and quantities likely to be needed in view of release risks, and strategically placed to be available when needed, and maintained in good condition		
15	Government organization - monitoring, follow up and post-remediation action management	An organization and system to follow up on release responses in necessary. This includes evaluation to assure the response was effective and complete; sharing learning from responses and incorporating them in future plans and resources; putting in place and managing any long term environmental monitoring needed; following up with and if appropriate reimbursing people impacted by releases; and following up on any legal actions or cost recovery actions resulting from the release.		

Capacity Building Needs

28 The results from the surveys and interviews will inform the recommendations for the government and the design of the Capacity Building Workshop to include relevant training topics. The interviews provided an overview of the types of officials to be trained and the technical capacity in each province. This information will be used to develop a capacity building workshop, assemble reference materials, refer national and local officials to appropriate organizations to address specific needs after this project or on an ongoing basis, organize a study tour, and will be included in the recommendations to the government in the final report.

Target Audiences

29 Due to the large number of people involved in environmental management and oversight at the national and local levels, it is recommended that the capacity building workshop be held for a limited audience who will then be training others. Also all sessions will be recorded and materials will be shared widely to allow distribution to a wider audience. The overall target audience includes:

- Relevant officials working at central authorities (about 150-200 people)

  + Group 1A: leadership at central level

+ Group 1B: managers (decision makers) at implementing level

+ Group 1C: technicians and specialists

- Relevant officials working at provincial authorities (about 300 officials of 28 EPAs, 100 officials of 28 PASIs and 200-250 specialists of 28 PCEMs)

  + Group 2A: leadership at local levels

  + Group 2B: managers (decision makers) at implementing level at EPAs and PASIs

  + Group 2C: technicians and specialists working at PCEMs and Provincial Authorities of industrial zone management

- The relevant staff (about 800-900 people) working at management boards of industrial zones and industrial clusters in 28 provinces (totally 304 industrial zones and 461 industrial clusters have currently been operated in 28 coastal provinces)

  + Group 3A: The owners of enterprises

  + Group 3B: Industrial zone developers and investors

  + Group 3C: Environmental officers of the enterprises

Skills and Technical Knowledge Gaps

30 To address skills and technical knowledge gaps, the project will conduct capacity building in the form of workshops, reference materials, a study tour, and referrals to other organizations to provide ongoing support or specialized training and services. Based on the initial needs assessment after the interviews, the following training topics are being considered for the Capacity Building Workshop:

- Forensic assessment
- Environmental monitoring of sediments, soil, water, and biota
- Modelling and mapping for planning and risk evaluation
- Emergency response and prevention protocols
- Clean-up and remediation options
- Incident Command, Control, and Communication
- Best Practices in environmental management policy

- Evaluating laboratory capacity for analysis

Figure 11. Training Needs (to be finalized with government)

No	Required knowledge/skills	Type of training	Target Groups
	Environmental risk evaluation and management		
	Awareness raising and risk communication		
	Environmental Monitoring		
	Incident Command, Control, and Communication		
	Clean-up and Remediation Options		
	Forensic Assessment		
	Modelling and Mapping for Planning and Risk Evaluation		
	Emergency Response and Prevention Protocols		

Next Steps

31 The next steps of the project are as follows:

- Presentation of Survey Report
- Capacity Building Workshop
- Study Tour
- Presentation of Final Report and Recommendations

32 This Preliminary Survey Report was submitted to MoNRE and other stakeholders in March 2017 and will be distributed at the upcoming meeting with stakeholders in May 2017. Responses of stakeholders will be taken into consideration in the final report of the project. Further comments or questions should be addressed by email to Madame To Thi Duong (to.duong@cecod.org.vn)and Lara Crampe (Lara@PureEarth.org).

TECHNICAL SUPPORT REQUESTS

Results from Training Seminar on Water and Marine Pollution

Danang, Vietnam March 4-9 2018

Foreword

This report summarizes the requests of Vietnamese governmental leaders from 26 provinces who attended a capacity building workshop series in Danang, Vietnam March 4-9, 2018 focused on water and marine pollution. Participants attended the multi-day training as a part of the USAID-funded project, “Reducing the Threat of Toxic Chemical Pollution to Human Health in Low and Middle-Income Countries.” The Vietnam Ministry of Natural Resources and Environment, USAID, and Pure Earth organized the training around recommendations derived from a preliminary needs assessment survey conducted among 32 provincial and central government authorities in December 2016. The aim of the training series was to share national and foreign experiences in preventing and managing water-related pollutants and to outline technical support and training gaps in the current infrastructure to improve the government’s capacity for detection, reporting, and responding to unplanned releases that threaten public health or the environment, with a particular focus on river and marine ecosystems.

The government of Vietnam is concerned about protecting water quality and has enacted environmental projection activities focused on preventing negative impacts of industry on health and the environment, particularly in coastal areas and along waterways. Of the 64 provinces in Vietnam, 28 are coastal and industry in these coastal provinces has increased steadily year over year now accounting for about half of the industrial output of the entire country. The majority of the industrial clusters operating in coastal provinces are small- and medium-scale, low-technology operations making oversight more complicated.

The main water pollution concerns among government officials according to the needs assessment are:

- Mining and Mineral Processing run-off and sludge
- Agricultural run-off including pesticides
- Textile/garment factories and dye industries
- Oil spillage/petrochemical waste
- Chemicals/pharmaceutical/rubber/plastics manufacture
- Metal smelting, steel, and metallurgy waste
- Sewage and domestic wastewater
- Food processing and manufacture particularly seafood processing

The key technical and infrastructure gaps identified by government officials indicated that Institutional arrangements for monitoring marine environment pollution are complex and while there are specific inspection and monitoring activities required under current legislation, there are at least twelve different oversight bodies responsible for the activities that must be coordinated and whose activities must be standardized so that data remains comparable. Additionally, the human resources capacity and technical skills within each province vary widely and no central training mechanism exists for the more than 750 people employed at the central and provincial authorities and the additional 800 people working within the industrial zones.

The participants in the workshop recognized and reiterated the need to develop and maintain a shared responsibility for oversight, response, and planning to protect human and environmental health from pollution, particularly in water. Participants indicated that a desired first step in taking concrete action towards that shared responsibility is to address the specific requested technical support and recommended future activities indicated in the document below. For ease of assigning future activities, the requests are color-coded into Requested Governmental Action (Blue), Resources/Tools/Consulting Requested (Orange), and Trainings Requested (Green) and further divided into 5 categories: Overall Management, Preparedness, Emergency Response, Recovery, and Province-Specific Requests. It is recommended that USAID and MONRE/VEA discuss these needs and appropriate technical support providers given available budgets.

Summary of Requests

1. Governance and Management

Participants highlighted 4 key needs in governance and management of water pollution: A National Plan (or several master plans), Policy review, Zoning, and Development Planning that seriously includes environmental considerations, Each of these are Requested Governmental Actions:

- A national-level mechanism with a clearly defined leader responsible for ensuring cooperation, efficiency, and coordinated mobilization of existing equipment, human resources and experts between various localities/provinces
  - Development of robust master plans for marine biodiversity protection and the management of wastes generated from agriculture and aquaculture
- Review and potential revision of current legislation on the control, preparedness and response to environmental accidents and emergencies to clarify responsibilities and procedures
- A recognition of the balancing act between the economic development and environmental protection through:
  - Zoning use of water bodies, land, and natural resources based on environmental sensitivity and protection of people's health and livelihoods
  - Evaluating environmental impacts of socio-economic development plans at provincial and regional levels and potential revising development plans; Development Planning

2. Prevention and Preparedness

Concerns related to prevention and preparedness centered around specific training needs, guideline requests, and tools or data needed for effective planning.

- Trainings Requested:
  - Identifying warning signs of water pollution for non-technical people
  - Disaster Risk Reduction at community and commune level
  - Available emergency response equipment and how to use it

  - Pollution control for industrial wastewater, sewerage, aquaculture, and thermo-power plants
  - Real-world simulation exercises – pollution prevention and oversight
  - Evaluating risks of various industries and reviewing companies' emergency response plans for compliance
  - How to monitor and manage risks of various industries
  - Policy dialogues and reviews for stakeholder coordination (not just environmental authorities) on risks, preparedness, and current legislation
- Governmental Action Requested: Clarification of guidelines for preparing and appraising provincial environmental accident preparedness plans as required by article 108 of Law on Environment Protection (2014) and official letter No.5183/BTNMT-TCMT dated on 2nd October 2017 (MONRE and VEA)
- Resources/Tools/Consulting Requested:
  - Automatic environmental monitoring systems
  - Remote sensing, GIS, Rada HF, etc for risk mapping
  - Oil/Chemical contingency planning by province
  - Environmental sensitivity mapping by province

3. Emergency Response

Emergency Response needs were as follows:

- Governmental Action Requested:
  - Decree No.30/2017/ND-CP provides regulations on response to natural disaster emergencies and the operation of search and rescue activities, every province shall have to prepare/issue the provincial plan on response to natural disaster emergencies and the operation of search and rescue activities. It is recommended that related authorities at central government (MoNRE and MoIT) should also provide detailed guidelines for the preparation of provincial plan for response to environmental emergencies caused from oil/chemical spills, unexpected release, etc
  - Clarify list of chemicals/materials allowable/prohibited to use for environmental emergency response

