ENVIRONMENTAL HEALTH PROJECT

Activity Report 110

# Support for Phase II of the Peru Lead Project to Determine Blood and Ambient Lead Levels in Metropolitan Lima and to Manage the Lead Exposure Problem in Critical Areas

by

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# About the Team

**Eduardo Perez** was the activity manager for this activity.

**Jorge Elgegren** was the biodiversity specialist in charge of the project for the Office of Environment and Natural Resources, USAID/Peru, though he moved to another project three months before the lead project came to a conclusion. Elgegren is an Economist with a degree from the *Pontificia Universidad Católica* del Perú, an MS in Amazonian Studies from the *Facultad Latinoamericana de Ciencias Sociales* (FLACSO/Ecuador), and an MSc in Environmental and Resource Economics from University College (University of London). Elgegren has been a USAID officer since 1996 and a university lecturer on environmental economics at *Universidad Nacional de Ingeniería* in Lima, Peru. His initial approach to DIGESA led to a growing cooperation effort between USAID and the government of Peru.

**Mauricio Hernandez-Avila** was the original project designer for the baseline blood lead survey, "Blood lead Study in Selected Populations of Lima and Callao, Peru," [1] in the first phase of the Lead Project; he also provided overall supervision to all further studies in the second phase. Together with Patricia Billig, Hernandez-Avila outlined the activities for the second phase of the Lead Project: "Further Assessment of Lead Contamination, Pediatric Lead Poisoning, and Interventions to Reduce Lead Exposure in Lima and Callao, Peru." [5] A physician with ample experience in the lead problem in the Americas, he is co-author of several books and publications on the subject and is currently the Executive Director of the Center for Research in Health within the National Institute of Public Health in Mexico.

**Carmen Gastañaga** was the contact link with the superior level in DIGESA. As the Technical Advisor to the General Director in DIGESA, she coordinated all resource and personnel movement for the project within the institution. A physician with a degree from the *Universidad Nacional Mayor de San Marcos* and studies in epidemiology and toxicology, Dr. Gastañaga was the only team member who saw the project from beginning to conclusion.

**Rocio Espinoza** was the original local project coordinator for DIGESA during 1999. A physician with a degree from the *Universidad Nacional Mayor de San Marcos* and with extensive experience in environmental problems, she moved on to the National Institute of Public Health in Mexico for an MSc in Environmental Epidemiology.

**Carlos Sanchez** became the second and final local project coordinator for USAID in Peru from 1999 to 2001. Dr. Sanchez is a physician and a biologist with an MSc degree in Public Health (from the *Universidad Peruana Cayetano Heredia*) who joined the original team after the results from the baseline study called for further assessment.

# Acknowledgments

All opinions in this document belong exclusively to the author and do not represent the views of USAID or the government of Peru. During the two years the project lasted, many contributors put in considerable time and effort, including USAID/Peru, EHP and DIGESA representatives, consultants, and other participants. The author wishes to express his gratitude to all of these and his hope that this report adequately reflects their contributions.

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# Abbreviations

| | |
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| BAL | dimercaprol |
| BLLRS | Blood Lead Laboratory Reference System |
| CDC | U.S. Centers for Disease Control and Prevention |
| CENTROMIN | *Empresa Minera del Centro del Perú S.A.*<br>Central Peru Mining Company |
| CFR | U.S. Code of Federal Regulations |
| CICOTOX | *Centro de Información y Control Toxicológico* (Toxicological Information and Control Center), Peru |
| DEEMA | *Dirección Ejecutiva de Ecología y Medio Ambiente* (Executive Direction of Ecology and Environment), Peru |
| DIGESA | *Dirección General de Salud Ambiental* (General Directorate of Environmental Health), Peru |
| DMSA | dimercaptosuccinic acid |
| EDTA | ethylenediaminetetraacetic acid |
| EHP | Environmental Health Project |
| EPA | U.S. Environmental Protection Agency |
| GIS | geographic information system |
| IEBUK | integrated exposure uptake biokinetic model |
| ILMC | International Lead Management Center |
| INAPMAS | *Instituto Nacional de Protección del Medio Ambiente y Salud* (National Institute for the Protection of Environment and Health), Peru |
| INSP | *Instituto Nacional de Salud Pública* (National Institute of Public Health), Mexico |
| NCEH | U.S. National Center for Environmental Health |
| NIOSH | U.S. National Institute for Occupational Safety and Health |
| ppm | parts per million |
| SONAMINPET | *Sociedad Nacional de Minería y Petróleo* (Mining and Petroleum National Society), Peru |
| USAID | U. S. Agency for International Development |

# Executive Summary

In 1997, the Environmental and Natural Resources Office in the U.S. Agency for International Development (USAID)/Peru contacted the Peruvian Ministry of Health's *Dirección General de Salud Ambiental* (General Directorate of Environmental Health) (DIGESA) as its local counterpart for the implementation of a program to phase out lead from gasoline in Peru. This collaboration began in November 1997, and included technical assistance in establishing a protocol for a baseline study to be conducted in selected areas of Lima and Callao, technical assistance to guide the study, donations of equipment and supplies to measure blood lead levels during the study, and the training of DIGESA personnel in the use of the donated equipment.