  - Clear definitions needed for evaluation and estimation of economic loss caused from environmental accidents in order to claim compensation

- Resources/Tools/Consulting Requested:
  - A database on organizations (both research institutions and service providers) for environmental accident control/preparedness, environmental emergency response and environmental rehabilitation accessible for the authorities at all levels (from central to grass-root levels) in order to get proper supports quickly during an emergency.
  - Members of the Appraisal Council for approval of oil spill response should be regularly trained and aware of current oil spill risks in particular localities
  - Technical guidelines needed on risk assessment, environmental emergency response procedures, oil/chemical spill control/response and evaluation of environmental damages caused from oil/chemical spills
- Trainings Requested:
  - Crisis communication training needed (for media and public as well as internally), in order to minimize the negative impacts and properly respond to emergencies
  - Emergency response and environmental rehabilitation of rich biodiversity areas affected by unexpected release cases

4. Recovery

Requests for support in the recovery and remediation of pollution were:

- Governmental Action Requested:
  - Technical Guidelines on oil/chemical spill remediation, oil/chemical spill impact assessment, restoration of the environment in the areas affected by oil/chemical spill accidents, use of dispersants, claim of oil/chemical spill compensation, designation of responsibilities among relevant stakeholders for the response to oil/chemical spill accidents; etc…

- Guidelines on treatment of oil/chemical wastes and the wastes collected after the oil/chemical spill accidents,
- Guidelines on dealing with oil/chemical spills from unknown sources
- Guidelines on Risk assessment of oil/chemical spills
- Guidelines on Evaluation of long- and short-term environmental damage and related economic loss caused from marine release accidents to serve for preparation of legal evidence in order to claim for compensation

- Resources/Tools/Consulting Requested: Environmental restoration/rehabilitation plans needed for the areas already affected by oil/chemical spills
- Trainings Requested:
  - the rehabilitation of mangrove forests, protected forests and biodiversity protected areas affected by pollution
  - low cost solutions for soil remediation

5. Specific Requests for Funding or Assistance

Finally, two provinces made direct requests for Resources/Tools/Consulting including:

- Thanh Hoa: Requested technical and financial support to establish and operate a marine environmental monitoring network for the prevention and management of marine environmental pollution and accidents
- Ben Tre: Requested financial and technical support to conduct thorough investigations of marine and coastal pollution in the province's 4 river estuaries downstream of the Mekong seafood processing areas and salinity intrusion and erosion along the coastline and propose a comprehensive plan with solutions and measures to control pollution, prepare for environmental emergencies, and manage delicate coastal ecology systems.

Recommended Next Steps

1. Distribution of Workshop Materials and Video - (Pure Earth/CECoD Deadline May 15)
2. Report review and comments - (All Stakeholders, Deadline May 31)
3. Assigning responsibilities and desired deadlines (for discussion, USAID and MONRE/VEA)

Annex A: Requests for Capacity Building by Office and Province

Organization	Proposed issues
VASI of MoNRE	1) Training needs for capacity building in the topics bellows: - Preparation of the legal documents and/or technical guidelines on the issues such as oil/chemical spill remediation, oil/chemical spill impact assessment, restoration of the environment in the areas affected by oil/chemical spill accidents, use of dispersant, claim of oil/chemical spill compensation, designation of responsibilities among relevant stakeholders for the response to oil/chemical spill accidents; etc… - Treatment of oil/chemical wastes and the wastes collected after the oil/chemical spill accidents, - Detection and dealing with oil/chemical spills from unknown sources - Risk assessment of oil/chemical spills - Development environmental restoration/rehabilitation plans for the areas affected by oil/chemical spills - Development of oil/chemical contingency plans - Development of environmental sensitivity maps 1) Develop and implement researches and studies regarding the issues mentioned above 2) Organize study tours to learn the experiences from developed countries regarding marine emergency response and related issues
Ca Mau DoNRE	3) It is urgent need to have detailed guidelines for the following issues: - MoNRE and VEA provide detailed guidelines on the preparation of provincial plan on environmental accident preparedness, control and response as required by article 108 of Law on Environment Protection (2014) and official letter No.5183/BTNMT-TCMT dated on 2nd October 2017. - As required by the Decree No.30/2017/ND-CP providing regulations on response to natural disaster emergencies and the operation of search and

Organization	Proposed issues
	rescue activities, every province shall have to prepare/issue the provincial plan on response to natural disaster emergencies and the operation of search and rescue activities. It is recommended that related authorities at central government (MoNRE and MoIT) should also provide detailed guidelines for the preparation of provincial plan for response to environmental emergencies caused from oil/chemical spills, unexpected release, etc… - List of chemicals/materials allowable/prohibited to use for environmental emergency response - Evaluation of environmental loss/damages caused from environmental accidents 4) It is needed to have a database on organizations (both research institutions and service providers) specialized on environmental accident control/preparedness, environmental emergency response and environmental rehabilitation accessible for the authorities at all levels (from central to grass-root levels) in order to get proper supports at quickest basis during the environmental emergency cases. 5) Knowledge and experiences on the rehabilitation of mangrove forest, protected forest and biodiversity protected areas affected by oil/chemical spills 6) Share more information/experiences on low cost solutions for soil remediation implemented by Pure Earth and how to apply in the localities of Vietnam, especially how to deal with the continuous release of hazardous substances into soil environment. Whether the solutions proposed by Pure Earth sustainable enough for application in any soil pollution area.
Tien Giang DoNRE	7) It is proposed to provide trainings for the communities living around pollution sources to develop their capacity on the identifying water pollution signs for; trainings to provide relevant stakeholders with the skills to response to environmental emergency and how to use available equipment for environmental emergency response, etc… 8) Central authorities should provide guidelines on the appraisal of

Organization	Proposed issues
	environmental accident control, preparedness and response procedures/plans prepared by various stakeholders and provide trainings to local authorities with the skills on review and appraisal of those procedures/plans
Bac Lieu DoNRE	9) Trainings on marine release control and response should also be provided to the environmental authorities at district and relevant personnel at commune level and communities living in the areas vulnerable to marine environmental emergency, especially the community capacity to protect their health, assets and livelihoods in emergency cases. It will be good if USAID can provide the training of trainers to the officers working for provincial authorities, then the trained staff can deliver the training to district and commune authorities and the communities. Trainings should be regularly organized and should be compulsory for some specific positions/authorities.
Tra Vinh DoNRE	10) Strengthen both institutional and technical capacity on the management of pollution sources such as industrial wastewater, sewerage systems, aquaculture activities, wastes from thermo power plants for all relevant stakeholders at provincial and local levels; 11) The members of the appraisal council for approval of oil spill response should be regularly trained in order to be updated with advanced knowledge and actual situation of pollution and environmental risks caused from oil spills in the localities 12) Provide automatic environment monitoring systems in order to control the unexpected marine releases 13) Provide technical support to conduct necessary investigations and studies for the evaluation of environmental impacts caused from socio-economic development plans of the province in order to identify the province development priorities and to revise/adjust the province development guidelines
Soc Trang DoNRE	14) It is needed to have regular trainings on appraisal of environmental accident control plans, environmental emergency response plans prepared enterprises/organizations; on environmental monitoring both for control of environmental accidents and for evaluation of environmental damages caused from environmental accidents 15) Provide monitoring equipment and equipment for emergency

Organization	Proposed issues
	response
Ben Tre DoNRE	16) This training provides many very useful information and knowledge that we can apply in our works at local level. This training should be provided on regular basis with simulation exercises on marine environment emergency response. Besides, the trainings with simulation exercise on environmental accident preparedness, control and emergency response should be also designed to provide to the enterprises operating the productions lines with high risks of chemical spills/leakage 17) Ben Tre province locates in the downstream of Mekong river with 4 river estuaries (namely Cua Dai, Cua Ba Lai, Cua Ham Luong and Cua Co Chieu). Therefore, Ben Tre is at risk of being polluted both by the pollution sources locating in upstream areas and the pollution caused from sea food industries highly concentrated within the region of Mekong delta. It is proposed that MoNRE and USAID (or any donor) can provide financial and technical supports for Ben Tre to conduct thorough investigation for the evaluation of marine and coastal pollution level of Ben Tren province and propose comprehensive plan with solutions and measures to control marine environment pollution, to prepare for marine environmental emergency cases, etc… 18) In addition, Ben Tre province with the total length of 65km of coastal line is now facing with serious salinity intrusion and erosion which threaten the marine and coastal ecology systems. We therefore requested to have both technical and financial supports for Ben Tre province to deal with those problems.
Ba Ria Vung Tau DONRE	19) Application of high (advanced) technologies such as remote sensing, GIS, Rada HF, etc… in the management of marine environment 20) Evaluation of both long-term and short-term environmental damage and related economic loss caused from marine release accidents to serve for preparation of proof of facts and legal evidences in order to claim for compensation 21) Balancing between the economic development and environmental

Organization	Proposed issues
	protection in terms of use/exploitation of water surface/bodies, land use and natural resources based on the zoning of water regions according to the environmental sensitivity to serve for socio-economic development and environmental management 22) Capacity building and awareness rising for leadership through study tours to learn the lessons from developed countries
Binh Dinh DoNRE	23) Provide trainings and research projects in order to strengthen the local capacity on preparedness, control and response to environmental accidents (both natural and man-made) 24) Transfer the experiences and lessons relating to the establishment and the operation of local environmental emergency response teams
Ninh Thuan DoNRE	25) The trainings similar this training should be provided regularly for various target groups of local authorities in order to update them with new knowledge, experiences and situations regarding the marine environmental risks, new technologies applied for marine environmental accident control and response, etc… 26) Develop technical guidelines on risk assessment, environmental emergency response procedures, oil/chemical spill control/response and evaluation of environmental damages caused from oil/chemical spills 27) Establish a network connecting the relevant specialists, scientists, companies and authorities to share the experiences and knowledge on the issues related to marine environment, marine release accident risks, etc…
Thua Thien Hue DoNRE	28) Trainings on the topics shared in this workshop should be provided regularly. It is proposed to have more in-depth training focusing on each and every issue such as risk evaluation, evaluation of environmental damages caused from unexpected releases, monitoring for risk control, how to communicate with the publics in environmental emergency case, etc… 29) Besides the in-depth trainings, one day policy dialogs and/or workshops should also be organized to involve all stakeholders (not only the environmental authorities) in the process of policy making, legislation

Organization	Proposed issues
	revision/updating to strengthen both the institutional and technical capacity of environmental emergency response, the control of environmental accidents
Quang Binh DoNRE	30) Capacity building activities should focus on chemical/wastewater release into coastal and marine environment; environmental emergency response and environmental rehabilitation of rich biodiversity areas affected by unexpected release cases
Thanh Hoa DoNRE	31) Provide technical and financial supports for Thanh Hoa province to establish and operate marine environmental monitoring network for the control of marine environmental pollution and accidents; 32) Providing trainings for the specialist and the staff involving in the process of appraisal of the plans of oil spill responses prepared by the companies/facilities owners 33) Providing trainings with simulation exercises for the relevant personnel of the companies/facilities on environmental emergency response and accident control (with the focus on oil spill and chemical spill/leakage).
Ninh Binh DoNRE	34) Communications for awareness raising should be provided in order to build the capacity on marine release control, environmental emergency response among relevant stakeholders (authorities, companies and communities) 35) Technical capacity should be strengthened among key authorities (environmental management, industry management, agriculture, etc…) through trainings, provision of equipment, 36) Infrastructure should be improved in order to facilitate and be ready for environmental emergency responses
Nam Dinh DoNRE	37) It is need to develop/operate a national mechanism/system for information sharing, cooperation, co-ordination among relevant authorities and stakeholders of all levels in environmental emergency response and environmental rehabilitation after environmental accidents. This system should also allow the mobilization/sharing of existing equipment, human resources and experts for environmental emergency responses between various localities/provinces 38) It is necessary to appoint a specific leader who will be responsible

Organization	Proposed issues
	and lead the deployment of necessary measures/acts in case of environmental emergency to avoid the overlapping of and the gap of the tasks assigned to various authorities
Thai Binh DoNRE	39) Legislation on the control, preparedness and response to environmental accidents and emergencies should be reviewed and revised in order to strengthen the institutional capacity on environmental emergency response; 40) Technical capacity of relevant stakeholders (companies, communities, service providers and authorities) should be strengthened through the investment in equipment and infrastructure required for pollution control, environmental accident control and environmental emergency response. Fund raising for that investment should be diversified in order to mobilize the contributions from various sources (e.g. international donors, private sector and State budget) 41) Provide guidelines and technical assistance to provinces for the development of provincial plans oil spill response 42) Strengthening capacity on development of marine biodiversity protection master plan/planning; master plan on the management of the wastes generated from agriculture and aquaculture sources
Quang Ninh DoNRE	43) Defining, evaluation and estimation of economic loss caused from environmental accidents in order to claim for compensation 44) How to deal with communication crisis during environmental emergency case (how to response to the media and the public, how to communicate/announce the emergency case, etc… in order to minimize the impacts and properly response to the emergency situation)
Hai Phong DoNRE	45) A mechanism for co-ordination of the acts and operations of necessary measures for environmental emergency response should be developed in order to increase the efficiency of response acts. Guidelines on who should be mobilized and how to act in various types of environmental emergency cases should be developed and circulated among various authorities at all levels to be well prepared for environmental emergency case. 46) Trainings (especially simulation exercises) should be provided regularly in order to enhance the skills of relevant stakeholders (authorities, enterprises and the communities at high risks)

Annex L – Vietnam Workshop Survey

Participant Code	Q 2					Q3					Q4					Q5					Q6					Q7				
	I have a firm understanding of the types of industries that could release pollutants into water environments					I can confidently identify potential toxin sources, pathways, and receptors at a release site.					I learned a lot of new and useful information during the training program.					There was a high degree of participation and involvement during the training program.					The program was well structured and sufficient time was allocated for both the presentations and participant discussions					Overall I feel the program was of great interest to all trainees.				
	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree																									
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
MS1		1						1			1						1					1					1			
MS2	1					1						1				1						1					1			
MS3		1				1						1					1				1					1				
MS4	1					1						1				1							1				1			
MS5	1					1						1				1							1				1			
MS6		1					1					1					1				1					1				
MS7		1				1					1						1					1					1			
MS8		1					1					1					1						1				1			
MS9		1					1					1					1					1						1		
MS10		1						1			1							1					1				1			
MS11		1						1				1						1			1						1			
MS12		1					1					1					1					1					1			
MS13		1						1				1					1					1					1			
MS14		1						1				1					1					1					1			
MS15		1						1				1					1					1					1			
MS16		1					1				1					1					1					1				
MS17		1					1					1					1					1					1			
MS18		1					1					1					1					1					1			
MS19		1					1					1					1					1					1			
MS20	1					1					1						1					1					1			
MS21		1					1					1					1					1					1			
MS22	1						1					1					1					1					1			
MS23		1						1					1					1				1					1			
MS24			1					1					1				1						1					1		
MS25		1					1					1					1					1					1			
MS26		1					1				1						1				1						1			
MS27		1						1			1						1				1					1				
MS28		1						1			1						1						1				1			
MS29	1					1					1						1				1						1			
MS30		1				1					1						1				1					1				
MS31		1						1				1						1				1					1			
MS32		1					1					1					1					1					1			
MS33		1					1					1					1						1				1			
MS34			1				1					1					1						1				1			
MS35		1					1						1				1						1			1				
MS36		1					1						1				1						1			1				
MS37			1					1				1						1					1					1		
MS38		1					1				1						1													
MS39			1				1						1				1					1					1			
MS40		1						1				1					1					1					1			
MS41		1					1					1					1						1				1			
MS42		1						1				1					1					1					1			
MS43		1					1						1				1						1				1			
MS44		1						1				1					1					1					1			
MS45		1					1					1					1						1				1			
MS46		1					1						1				1					1					1			
MS47		1					1						1				1						1				1			
MS48		1					1						1				1						1				1			
MS49			1				1					1						1					1				1			
MS50		1						1				1						1					1				1			
MS51		1					1						1				1						1				1			
MS52			1					1					1				1						1				1			
MS53	1							1				1					1						1				1			
MS54		1						1				1					1					1					1			
MS55		1					1				1						1				1						1			
MS56		1					1				1					1					1					1				
MS57	1						1				1					1					1					1				

MS58	1						1					1				1						1					1			
MS59			1					1				1				1					1						1			
MS60		1					1					1					1						1				1			
MS61			1					1				1				1						1					1			
MS62	1							1				1				1					1					1				
MS63			1					1				1				1					1					1				
MS64		1						1				1				1					1						1			
MS65		1					1				1					1					1					1				
MS66			1					1				1					1					1					1			
MS67		1					1					1				1						1					1			
MS68		1					1					1					1					1					1			
MS69		1					1					1					1					1					1			
MS70			1				1					1					1						1				1			
MS71		1						1					1				1					1					1			
MS72		1						1					1				1					1						1		
MS73			1					1					1				1					1					1			
MS74		1					1					1					1					1					1			
MS75		1					1				1					1						1					1			
MS76		1					1						1				1						1				1			
MS77		1					1					1					1						1				1			
MS78		1					1					1					1				1						1			
MS79			1					1				1					1					1					1			
MS80		1					1						1					1				1					1			
MS81		1					1					1					1					1					1			
MS82		1						1			1							1			1					1				
MS83		1					1					1					1					1					1			
	I have a firm understanding of the types of industries that could release pollutants into water environments					**I can confidently identify potential toxin sources, pathways, and receptors at a release site.**					**I learned a lot of new and useful information during the training program.**					**There was a high degree of participation and involvement during the training program.**					**The program was well structured and sufficient time was allocated for both the presentations and participant discussions**					**Overall I feel the program was of great interest to all trainees.**				
	10	**60**	**13**	**0**	**0**	**8**	**45**	**30**	**0**	**0**	**17**	**50**	**16**	**0**	**0**	**15**	**59**	**9**	**0**	**0**	**18**	**39**	**25**	**0**	**0**	**13**	**65**	**4**	**0**	**0**
	12	72	16	0	0	10	54	36	0	0	20	60	19	0	0	18	71	11	0	0	22	47	30	0	0	16	78	5	0	0