In June 1998, during the delivery ceremony of lead monitoring equipment donated by USAID to Peru's DIGESA, the Peruvian vice minister of housing publicly announced a strategy to gradually eliminate lead from gasoline before the year 2004. As part of the program, the Peruvian government proposed the implementation of a blood lead survey to evaluate current lead exposure in Lima and to obtain baseline data to monitor changes in blood lead associated with the phase out of lead. Between July 1998 and March 1999, DIGESA conducted a USAID-funded study to determine blood lead levels in probable high-risk populations, mainly children and women.

A total of 2,510 children aged 6 months to 9 years and 814 early postpartum women living in Lima and Callao (a district of Lima, see Figure 1) were studied to determine potential sources of lead exposure and health effects. This baseline study[1] identified unexpected critical areas with severe lead contamination in Callao. The unusually severe lead contamination in an area near the port of Callao caused examiners to look at probable causes of contamination other than lead in gasoline. Although leaded gasoline is a known source of lead contamination in countries like Peru, where it is still used as an antiknock agent to boost octane, it seldom causes blood lead levels as high as those found in Callao. Other possible sources were considered, including mineral storehouses located in the area, which were regarded as highly probable sources of lead contamination. As a result of study findings, DIGESA, EHP, and USAID agreed to design a follow-on phase of the study entitled, "Peru Lead Project Phase II: Further Analysis of Lead Contamination, Pediatric Lead Poisoning, and Interventions to Reduce Lead Exposure in Lima and Callao." The purpose of this phase was to clearly identify the source of lead exposure and to solve the problem in a participatory manner.

During Phase I of the baseline study, the senior environmental health scientist for the National Center for Environmental Health of the Centers for Disease Control and Prevention (CDC) and the EHP consultant from the Mexican National Institute of Public Health took soil samples during their visits to the mineral storehouses. The DIGESA laboratory in Lima analyzed these initial samples for lead concentration and sent them to the CDC laboratory in Atlanta, Georgia, for isotope determination.

**Figure 1. The Port of Callao in Peru, 1999**

In the work plan designed in April 1999, DIGESA determined that further sampling should be considered for the second phase of the lead project. The project activities were designed to provide DIGESA with stronger evidence regarding the sources of lead in the area in order to establish the role and responsibility of the companies involved in the storage of minerals. Because mining is such an important activity in Peru, an environmental soil sampling study was needed to provide scientific evidence that would assign responsibility to the mining companies and demand containment of the contamination. Such a study would also provide a strong technical foundation for future regulatory and control activities implemented by DIGESA to prevent lead exposure in Callao or other areas with similar exposures.

DIGESA’s Director for Ecology and Environment was responsible in November 1999 for contacting the National Society for Mining and Petroleum (SONAMINPET in Spanish) to request proper authorization to take samples from inside the mineral storehouses, as well as to request information on the mineral flow through the storehouses. Samples were taken and analyzed, and the data was presented to DIGESA on July 4, 2000. The report concluded that the huge uncovered piles that lie within the mineral storehouses represent the most probable major source of lead contamination of the soil and of the population in the port area of Callao.

The report also sought to establish any possible associations between the lead in blood and the lead isotopic composition of environmental and gasoline samples. The EHP consultant designed the study to evaluate the isotope composition of lead present in the blood of children living in the Puerto Nuevo area and in other control areas in Lima. A full study protocol had to be developed for approval by the Institutional

Review Board at CDC, including the sampling methodology for 50 children with known blood lead concentrations (high and low) from schools inside and outside Callao.

The environmental and population sampling for this activity clearly linked the lead of the mineral concentrates with that of the children with high blood lead values in Callao. Though less conclusive, the results also linked the isotope lead ratio in mineral concentrates with that of children with low blood lead values who do not live in Callao, implying that children outside Callao also had traces of mineral lead in their blood. Air filter samples analyzed by the CDC also gave valuable insight into the complexity of the problem. Lead in the air in Lima was found to resemble a combination of the lead in gasoline and lead in minerals, suggesting that minerals may be contributing more than originally expected to the lead in the air. The mineral isotopic pattern found in Callao more closely resembled that of mineral lead, while the city of Lima (as a whole) showed a mixture of both mineral and gasoline patterns.

The results did not contradict the original hypothesis that mineral lead (and not leaded gasoline) accounted for the primary source of lead exposure in the population of Callao. The results, however, did indicate a larger environmental lead contamination problem in Lima, which will require further investigation.

The study also attempted to determine the relative contributions of water, soil, and dust as sources of lead contamination in Lima and Callao. It concluded that lead present in dust and soil is the most probable exposure pathway for children who live near the mineral storehouses. During the initial lead study, interviews with the parents of tested children revealed information regarding such behaviors that increased the risk for individual lead exposure. Children (especially those under five years of age) are highly exposed to lead in dust and soil primarily because of their natural habit of putting fingers, toys and other objects that may be contaminated with dust or soil into their mouths.

Although controlling the sources of lead contamination, providing access to running water and improving cleaning efforts in the classrooms and homes can reduce lead exposure, community-based interventions can also have important beneficial effects reducing individual exposure. Furthermore, until other measures are implemented, community-based programs that increase awareness of the routes of lead exposure in children and promote behavior changes to improve personal hygiene practices and cleaning activities may be the only effective intervention. The best way to approach advocating changes in behavior and follow up with the community is through local advocacy groups (in this case, health promoters from the local center) who can reinforce the ideas presented during the health education campaign. It was recommended that a trained volunteer group visit the families, forging a valuable link between DIGESA and the community, while gathering important information, first to develop and later to monitor a behavior change program.