	Q8					**Q9**					**Q10**					**Q11**					**Q12**					**Q13**					**Q14**				
Participant Code	**Overall the program met my expectations for content and material shared.**					**The training materials provided were thorough and easy to follow.**					**The program was well managed and the venue was comfortable**					**The program was relevant to my professional**					**I feel this training was helpful in updating my skills.**					**I feel prepared to improve my or my department's response to future unplanned releases in water environments.**					**The length of the training was appropriate.**				
	A	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
MS1		1				1					1							1			1						1				1				
MS2		1					1					1				1						1						1				1			
MS3		1					1					1					1					1				1						1			
MS4	1					1					1						1					1						1				1			
MS5			1				1				1						1					1						1					1		
MS6		1					1				1						1				1						1				1				
MS7		1					1					1					1					1					1					1			
MS8			1					1				1					1					1										1			
MS9	1					1							1				1					1					1						1		
MS10		1						1			1					1					1					1						1			
MS11		1					1				1					1						1					1					1			
MS12		1				1					1					1					1					1						1			
MS13		1					1					1					1					1					1					1			
MS14		1					1					1					1					1					1					1			
MS15		1					1					1					1					1					1					1			
MS16	1					1					1					1					1					1					1				
MS17		1					1				1						1					1					1					1			
MS18		1				1					1						1					1						1					1		
MS19		1					1				1						1					1					1						1		
MS20	1					1					1					1					1					1					1				
MS21		1					1				1					1						1					1				1				

MS22		1				1					1					1					1					1					1				
MS23		1				1					1						1					1					1				1				
MS24			1				1				1						1					1					1					1			
MS25		1					1					1					1					1					1				1				
MS26		1				1					1						1					1					1				1				
MS27		1					1				1					1						1					1					1			
MS28			1					1			1						1				1						1				1				
MS29		1				1					1					1					1					1						1			
MS30		1					1					1					1					1					1					1			
MS31			1					1			1					1					1					1					1				
MS32		1					1				1						1					1					1					1			
MS33		1						1				1					1					1						1				1			
MS34			1					1			1					1					1						1					1			
MS35			1					1				1						1				1					1						1		
MS36			1					1				1						1				1					1						1		
MS37			1					1			1							1					1					1				1			
MS38																																			
MS39		1					1						1				1					1						1				1			
MS40		1					1					1					1					1					1					1			
MS41			1				1					1						1					1					1				1			
MS42		1					1					1					1					1					1					1			
MS43		1						1					1				1					1					1						1		
MS44		1					1					1				1						1					1					1			
MS45		1					1						1				1					1					1					1			
MS46			1					1				1					1						1				1					1			
MS47			1					1				1						1					1				1					1			
MS48			1					1				1					1						1				1					1			
MS49			1					1					1					1					1					1					1		
MS50		1						1				1					1				1						1					1			
MS51		1						1				1				1					1							1					1		
MS52		1						1				1					1					1					1					1			
MS53		1					1					1					1				1							1				1			
MS54		1					1					1					1				1							1				1			
MS55	1						1				1							1				1					1					1			
MS56		1				1					1					1					1					1									
MS57		1					1				1					1					1					1					1				
MS58		1					1				1					1					1						1				1				
MS59	1					1					1											1					1					1			
MS60		1					1					1					1					1					1					1			
MS61		1						1				1				1					1					1						1			
MS62		1					1				1					1						1				1					1				
MS63	1					1					1					1					1					1					1				
MS64	1					1					1						1				1							1			1				
MS65	1					1						1				1					1					1						1			
MS66		1					1						1				1					1					1					1			
MS67		1					1					1					1					1				1						1			
MS68		1					1					1					1					1					1					1			
MS69		1					1					1					1					1					1					1			
MS70		1						1			1						1					1				1					1				
MS71		1					1				1					1						1						1				1			
MS72		1					1				1					1						1						1				1			
MS73		1					1					1					1					1					1					1			
MS74			1					1			1						1					1						1				1			
MS75		1						1			1					1					1						1				1				
MS76		1					1				1						1						1					1					1		
MS77		1					1				1						1					1					1				1				
MS78	1						1				1					1					1						1				1				
MS79	1						1					1				1					1						1					1			
MS80		1					1					1					1					1					1					1			
MS81	1					1					1						1					1				1						1			
MS82	1							1			1					1					1						1				1				
MS83		1					1					1					1					1					1					1			

	Overall the program met my expectations for content and material shared.					**The training materials provided were thorough and easy to follow.**					**The program was well managed and the venue was comfortable**					**The program was relevant to my professional**					**I feel this training was helpful in updating my skills.**					**I feel prepared to improve my or my department's response to future unplanned releases in water environments.**					**The length of the training was appropriate.**				
	13	**54**	**15**	**0**	**0**	**17**	**43**	**22**	**0**	**0**	**42**	**34**	**6**	**0**	**0**	**27**	**46**	**8**	**0**	**0**	**26**	**49**	**7**	**0**	**0**	**17**	**47**	**17**	**0**	**0**	**21**	**50**	**10**	**0**	**0**
	16	65	18	0	0	20	52	27	0	0	51	41	7	0	0	33	55	10	0	0	31	59	8	0	0	20	57	20	0	0	25	60	12	0	0

Overall, how would you rate the training on a scale from 1-10 (10 being the best)?

Participant Code	1	200%	3	4	5	6	7	8	9	10
MS1								1		
MS2								1		
MS3								1		
MS4							1			
MS5										1
MS6									1	
MS7								1		
MS8								1		
MS9							1			
MS10								1		
MS11								1		
MS12								1		
MS13								1		
MS14								1		
MS15								1		
MS16										1
MS17									1	
MS18									1	
MS19									1	
MS20									1	
MS21									1	
MS22									1	
MS23									1	
MS24							1			
MS25									1	
MS26										1
MS27										1
MS28									1	
MS29										1
MS30									1	
MS31								1		
MS32									1	
MS33							1			
MS34							1			
MS35								1		
MS36								1		
MS37							1			
MS38								1		
MS39								1		
MS40								1		
MS41							1			
MS42									1	
MS43								1		
MS44									1	
MS45								1		
MS46							1			
MS47							1			
MS48							1			
MS49								1		

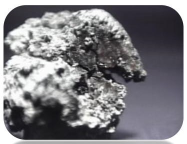
MS50								1		
MS51							1			
MS52									1	
MS53									1	
MS54									1	
MS55									1	
MS56										1
MS57									1	
MS58									1	
MS59									1	
MS60									1	
MS61										1
MS62										1
MS63									1	
MS64									1	
MS65								1		
MS66								1		
MS67									1	
MS68								1		
MS69									1	
MS70								1		
MS71								1		
MS72								1		
MS73								1		
MS74								1		
MS75									1	
MS76									1	
MS77									1	
MS78								1		
MS79									1	
MS80								1		
MS81									1	
MS82									1	
MS83								1		
Tổng	0	0	0	0	0	0	11	32	32	8
%	0	0	0	0	0	0	13.3	38.6	38.6	9.64

Annex M – Community Education Materials examples

LEAD FACT SHEET

Pagkalason sa Tingga ay Iwasan!

Ano ang Tingga?



Nakalalasong metal na hindi kailangan ng katawan

Paano napupunta ang Tingga sa katawan ng tao?

Paglanghap ng alikabok, usok, o hangin na may Tingga

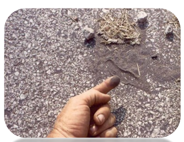
Paghawak o pagyapak sa lupa na may Tingga

Pagsubo ng kamay/ pagkain; pag-inom ng tubig na may Tingga

Saan maaaring manggaling o matagpuan ang Tingga?

Pintura

Usok mula sa planta o sigarilyo



Lupa o alikabok

Tubig, Pagkain/ Pananim, Hayop na kontaminado

Planta/ Trabaho

Laruan/ gamit pang-eskwela/

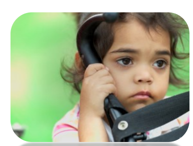
Cosmetics

Bakit masama ang Tingga sa kalusugan lalo na sa mga bata?

Pagbaba ng antas ng talino o pagkabobo

Mga problema sa pag -kilos at pag-uugali; kawalan ng *focus*

Mabagal na paglaki o pag-unlad

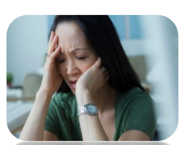


Problema sa pandinig o pagsasalita

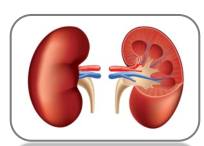
Sakit sa dugo o *Anemia*

Maaring makunan; mapaaga ang panganganak; magkaproblema sa utak ang sanggol

Panghihina ng mga kamay at paa, pamamanhid, kawalan ng koordinasyon ng paggalaw o pagkilos



Pagka-hilo, makakalimutin, kawalan ng konsentrasyon, pagiging *irritable*, pagtaas ng presyon ng dugo



Negatibong epekto sa iba pang bahagi ng katawan katulad ng bato, *reproductive* at *hematologic system*

Kahit sa mababang lebel, ang Tingga ay nakasasama pa rin sa kalusugan!

LEAD FACT SHEET

Pagkalason sa Tingga ay Iwasan!

Paano maiiwasan ang pagkalason sa Tingga?

1. Huwag Hayaang Madala ang Alikabok ng Tingga sa Loob ng Bahay

Panatilihing malinis ang bahay - maglampaso ng sahig, punasan ang mga gamit o laruan gamit ang basahan at tubig.

Huwag ipasok sa bahay ang sapatos, sandalyas at tsinelas na panlabas.

Maglagay ng basahan sa entrada ng bahay para mapanatili ang dumi sa labas.

2. Huwag Hayaang Mapunta ang Tingga sa Bibig

Laging maghugas ng mga kamay lalo na bago kumain. Siguraduhing ginagawa ito ng mga bata.

Hubarin ang kasuotan at sapatos pantrabaho at ihiwalay ang paglalaba ng mga ito.

Huwag hayaang maglaro ang mga bata sa lugar na kontaminado ng Tingga.

3. Kumain ng regular at ng masustansiyang pagkain

Iron - Karne *(lean red meat)*; atay at iba pang laman-loob, pula ng itlog, *shells*, madadahong gulay, butong gulay, at iba pa.

Vitamin C - citrus fruits, iba pang prutas tulad ng bayabas, kasuy, manga; kamatis, *bell pepper*, atbp.

Calcium - Keso, gatas, berde at madadahong gulay, butong gulay, dilis, tahong, atbp.

Ang materyal na ito ay ginawa sa ilalim ng proyektong "Pagpigil o Pagpapababa ng Lebel ng Pagkalantad sa Tingga"

National Poison Management & Control Center
University of the Philippines – Philippine General Hospital
T: 02 524-1078, 554-8400 local 2311

Pagkalason sa Tingga ay 'wag hayaan, Siguraduhing ligtas ang inyong tahanan!

- Panatilihing malinis ang inyong bahay
- Huwag gamitin ang mga baklas na bahagi ng baterya o anumang gamit o panambak sa tinggaan sa inyong bahay o bakuran
- Maligo at palitan ang damit pantrabaho bago pumasok sa bahay

Ang materyal na ito ay ginawa sa ilalim ng proyektong
"Pagpigil o Pagpapababa ng Lebel ng Pagkalantad sa Tingga"

National Poison Management & Control Center
University of the Philippines – Philippine General Hospital
T: 02 524-1078, 554-8400 local 2311

Ang materyal na ito ay ginawa sa ilalim ng proyektong
"Pagpigil o Pagpapababa ng Lebel ng Pagkalantad sa Tingga"

National Poison Management & Control Center
University of the Philippines – Philippine General Hospital
T: 02 524-1078, 554-8400 local 2311

KAPAKANAN NG INYONG ANAK AY MAPAG-IINGATAN KUNG TINGGA AY IIWASAN!

Maging mapagmatyag sa mga sintomas ng pagkalason sa Tingga. Ilan dito ay ang mga sumusunod:

- ***Pagbawas ng antas ng talino o panghihina sa klase***
- ***Problema sa pagkilos at pag-uugali; kawalan ng focus***
- ***Problema sa pandinig at pagsasalita***
- ***Mabagal na paglaki, pamumutla, at pananamlay***

Agad na sumangguni sa inyong barangay o rural health center kapag nakita ninyo ang mga sintomas na ito sa inyong anak.

Ang materyal na ito ay ginawa sa ilalim ng proyektong

"Pagpigil o Pagpapababa ng Lebel ng Pagkalantad sa Tingga"

National Poison Management & Control Center

University of the Philippines – Philippine General Hospital

T: 02 524-1078, 554-8400 local 2311

Kalusugan ay mahalaga, sa pagkalason sa tingga 'wag maging biktima!

Maging mapagmatyag sa mga sintomas ng pagkalason sa Tingga lalo't higit kung nag-tatrabaho sa tinggaan o naninirahan malapit dito. Ilan dito ay ang mga sumusunod:

- ***Panghihina ng mga kamay at paa, pamamanhid, kawalan ng koordinasyon sa pagkilos***
- ***Pagkahilo, pagiging irritable at makakalimutin, pagtaas ng presyon ng dugo***
- ***Problema sa bato o dugo***

Agad na sumangguni sa inyong barangay o rural health center kapag naramdaman ninyo ang mga sintomas na ito.

Ang materyal na ito ay ginawa sa ilalim ng proyektong "Pagpigil o Pagpapababa ng Lebel ng Pagkalantad sa Tingga"

National Poison Management & Control Center

University of the Philippines – Philippine General Hospital

T: 02 524-1078, 554-8400 local 2311

¿Sabías que?

El plomo es un metal que se encuentra naturalmente en el suelo, sin embargo a través del tiempo, los seres humanos lo han utilizado de diferentes maneras dispersándolo al medio ambiente.

El uso más amplio del plomo se encuentra en la fabricación de baterías para carros y motos, pero también se usa en forros para cables, elementos de construcción, pinturas, esmaltes usados en alfareria tradicional, productos cosméticos, soldadura suave y municiones.

Enero 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

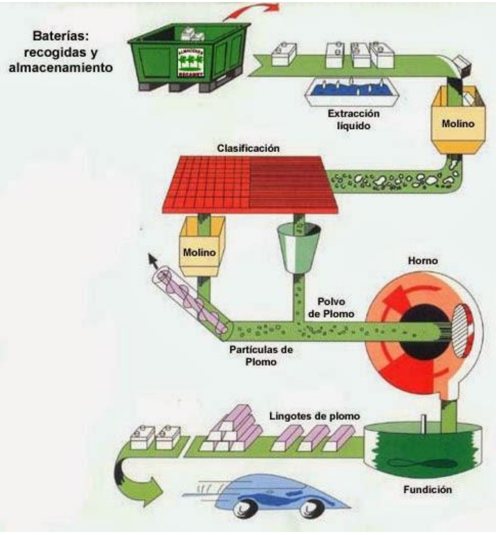
¡No existe un nivel de exposición al plomo que pueda considerarse seguro!

(Organización Mundial de la Salud,2017).

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

Además…



Actualmente algunas empresas se dedican a la recuperación del plomo que se encuentra en baterías viejas, el cual se funde en hornos a altas temperaturas y posteriormente se comercializa principalmente para fabricación de nuevas baterías.

Cuando estos procesos de fundición no se realizan en condiciones adecuadas de seguridad para los trabajadores y el medio ambiente, pueden afectar las plantas, los animales, los cultivos, el suelo, el aire, el agua y en especial a las personas.

Febrero 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28			

El 95% del plomo de las baterías viejas puede volver a utilizarse en fabricación de baterías (Ambientum, 2016).

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿Cómo ingresa el plomo a nuestro cuerpo?

Marzo 2018

A través de la respiración de partículas de plomo que haya en el ambiente, ya sea por actividades que se desarrollen cerca de la vivienda o en el lugar de trabajo.

Por medio de la ingestión, es decir, cuando se tiene contacto con elementos contaminados con plomo a través de las manos, juguetes, alimentos, y estos ingresan a la boca sin lavado previo.

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	31

Los niveles de plomo en el ambiente han aumentado más de 1000 veces durante los últimos 300 años como consecuencia de la actividad humana

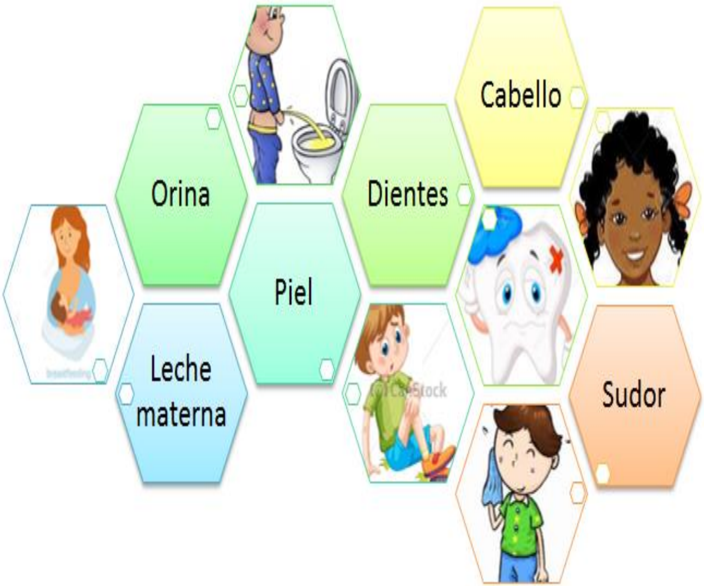
(Espinoza, Llinima, & Mauricio, 2017).

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿ De qué manera nuestro cuerpo puede eliminar el plomo no absorbido?

Abril 2018



Dom	Lun	Mar	Mié	Jue	Vie	Sáb
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30					

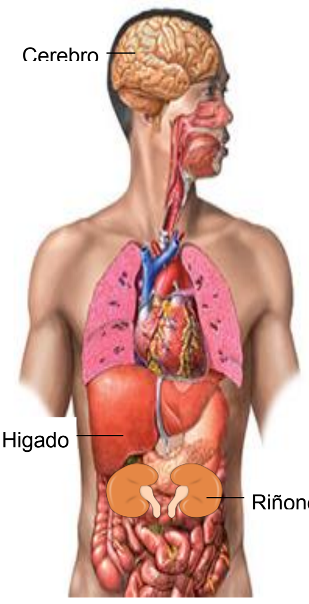
El plomo es considerado por la Organización Mundial de la Salud como una de las diez sustancias químicas de mayor preocupación para la salud pública.