The Lead Project Phase II study identified technical areas where training was needed in order to improve and expand DIGESA's surveillance and regulatory capabilities in the investigation of environmental problems, possible sources of contamination, and effects on human health. The last set of activities undertaken during Phase II of the study was designed to support DIGESA in its effort to deal appropriately with the environmental problems at hand. Through a workshop and other interventions, DIGESA personnel were trained in environmental epidemiology concepts and applications, introduced to the uses of geographical information systems to assess environmental problems and given a means for receiving additional donated equipment and supplies to support current and future studies of lead contamination.

In summary, a total of 12 activities were completed between November 1999 and July 2001 during the Lead Project Phase II. These included activities to clarify sources of lead contamination, studies to estimate the magnitude of the problem, interventions to reduce lead exposure and training and capacity building for DIGESA.

# 1. Introduction

## 1.1. Lead Poisoning as a Global Concern

Worldwide the main source for lead contamination in urban populations has been lead in gasoline. The United States started to phase lead out of gasoline in the early 1970s, even before conclusive data on its impact on child development was available. Analysis of a chronological trend in data from the second National Health and Nutrition Examination Survey indicated that average blood lead levels in the United States dropped approximately 37 per cent (5.4 micrograms per deciliter, or 5.4 μg/dL) from February 1976–February 1980. The correlation of blood lead levels with the lead level in gasoline was highly significant (P less than 0.001) overall.[2]

Although strong correlation does not prove cause and effect, the most likely explanation for the fall in blood lead levels in the United States was a reduction in the lead content of gasoline during this period. Between 1976 and 1994, the mean blood lead concentration in children dropped from 13.7 μg/dL to 3.2 μg/dL, in direct proportion to the amount of tetraethyl lead produced.[3] (Exposure to lead is estimated by measuring levels in the blood as micrograms per deciliter. The Centers for Disease Control and Prevention (CDC) has set a blood lead level of concern at 10 μg/dL.)

By 1999, several Latin American countries had already removed the lead from their gasoline. In the late 1990s, Peru set out to reproduce this achievement and have lead-free gasoline by the year 2005.

## 1.2. Addressing Lead Contamination Levels in Peru

Lead poisoning is a significant environmental problem for many children, especially in poverty stricken areas. Lead exposure in young children is of particular concern because children absorb lead more readily than adults and their developing nervous systems are particularly vulnerable to lead's effects.[4] The amount of lead ingested by a child that is absorbed in the digestive tract depends on the bio-availability of the lead compound, the quantity ingested and the nutritional status of the child. As part of their normal activities, children consume 80–135 mg of dust and soil every day. More consumption could be expected in dry, dusty environments with poor hygiene, such as the port area in Callao, Peru. Ingestion rates may increase further due to low accessibility to ru0nning water, certain behavioral patterns, such as infrequent hand washing, or certain characteristics of the playgrounds (e.g., soil versus concrete). In areas with socioeconomic characteristics similar to those observed in the settlement of Puerto Nuevo, in the district of Callao, it is commonplace that children experience multiple micronutrient deficiencies. As a result, it is probable that a considerable proportion of children have deficient iron and calcium diets, and these deficiencies increase absorption of lead, enhancing its toxic effects.

It is well established that lead in dust and soil is an important predictor of blood lead levels in children. The relation between lead in soil and lead in the blood of children can be estimated using published mathematical models like EPA's integrated exposure uptake biokinetic (IEBUK) model. The observed blood lead levels in Callao should be the result of a 15,000 ppm in the soil lead content. This estimated lead content is larger than that observed in the Callao environmental sampling study (observed range, 2,800 ppm). This discrepancy between the observed and predicted content suggests that the contamination could be caused by a lead compound with a high absorption rate or by the coexistence of other conditions that may increase lead absorption. High blood lead levels among children living close to mineral storage areas located near Puerto Nuevo made it clear that action to decrease exposure was urgently needed.

## 1.3. Neighborhoods Studied

### 1.3.1. Port of Callao

Established as a Spanish settlement in 1535, the same year as the city of Lima, Callao is similar in shape and size to any current district of Lima. However, in 1857 during the first years of the Republic, Callao was granted the title of "constitutional province" by the president of Peru. In those times, the port area of Callao was separated from the city of Lima and was accessible only by railroad. Today, urban development has merged the city and the port. As a constitutional province, Callao contains six districts: Callao, Bellavista, Carmen de la Legua-Reynoso, La Perla, La Punta and Ventanilla, as well as six small islands (Figure 2).

The IEBUK is designed to predict the probably blood lead concentration for children between six months and seven years of age who have been exposed to lead through environmental media (air, dust, soil, water, etc.).

### 1.3.2. Puerto Nuevo

Puerto Nuevo is a very poor settlement within the district of Callao. A mere 200 meters separate it from the port docks, and it is almost completely surrounded by storage areas for minerals that are shipped from the port. With an estimated 1,000 families currently living in Puerto Nuevo, controversy still remains over whether the community or the industry was the first to arrive in the area. Small family farms and mineral storehouses have existed there for over 70 years. For decades, as the population increased in the area, people were forced to live closer and closer to the storehouses without any knowledge of the health hazard this implied. With no paved streets or running water (Figure 3), Puerto Nuevo is an ideal place for diseases associated with poor sanitation, of which the lead problem is just one. Puerto Nuevo also is now a very violent and dangerous neighborhood, with drug addicts and thieves roaming the streets after sunset. To date, attempts to maintain a police station there have failed. Daily, the undernourished children living in Puerto Nuevo face many more dangers than those posed by lead.

**Figure 2. Puerto Nuevo in Callao, 1999**

**Figure 3. Street and Houses of Puerto Nuevo, 1999. Courtesy of DIGESA**

## 1.4. DIGESA's Role

The Peruvian Ministry of Health's General Directorate of Environmental Health (DIGESA) is in charge of monitoring and studying the characteristics of the environment that can compromise the health of Peruvian residents. Thus, DIGESA has divisions oriented toward the study of ecology, environment, foods, sanitation, occupational health and zoonosis. By decree of the Peruvian legislature, however, DIGESA (unlike its counterparts in other countries) lacks the ability to sue, fine or tax any institution or person. Its range is limited to studying a case and submitting the results to the proper authorities. In a case involving a company producing health effects but not itself health related (and therefore under the authority of the Ministry of Health), the proper authorities would be in another corresponding ministry, over which neither DIGESA nor the Peruvian Ministry of Health have any authority. In much the same way, the Ministry of Health can remain elusive to pressures or interests from other Peruvian ministries.

In 1997, the Environmental and Natural Resources Office in the U.S. Agency for International Development (USAID)/Peru contacted DIGESA as its local counterpart in implementing a program to phase out lead from gasoline in that country. This collaboration included the following:

- Technical assistance by Dr. Mauricio Hernández-Avila, who collaborated with DIGESA to prepare a protocol for the baseline study[1] ("Blood Lead Study in Selected Populations of Lima and Callao, Peru") to determine blood lead levels of children and postpartum mothers in the metropolitan area of Lima.

- Technical assistance by Dr. Hernández-Avila to guide and monitor the implementation of the study (particularly from an epidemiological standpoint).

- Donations of equipment (four portable LeadCare units) as well as corresponding supplies to measure blood lead levels during the study and one portable Palintest unit to determine environmental lead levels (in the air, water, soil, paintings, etc.).

- Technical assistance by Dr. Steven Wegner from AndCare Inc., to train DIGESA personnel in the use of the donated equipment.

In June 1998, during the delivery ceremony of lead monitoring equipment donated by the USAID to DIGESA, the Peruvian vice minister of housing publicly announced a strategy to gradually eliminate lead from gasoline before the year 2004. As part of the program to remove lead from gasoline, the Peruvian government proposed the implementation of a blood lead survey to evaluate current lead exposure in Lima and to obtain baseline data to monitor changes in blood lead associated with the phase out of lead. A USAID-funded study was designed by Dr. Mauricio Hernández-Avila to be carried out by DIGESA to determine blood lead levels in probable high-risk populations.

Between July 1998 and March 1999, DIGESA conducted a study on young children and women to assess possible problems with blood lead poisoning. A total of 2,510 children, ages six months to nine years, and 814 early postpartum women living in Lima and Callao were studied to determine potential sources of lead exposure and health effects. This baseline study[1] identified unexpected critical areas with severe lead contamination in Callao.

Following the results of that study, DIGESA, EHP, and USAID agreed to design a follow-on phase entitled, "Peru Lead Project Phase II: Further Analysis of Lead Contamination, Pediatric Lead Poisoning, and Interventions to Reduce Lead Exposure in Lima and Callao." The purpose of this study was to identify clearly the source of lead exposure and to solve the problem in a participatory manner.

In designing the work plan for Phase II, DIGESA determined that further sampling should be considered. The project activities were designed to provide DIGESA with stronger evidence regarding the sources of lead in the area in order to establish the role and responsibility of the companies involved in the storage of minerals. Because mining is such an important activity in Peru, an environmental soil sampling study was needed to provide scientific evidence that would assign responsibility to the mining companies and demand containment of the contamination. Such a study would also provide a strong technical foundation for future regulatory and control activities implemented by DIGESA to prevent lead exposure in Callao or other areas with similar exposures.

The National Society for Mining and Petroleum (SONAMINPET) is a Peruvian organization that represents various mining companies in the country. Four mining companies own the storage sites in Puerto Nuevo, Callao, and other companies rent the space waiting for shipment. This society would normally represent the interests of the mining private sector in addressing the lead problem, but most of the local mining companies belong to larger multinational companies, and USAID's Mission in Peru decided that they too should be invited to participate in solving the Puerto Nuevo problem.

In November 1999, USAID/Peru contacted the executive director of the International Lead Management Center (ILMC) to define and structure DIGESA's interaction with the ILMC. The center presented itself as an independent company, sponsored by major mining companies in the United States, that works in a multi-stakeholder fashion to promote cooperative solutions. The ILMC, founded and sponsored by the lead-producing industry, claims also to have established cooperative links with the industry that uses lead products, for example, oil refining, medical, nuclear, aerospace, automotive, etc. ILMC expertise and advice is therefore available across the full range of issues associated with the production, application, recycling and disposal of lead. In Peru, the ILMC was in a position to facilitate cooperative arrangements with the mining industry regarding engineering solutions to the lead problem, and the actual health issues could be approached as a direct interaction between the ILMC and DIGESA. The industry is committed, through the ILMC, to work with governments, industries and the international community to manage the risk of lead exposure.

## 1.5. EHP Activities and Work Plan

In April 1999, after several meetings with USAID/Peru and DIGESA, EHP assigned Dr. Mauricio Hernandez and Patricia Billig to prepare the work plan for the second phase of the Peru Lead Project.[5] (Specific details concerning the activities of the work plan are provided in Appendix A.)