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿Qué hace el plomo en el cuerpo?

- Una vez que el plomo entra en su cuerpo, se queda allí por bastante tiempo.
- El plomo se distribuye por el organismo hasta alcanzar el cerebro, el hígado, los riñones y se deposita en los dientes y en los huesos.
- La exposición prolongada a esta sustancia genera acumulación de plomo en el cuerpo (lo cual puede ocasionar intoxicación por plomo).
- Las primeras manifestaciones en el cuerpo pueden sentirse mucho tiempo después de estar expuesto al plomo.



Mayo 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

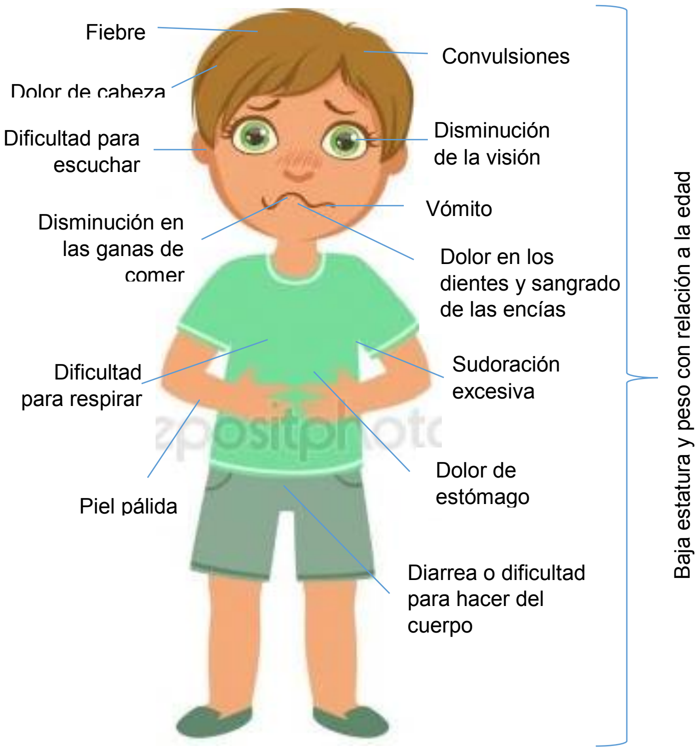
La exposición al plomo en condiciones similares afecta en mayor medida a los niños en comparación con los adultos.

(Pure Earth)

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿Cómo se manifiesta el plomo en el cuerpo de los niños?



Junio 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

El plomo puede afectar la maduración sexual en niños y adolescentes. (I, L, & A, 2009) citado en (Tellez & al, 2017)

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿Cómo se manifiesta el plomo en el comportamiento de los niños?

Pérdida de memoría

Falta de concentración

Cambios de comportamiento

Hiperactividad o cansancio

Menor rendimiento escolar

Retraso mental

Julio 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

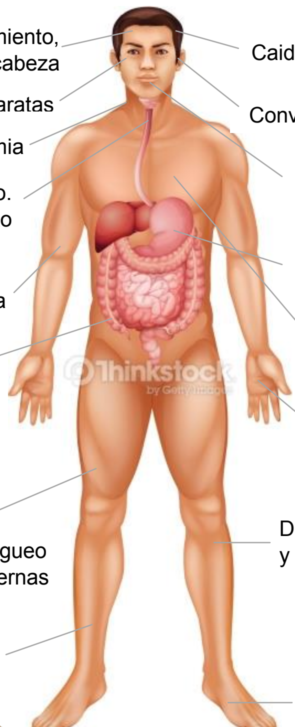
Los niños con desnutrición son más vulnerables a las consecuencias del plomo porque sus organismos tienden a absorber mayores cantidades de este metal.

(Organización Mundial de la Salud, 2017)

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿Cómo se manifiesta el plomo en el cuerpo de los adultos?



Agosto 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

¿Qué hacer si usted o alguno de sus familiares presenta estos síntomas?

- **Acuda al servicio de salud más cercano**
- **Cuéntele a su médico los síntomas que presenta.**
- **Informe al médico si usted trabaja con plomo**

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿ Cómo se manifiesta el plomo en el comportamiento de los adultos?

Septiembre 2018

1. Dificultad para dormir.
2. Disminución del deseo sexual.
3. Cambios de comportamiento, mal humor, irritabilidad.
4. Falta de coordinación en los movimientos.
5. Pérdida de la memoria y falta de concentración.

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

- Nacimientos prematuros.
- Bebés más pequeños al nacer.
- Bebés bajos de peso al nacer.
- Muerte fetal.
- Abortos espontáneos.

El plomo no es un elemento necesario para ninguna función del organismo humano. (Rodríguez, 2016).

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿ Cómo proteger a los niños de la exposición al plomo?

Lavar manos y cara con agua y jabón, después de jugar, antes de comer y antes de acostarse.

Lavar los alimentos.

Jugar lejos de tierra y polvo, mejor en el pasto.

Lavar periódicamente los juguetes.

Dar a los niños bocaditos saludables ricos en hierro, calcio y vitamina D, vitamina C

Hierro

Calcio y Vitamina D

Vitamina C

Octubre 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

Ayunar puede aumentar el nivel de plomo en el cuerpo. La nutrición apropiada puede ayudar a reducir los niveles de plomo.

(Mass.gov, 2017).

PURE EARTH BLACKSMITH INSTITUTE

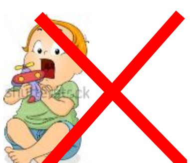
USAID FROM THE AMERICAN PEOPLE

Acciones preventivas para los adultos

No permita que los niños jueguen directamente con el suelo en tierra.

Nunca limpie o barra el polvo en seco, siempre limpie con agua.

Nunca sacuda el polvo en seco, siempre limpie ventanas, corredores, pisos, muebles, utensilios de uso doméstico y otras áreas con un trapo mojado.



No permita que los niños tenga contacto con juguetes sucios, procure lavarlos con frecuencia.

Noviembre 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

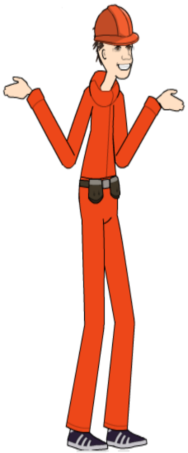
Algunos efectos dañinos del plomo son permanentes.

(Administración de Seguridad y Salud Ocupacional, OSHA, 2017).

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

¿Qué hacer si usted o algún familiar trabaja con plomo?



- Una vez termine su jornada laboral bañese (si es posible), lave su cabello y cambie su ropa, incluyendo los zapatos (es importante que la ropa y zapatos de trabajo sean usados únicamente para este fin).
- No sacuda las prendas de trabajo
- Guarde su ropa y zapatos de cambio separada de la ropa de trabajo.
- Limpie su área de trabajo con un paño húmedo, nunca sacuda el polvo.
- Lave la ropa de trabajo separada de la del resto de la familia.
- En el trabajo consuma líquidos y alimentos solamente en las áreas que están libres de polvo y vapores de plomo. Lavase las manos y la cara muy bien antes de comer o tomar alimentos.
- Pregunte a la ARL o a su médico las características y tipo de elementos de protección personal que debe usar (máscara respiradora, guantes protección ocular overol calzado adecuado).
- Asegúrese de que la máscara respiradora se ajuste a su rostro y límpiela después de cada uso.

Diciembre 2018

Dom	Lun	Mar	Mié	Jue	Vie	Sáb
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

Los niños menores de 5 años son los más vulnerables porque absorben cuatro a cinco veces más cantidad de plomo que los adultos, ya que su sistema nervioso se encuentra en desarrollo.

(Organización Mundial de la Salud, 2017).