The EHP consultant designed the study to evaluate the isotope composition of lead present in the blood of children living in the Puerto Nuevo area and in other control areas in Lima. A full study protocol had to be developed for approval by the Institutional Review Board at CDC, including the sampling methodology for 50 children with known blood lead concentrations (high and low) from schools inside and outside Callao. The study also attempted to determine the relative contributions of water, soil and dust as sources of lead contamination in Lima and Callao.

The original work plan was still a draft at the time the local coordinator was hired in November 1999. One of the first tasks of the local coordinator was to revise and complete a plan of action based on the work plan produced in April 1999 and revised in September 1999. However, based on the original corresponding timeframe of six months to conclude the second phase (which eventually took longer) and in order to achieve the desired results to the extent possible, some activities had to be withdrawn and others redesigned in their implementation while retaining their original purpose.

While the work plan contemplated that most of the activities would be sponsored by USAID, sponsors had to be found for some of the activities. As the second phase of the Lead Project progressed, six of these activities required outside funding.

The only pair of activities still pending by the time the project officially concluded in 2001 were interventions to reduce ingestion of soil contaminated with lead and nutritional interventions to decrease lead absorption and treat iron deficiency. The Behavior Change Program activity, which was designed to reduce individual exposure to environmental lead, took much more time and funding than originally expected, and its final stages are included in the new Environmental Activity that USAID initiated with DIGESA in 2001 following the Lead Project Phase II experience. The Nutritional Supplement Study, which aimed to address iron and calcium supplementation to diminish lead absorption in children, had to be redesigned in March 2001 and eventually became part of the Behavior Change Program in the form of healthy nutrition guidelines that will be presented to the community. This change resulted from the discovery that supplementary nutrition is not the best way to deal with malnutrition issues in the long term.

## 1.6. Organization of Report

This report consists of six chapters, including this introduction. Chapter 2 discusses the activities undertaken during the project to clarify the sources of lead contamination. Chapter 3 provides more detail concerning the magnitude of the problem of lead contamination in specific areas in Peru. Interventions that could help reduce exposure to lead are discussed in Chapter 4. Chapter 5 addresses the types of training and capacity building needed in this area to effectively address lead contamination. Finally, Chapter 6 offers any conclusions and recommendations resulting from this project.

# 2. Clarifying Sources of Lead Contamination

Identifying the correct sources and pathways of lead in the environment and in humans is fundamental to the implementation of the most cost-effective remedial actions. One of the most valuable results of Phase I of the "Blood Lead Study in Selected Populations of Lima and Callao, Peru" was the identification of an area near the port of Callao where the population had abnormally high blood lead levels. Leaded gasoline is a known source of lead contamination in countries like Peru, where it is still used as an antiknock agent to boost octane, but it seldom causes blood lead levels as high as those found in Callao. Other possible sources of contamination in this area (such as informal battery recycling or smelting) usually account for a small exposure area (for example, a single family) and usually do not account for contamination of an entire community. Mineral storehouses located within the district of Callao (Figure 4) constituted the next most probable source.

**Figure 4. Mineral Storage Areas near Puerto Nuevo in 1999. Courtesy of Maurio Hernández-Avila.**

## 2.1. Methods Used to Identify Sources and Pathways of Contamination

### 2.1.1. Environmental Sampling Study

During Phase I of the Lead Project (the baseline study) in March 1999, the senior environmental health scientist for the National Center for Environmental Health (NCEH) of the CDC and the EHP consultant from the Mexican National Institute of Public Health (INSP) took soil samples during their visits to the mineral storehouses. The DIGESA laboratory in Lima analyzed these initial samples for lead concentration and sent them to the CDC laboratory in Atlanta, Georgia, for isotope determination.

In the work plan design of Phase II, DIGESA determined that it was necessary to complete the environmental sampling study begun in Phase I so as to provide stronger scientific evidence regarding the sources of lead in the area. Such evidence was needed in order to establish the role and responsibility of the companies involved in the storage of minerals there. Because mining is such an important activity in Peru, this experience would also provide a strong technical foundation for future regulatory and control activities implemented by DIGESA to prevent lead exposure in Callao or other areas with similar exposures.

It was determined that the EHP consultant would design the sampling strategy, while DIGESA personnel took charge of the field samples. To better understand the problem posed by the mineral storage areas, DIGESA would request information from mining company records regarding origin, quantities, time of storage and type and composition of mineral concentrates, as well as the procedures used for the transportation of minerals within the area.

Peru ranks fourth as a “primary” lead mining country. Understandably, the mining sector is a very powerful economical and political stakeholder, and initial reluctance within this sector to accept responsibility for possible contamination was not surprising. Nonetheless, DIGESA acknowledged from the beginning that these mining companies would have a critical role in the implementation of remedial actions, very probably at a high economic cost for their companies. Having the best scientific evidence with a high degree of certainty would allow those representing the population at risk to overcome potential resistance by the mining companies. The initial results DIGESA discovered emboldened other local actors to appear during the two years of the second phase of the Lead Project. Community representatives, municipality officials, local health officers and even Peruvian congressmen all relied on the results of the environmental sampling study of the Lead Project Phase II to assign responsibility to the mining companies and demand containment of the contamination.

The expected results from the environmental soil samples were as follows:

- The demonstration of high lead values in soil and dust in Callao would provide the scientific rationale to support educational interventions aimed at reducing exposure by decreasing human contact with soil or dust having a high lead-content.

- A written report (endorsed by CDC) establishing a positive association between these deposit areas and lead in the blood of the population would be a valuable tool for DIGESA to use to persuade other organizations to reduce lead exposure in Callao.

## Summary of Activities

Since the mining companies must authorize the collection of extra samples and provide information on movements of minerals within the storehouses, DIGESA decided that institutions must establish an official approach. DIGESA's Director for Ecology and Environment was responsible in November 1999 for contacting SONAMINPET to request proper authorization to take samples from inside the mineral storehouses, as well as to request information on the mineral flow through the storehouses. In January 2000, SONAMINPET finally answered DIGESA's request, but the organization refused to authorize the sampling. DIGESA sent a letter to each of the four individual storehouse owners asking for information on mineral flow and permission to sample the soil inside. In February, DIGESA started to receive information on mineral flow from two of the mineral deposits, and the EHP consultant's visit to design the sampling strategy and take the samples was postponed from January to May 2000.

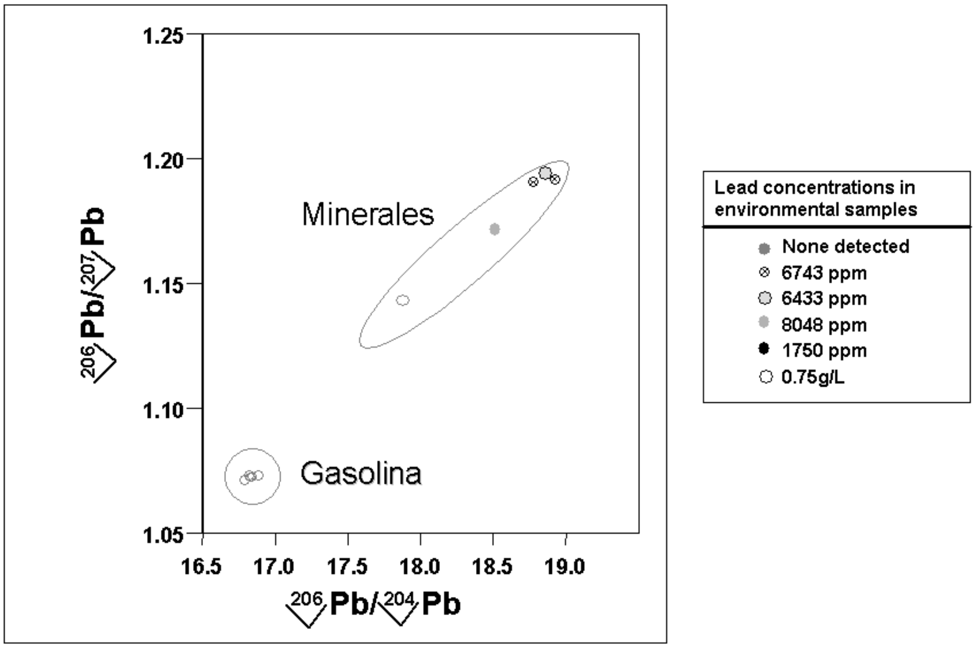
On May 5, DIGESA collected the first set of samples from inside the CENTROMIN storehouse, one of the mineral storage areas near Puerto Nuevo. Further sampling from another mineral storehouse and other port sites was undertaken by the EHP consultant and DIGESA personnel on May 18. The University of California, Santa Cruz, analyzed these new samples. The EHP consultant then analyzed all the data and presented the first draft of his report to DIGESA on July 4, 2000. Authorities at DIGESA revised the document, and on August 24 they cleared it to be sent to EHP for publication. On September 6, the Peru Mission of USAID revised the report as well. A printout was corrected and mailed by the local coordinator to the EHP activity manager on October 12. The final printed version of Activity Report 104 [6], which summarizes results for Activities 1.1, 1.2, 1.4, 1.5 and 2.1 (see Appendix A) and also includes the analysis of the environmental sampling study, reached USAID/Peru in January 2001.

CDC developed its own report based only on the lead isotope analysis, which established the association between lead in the soil and in storehouses with lead in the blood of the population.

## 2.1.2. Lead Isotope Composition of Environmental and Gasoline Samples

A second activity in the Lead Project Phase II sought to establish any associations between the lead in blood and the lead isotopic composition of environmental and gasoline samples.

Lead consists of four natural stable isotopes ($^{204}$Pb, $^{206}$Pb, $^{207}$Pb, and $^{208}$Pb). The relative abundance of each isotope varies from one lead ore to another and is determined by the time of lead formation in that ore. Therefore, the percentage of each type of isotope in any given lead source provides an identification of the mineral lead from that source. Because isotopic ratios remain constant, it is possible to measure lead isotope ratios from different sources and to compare these ratios to the isotope ratio of lead in blood to evaluate the contribution of potential sources for human exposure. Such identification assumes that the ratios of the probable sources being compared are different (Graph 1). In other words, if sources have similar backgrounds, the analysis remains inconclusive. Also, results can become uncertain when the sources of lead are mixed within a sample, as may be the case in soil or blood samples. The tetraethyl lead compound produced in Australia, for example, is the source of lead in Peruvian gasoline, but mineral piles at the port of Callao come from mines in the Peruvian Andes, a completely different ore formation from a different continent.