PURE EARTH BLACKSMITH INSTITUTE

USAID FROM THE AMERICAN PEOPLE

PURE EARTH
BLACKSMITH INSTITUTE

USAID
FROM THE AMERICAN PEOPLE

AGENDA ESCOLAR 2018

Estudiante:

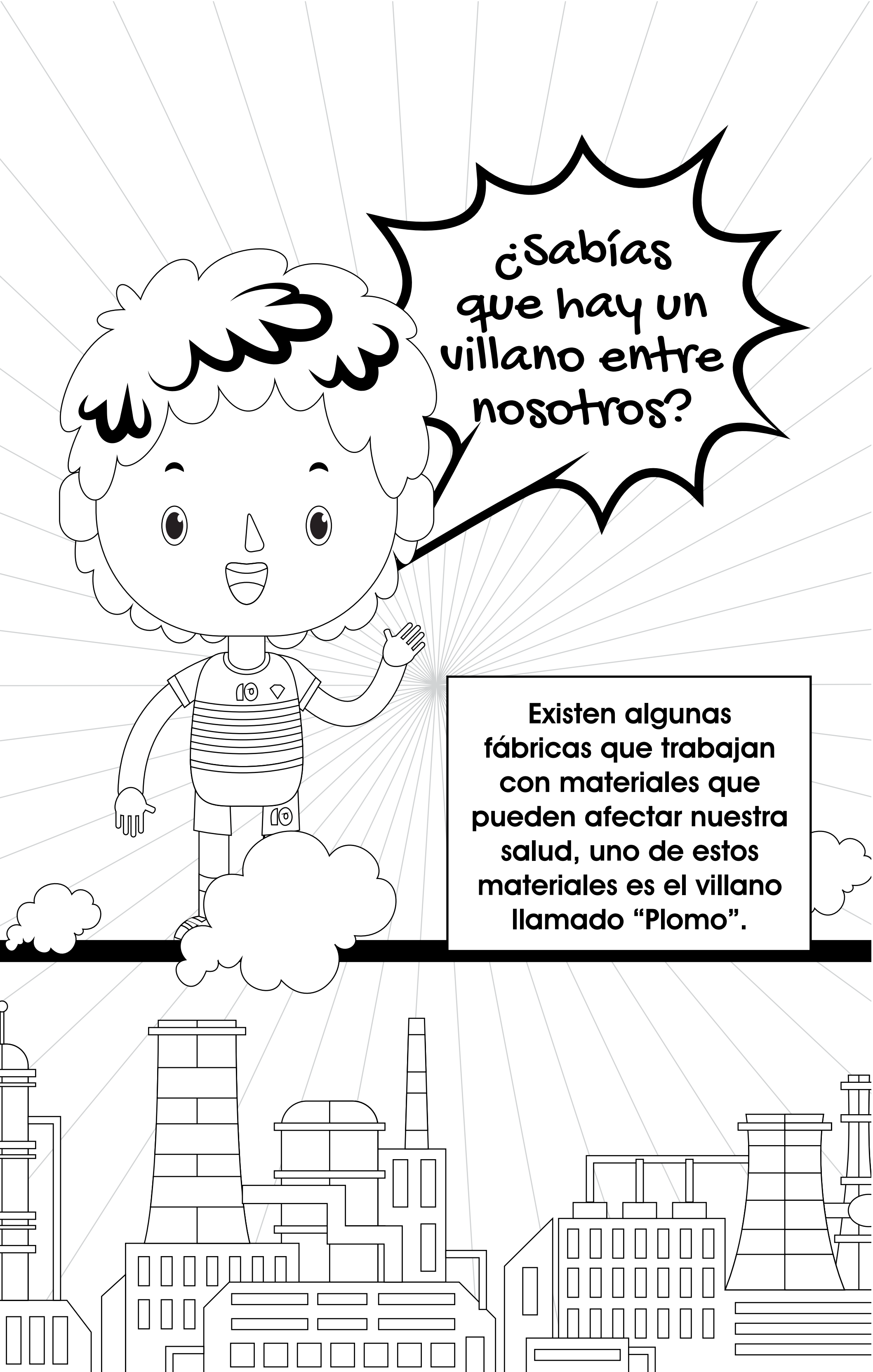
PURE EARTH
BLACKSMITH INSTITUTE

USAID
FROM THE AMERICAN PEOPLE

AGENDA ESCOLAR
- 2018 -

Día Mes Año


¿Sabías que hay un villano entre nosotros?
Existen algunas fábricas que trabajan con materiales que pueden afectar nuestra salud, uno de estos materiales es el villano llamado “Plomo”.


¿Sabías que hay un villano entre nosotros?
Existen algunas fábricas que trabajan con materiales que pueden afectar nuestra salud, uno de estos materiales es el villano llamado “Plomo”.


Este metal de color gris brillante se encuentra encerrado en las baterías viejas de carros y motos, al abrirlas el plomo se escapa y puede tomar diferentes formas (líquido, vapor).
¿Dónde está el Plomo?


Este metal de color gris brillante se encuentra encerrado en las baterías viejas de carros y motos, al abrirlas el plomo se escapa y puede tomar diferentes formas (líquido, vapor).
¿Dónde está el Plomo?

¿Por qué es un villano?

Porque viaja por el aire, se esconde en la tierra, en las materas, en las plantas, en los alimentos y puede entrar a nuestro cuerpo.


¿Por qué es un villano?
Porque viaja por el aire, se esconde en la tierra, en las materas, en las plantas, en los alimentos y puede entrar a nuestro cuerpo.

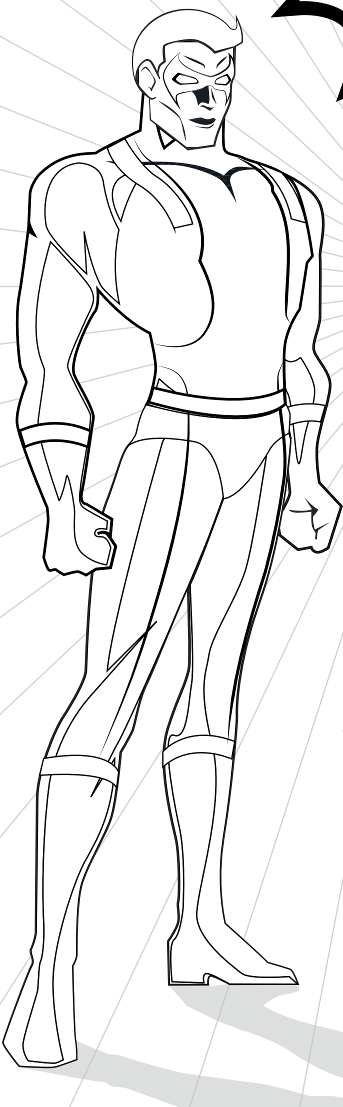
¿Qué pasa si el villano logra entrar a tu cuerpo?

Puedes sentir:

- **Cansancio.**
- **Dolor de cabeza.**
- **Dolor de estómago.**
- **Dificultad para ir al baño.**
- **Disminución en las ganas de comer.**

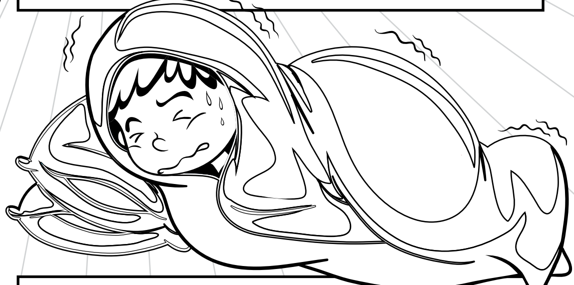
- **Dificultad para concentrarte.**
- **Disminución de la visión.**
- **Dificultad para respirar.**
- **Dificultad para escuchar.**
- **Dolor en los dientes.**

¿Qué pasa si el villano logra entrar a tu cuerpo?



Puedes sentir:

- **Cansancio.**
- **Dolor de cabeza.**
- **Dolor de estómago.**
- **Dificultad para ir al baño.**
- **Disminución en las ganas de comer.**



- **Dificultad para concentrarte.**
- **Disminución de la visión.**
- **Dificultad para respirar.**
- **Dificultad para escuchar.**
- **Dolor en los dientes.**


¿Quieres ser un superhéroe y ayudarnos a combatir a este villano?


¿Quieres ser un superhéroe y ayudarnos a combatir a este villano?


Lava manos y cara con agua y jabón, después de jugar, antes de comer y antes de acostarte.
Lava los alimentos.
Juega lejos de tierra y polvo, mejor en el pasto.
Lava los juguetes


Lava manos y cara con agua y jabón, después de jugar, antes de comer y antes de acostarte.
Lava los alimentos.
Juega lejos de tierra y polvo, mejor en el pasto.
Lava los juguetes


Come alimentos ricos en hierro.
Come carne de res, de cerdo, pollo, pavo y atún.
ATÚN
Fríjol, arveja verde, granos integrales, panes fortificados,
huevos, espinaca y vegetales verdes.


Come alimentos ricos en hierro.
Come carne de res, de cerdo, pollo, pavo y atún.
ATÚN
Fríjol, arveja verde, granos integrales, panes fortificados,
huevos, espinaca y vegetales verdes.


Come alimentos ricos en calcio y vitamina D.
Como queso, leche, yogurt, huevos,
Yogurt
acelgas, lentejas, garbanzos, pasta,
salmón, champiñones, atún, huevos y sardinas.
ATÚN


Come alimentos ricos en calcio y vitamina D.
Como queso, leche, yogurt, huevos,
Yogurt
acelgas, lentejas, garbanzos, pasta,
salmón, champiñones, atún, huevos y sardinas.
ATÚN


Consume alimentos ricos en vitamina C
naranjas, guayabas, mandarina, fresa, kiwi,
papaya, melón, tomates, coliflor, y brócoli.


Consume alimentos ricos en vitamina C
naranjas, guayabas, mandarina, fresa, kiwi,
papaya, melón, tomates, coliflor, y brócoli.


¡Si sigues estas recomendaciones el Plomo no podrá causarte daño y salvarás tu cuerpo!


¡Si sigues estas recomendaciones el Plomo no podrá causarte daño y salvarás tu cuerpo!