**Graph 1. Lead isotope ratios for mineral and gasoline samples.**

The NCEH environmental health scientist and the EHP consultant took the first set of soil samples during their visits to the mineral storehouses in March 1999 as part of the Lead Project Phase I. Isotope compositions of those soil and dust samples from Callao (from inside and outside the mineral storage areas), samples from other control areas not in Callao, and samples from gasoline used in Lima in 1999 were all evaluated for isotopes at the CDC laboratory.

Within the U.S. government, the Environmental Protection Agency (EPA) or the agency's contract laboratories normally analyze water, soil, paint, gasoline and air filters for environmental contaminants. CDC usually only analyzes a few selected materials for rapid evaluation of the source of lead or other environmental toxicants entering humans. The analysis of the Peruvian samples was possible through an interagency agreement between USAID and CDC.

There are two separate procedures for measuring lead in gasoline:

1. Measurement of the lead isotope ratios in gasoline by nitric acid extraction (rarely done by the CDC).

2. Determination of the total lead content in gasoline (not done at the CDC).

The EHP consultant designed the study to evaluate the isotope composition of lead present in the blood of children living in the Puerto Nuevo and in other control areas in Lima. A full study protocol had to be developed for approval by the Institutional Review Board at CDC, including the sampling methodology for 50 children with known blood lead concentrations (high and low) from schools inside and outside Callao. Children living outside Callao would be the control group (where lead in gasoline should be an important contaminant) to be compared with the exposed group composed of children living in Puerto Nuevo (where mineral lead from the storage areas would be the primary exposure source). Of course, children in Puerto Nuevo also would be exposed to lead in gasoline, and children outside Puerto Nuevo should not be exposed to mineral lead, two factors that had to be taken into account when performing the analysis.

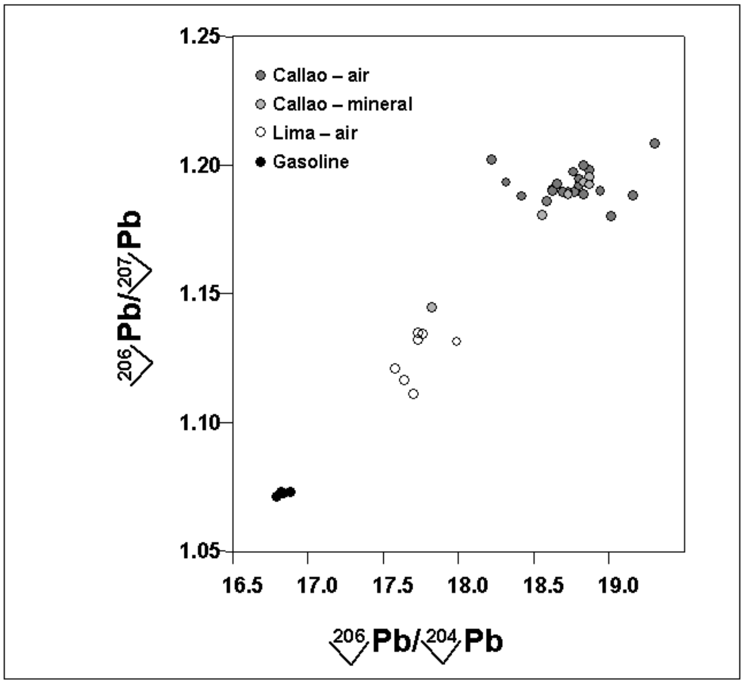
The expected results of the lead isotope activity were the following:

- Lead isotope ratios both from soil samples within and around the mineral deposits and from gasoline samples could be related to lead isotope ratios in blood samples, thus differentiating the source of lead in people.

- A written report (supported by the CDC) that could identify soil and dust as the major sources of lead contamination for the population in Callao could conclusively resolve any differences of opinion and fix responsibility for lead contamination in the port area.

## Results of Activity

Environmental and population sampling for this activity concluded in June 1999, before the arrival of the local lead coordinator for the project. The first results of the CDC report arrived at DIGESA in March 2000. The results, reviewed by DIGESA and returned to the CDC for the final report, clearly linked the lead of the mineral concentrates with that of the children with high blood lead values in Callao. This difference was statistically significant. Though less conclusive, the results also linked the isotope lead ratio in mineral concentrates with that of children with low blood lead values who do not live in Callao, implying that children outside Callao also had traces of mineral lead in their blood, though none had the high blood lead levels found in Callao. Furthermore, air filter samples (which the CDC also analyzed, though they were not included in the isotope report) also gave valuable insight into the complexity of the problem. First, the samples differentiated the air from Lima from the air from Callao, meaning their primary lead contamination sources were different. The mineral isotopic pattern found in Callao resembled more that of mineral lead, while the city of Lima (as a whole) showed a mixture of both mineral and gasoline patterns (Graph 2).