AGENDA ESCOLAR 2018

PURE EARTH
BLACKSMITH INSTITUTE

USAID
FROM THE AMERICAN PEOPLE

- ✓ "Sumemos esfuerzos para una Vida Libre de Plomo".
- ✓ "Esta publicación es posible gracias el generoso apoyo del pueblo Estadounidense".
- ✓ "El contenido de este cuaderno es responsabilidad exclusiva de Pure Earth y de ninguna manera puede tomarse como reflejo de los puntos de vista de USAID".


জন্ম, সৃষ্টির
সিমেন্ট

মানবদেহে সীসা দূষণের প্রধান উপায়সমূহঃ

- সাধারণত তাৎক্ষনিক কোন প্রভাব পড়ে না।
- শিশুর বুদ্ধিমত্তা হ্রাস পাওয়া।
- কাজ করায় অনীহা এবং কথা বলায় আড়ষ্টতা
- পেট ব্যথা, অবসাদগ্রস্ততা, ওজন কমে যাওয়া এবং অনুভূতি হ্রাস পাওয়া।
- উচ্চমাত্রার দূষণের ফলে শারীরিক অক্ষমতা এমনকি মৃত্যু পর্যন্ত ঘটতে পারে।

শিশুদের সবচেয়ে বেশী আক্রান্ত হওয়ার কারণঃ

- শারীরিক আকৃতি ছোট হওয়ার কারণে তাদের উপর দূষণের প্রভাব আনুপাতিক হারে অনেক বেশি হয়।
- শিশুরা সাধারণত উন্মুক্ত জায়গায় খেলা করার কারনে সীসা দূষিত ধূলিকণা দ্বারা বেশি আক্রান্ত হয়।
- তাদের শারীরিক এবং স্নায়বিক বিকাশ বাড়ন্ত অবস্থায় থাকে বলে সীসার ক্ষতিকর প্রভাব বেশী দেখা দেয়।

সীসা দূষণ সংক্রান্ত স্বাস্থ্য ঝুকি থেকে নিজেকে রক্ষার জন্য করণীয়ঃ

- হাতমুখ ধোয়া বিশেষ করে খাওয়ার আগে এবং ঘুমাতে যাওয়ার আগে ভালমত ধোয়া।
- আপনার বাড়িঘর নিয়মিত পরিষ্কার-পরিচ্ছন্ন ও ধূলামুক্ত রাখা।
- নিয়মিত বাড়ির আসবাবপত্র ধুয়ে মুছে পরিষ্কার রাখা এবং খাওয়ার বাসন ধুয়ে রাখা।
- এছাড়া যারা সীসার দূষণযুক্ত এলাকায় কাজ করেন তারা যেন বাড়িতে ফেরামাত্র তাদের জামাকাপড় আলাদা করে রেখে ধুয়ে দেন এবং দ্রুত পরিষ্কার কাপড় পরিধান করেন।
- দূষণকৃত এলাকায় ব্যবহারকৃত গাড়ির ভিতরেও ভালমত পরিষ্কার করা।
- খালি পায়ে দূষিত এলাকা দিয়ে হাঁটাহাঁটি না করা।
- অকারণে ধূলাবালি তৈরি না করা।
- বাড়ির আঙ্গিনা পরিষ্কার মাটি দ্বারা ঢেকে দেওয়া (সম্ভব হলে বাইরে থেকে মাটি এনে তা দিয়ে ঢেকে দেওয়া)।
- বাড়ির উঠান ঘাস দ্বারা ঢেকে দেওয়া।
- দূষণযুক্ত এলাকার উৎপাদিত শাক-সবজি ও ফলমূল ভালমত ধুয়ে খাওয়া বা রান্না করা।
- এছাড়া এলাকার নর্দমা পরিষ্কার রাখা যাতে বৃষ্টির সময় সীসার দূষণকৃত এলাকা থেকে দূষিত মাটি চারিদিকে ছড়িয়ে পড়তে না পারে।

সীসা দূষণ উপসম প্রকল্প

কাঠগড়া, আশুলিয়া, সাভার, ঢাকা

সীসার দূষণ ও স্বাস্থ্য ঝুকিঃ যা জানা প্রয়োজন

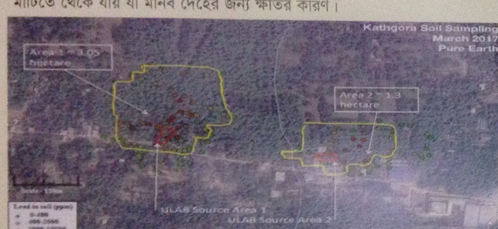
বাস্তবায়নেঃ PURE EARTH USAID

সীসা কি ?

সীসা একটি বিষাক্ত ভারী ধাতু যা মানব দেহের জন্য অত্যন্ত ক্ষতিকর।

কাঠগড়াতে সীসা দূষণঃ

কাঠগড়াতে অপরিকল্পিত অবৈধভাবে পুরাতন ব্যাটারির সীসা গলানোর কাজ করার ফলে অত্যন্ত ক্ষুদ্র সীসার কণা মাটিতে উচ্চমাত্রায় মিশ্রিত হয়ে আছে। উক্ত স্থানে ব্যাটারির কারখানা বন্ধ হয়ে গেলেও সীসা কণা দীর্ঘদিন ধরে মাটিতে থেকে যায় যা মানব দেহের জন্য ক্ষতির কারণ।



সীসা দূষণ উপসম প্রকল্প, কাঠগড়া, আশুলিয়া, সাভার, ঢাকা।

সীসার দূষণ যেভাবে পরিবেশে ছড়ায়ঃ

সীসা গলানোর সাহায্যেঃ

- উন্মুক্ত স্থান, যেখানে সেখানে অপরিকল্পিতভাবে সীসা গলানোর কারণে।

উড়ন্ত ধূলিকণার সাহায্যেঃ

- তীব্র বায়ুপ্রবাহের মাধ্যমে ফেলে রাখা ব্যাটারির বর্জ্য থেকে।
- সীসার কারখানার দূরবর্তী এলাকা থেকে উৎসের নিকটবর্তী এলাকায় দূষণের সম্ভাবনা বেশি।
- জনগনের চলাফেরা এবং গাড়ি চলাচলের কারণে যে ধূলা উৎপন্ন হয় তার মাধ্যমে।

মাটির উপরিভাগে পানি প্রবাহের মাধ্যমেঃ

- সীসার কণা বৃষ্টির সময় ভূপৃষ্ঠে পানি প্রবাহ ও নালার মাধ্যমে ছড়িয়ে পড়ে।

ব্যাটারি কারখানায় কাজের মাধ্যমেঃ

- সীসার দূষণযুক্ত এলাকা এবং ব্যাটারির কারখানায় যারা কাজ করেন তাদের পরিধেয় জামাকাপড় এবং জুতার মাধ্যমে।

দূষিত এলাকায় গাড়ী চলাচলের মাধ্যমেঃ

- গাড়ী চলাচল করলে তার টায়ারের মাধ্যমেও দূষণ ছড়িয়ে পড়ে।

সীসার দূষণে স্বাস্থ্য ঝুকির নিয়ামকসমূহঃ

- মাটিতে সীসার দূষণের মাত্রা।
- ধূলাযুক্ত দূষিত মাটি।
- সীসার দূষণযুক্ত এলাকায় মানুষের অবাধ বিচরনের কারণে বিশেষকরে শিশুদের অবস্থানের সময়কাল।

মানবদেহে সীসা দূষণের প্রধান উপায়সমূহঃ

গলধকরনের (খেয়ে ফেলা) মাধ্যমেঃ

- সীসার দূষণযুক্ত স্থান থেকে এসে হাতমুখ না ধুয়ে খাওয়া-দাওয়া করা।
- শিশুদের দূষণযুক্ত মাটি মুখে নেওয়া ও চোষা।
- কফ খেয়ে ফেলা।

সীসাযুক্ত খাবার গ্রহণের মাধ্যমেঃ

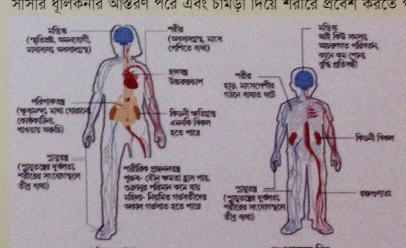
- দূষণযুক্ত এলাকার উৎপাদিত শাকসবজি ও ফলমূল না ধুয়ে খাওয়ার কারনে।

শ্বাস-প্রশ্বাসের মাধ্যমেঃ

- সীসাযুক্ত দূষিত ধূলিকণার নিঃশ্বাস গ্রহণ, সীসার ক্ষুদ্রাতিক্ষুদ্র কণা ফুসফুসে প্রবেশ করে এবং রক্তের সাথে মিশে যায়।

শরীরের চামড়ার মাধ্যমে

- সীসার দূষণযুক্ত এলাকায় শিশুরা খেলাধুলা করলে তাদের শরীরের বহিরাংশে সীসার ধূলিকনার আস্তরণ পরে এবং চামড়া দিয়ে শরীরে প্রবেশ করতে পারে।



সীসা দূষণের কারণে সংক্রমিত মানবদেহের সম্ভাব্য অঙ্গপ্রত্যঙ্গ সমূহ


CHAMPIONS
BIG:MATCH