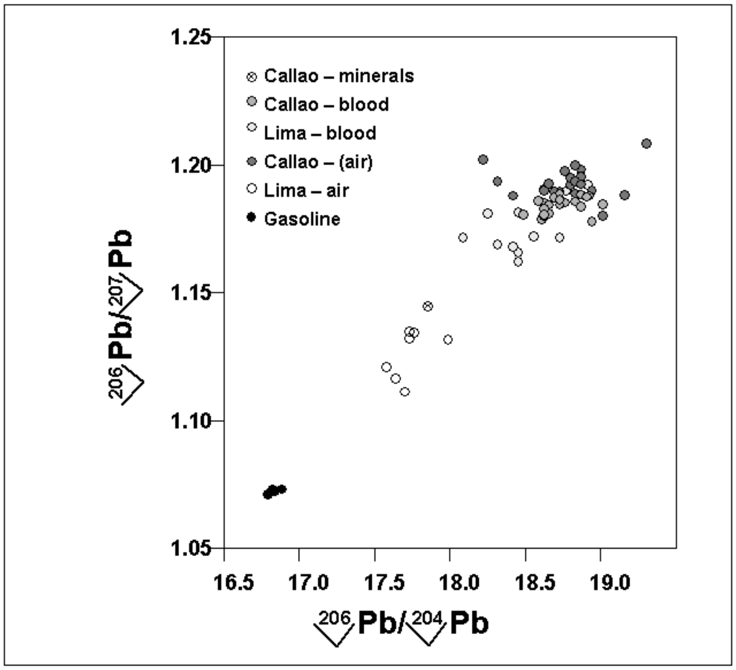


**Graph 2. Lead isotope ratios for air samples in Lima and Callao.**

The filter samples also associated lead in the air from the port of Callao with lead in the air from the district of Comas, a district of Lima farther inland from the port area. The initial response to this result suggested a potential cross-contamination of the filters. During his visit to Lima in May 2000, the EHP consultant took new as well as stored samples from Comas to confirm the new evidence. The University of California, Santa Cruz, analyzed these additional samples from Comas, and the results showed that mineral lead composition in the samples from Comas had an isotope ratio similar to that observed in the minerals from Callao, but the lead content found in Callao (7.5 µg/m$^3$) was much higher than that found in Comas (0.5 µg/m$^3$). Though the two areas probably shared some similar sources, Callao was far more heavily contaminated. These results were unexpected, but they do not contradict the original hypothesis that mineral lead (and not leaded gasoline) accounted for the primary source of lead exposure in the population of Callao. The results do, however, indicate a larger environmental lead contamination problem in Lima, which will require further investigation.

The lead isotope activity resulted in the following conclusions:

- Lead in the air in Lima is different from lead in the air in Callao.
- Lead in the air in Lima is different from lead in minerals.
- Lead in the air in Callao is similar to lead in minerals.
- Lead in the air in Lima and lead in the air in Callao were different from lead in gasoline.
- Lead in the air in Lima was different from lead in the blood of both the exposed (Callao) and the control (Lima) groups (Graph 3).
- Lead in the air in Callao was different only from lead in the blood of control children.
- Lead in the blood of the exposed group was different from lead in the blood of the control group, lead in gasoline, and lead in the air from Lima.
- Lead in the blood of the exposed group was not different from lead in minerals or in the air from Callao.
- Lead in the blood of the control group was different from lead in gasoline, lead in the air in Lima and Callao and lead in minerals.



**Graph 3. Lead isotope ratios for blood samples from Lima and Callao.**

## 2.2. Creating a Geographic Information System

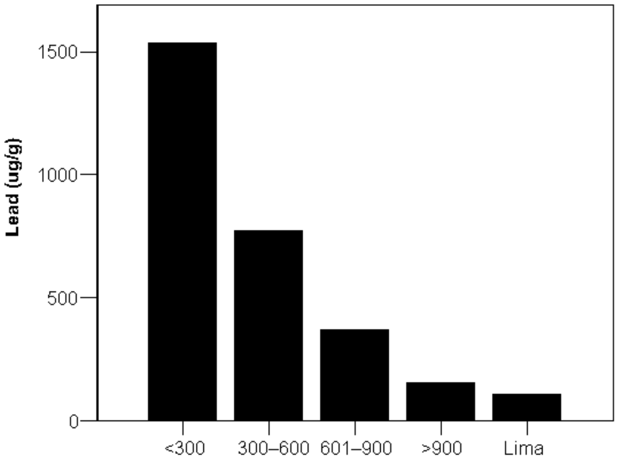
Results from Phase I of the Lead Project showed a strong inverse correlation ($r = -.62$, $p < .01$) between the distance from the mineral storage area and the concentration of lead in dust samples (Graph 4). A similar pattern was observed when investigators used a map to plot the locations of the schools attended by the children in the study: the closer the storage area to the school, the higher the blood lead level of the children. The mean blood lead level of children decreased as the distance between school and mineral storage areas increased. This proved to be strong evidence that the mineral storage areas were the source of lead contamination. It also suggested that the contamination might spread geographically. As a result, it was determined that one of the activities for Phase II should be the creation of a geographic information system (GIS) for Callao to search for geographical patterns of contamination.

GIS can be defined as a computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the earth's surface. GIS consists of graphic data in the form of points, lines and areas that are linked to attribute information stored in a relational database. The data are formatted into visual structures, or maps, to facilitate their interpretation. GIS maps are represented as several different layers, each of which holds data about a particular feature that is linked to a position on the map. This simple combination of two types of information results in a very powerful tool for environmental analysis.

The expected results of this activity were the following:

- The design of a GIS for the Callao area would increase analysis capabilities and improve understanding of the lead contamination problem. This would be a first step in developing the use of this analysis tool for DIGESA.

- The EHP consultant would use this tool to confirm and present the characteristics of lead contamination in the area of Puerto Nuevo in Callao.



**Graph 4. Lead Concentration in Soil and Distance to Nearest Storage Area**

Four local contractors were contacted by the local lead coordinator to develop the GIS tool, and in January 2000, DIGESA's deputy director and computer department chief selected one on the basis of readiness to deliver the product and the cost. Though the contractor was ready to begin work in January 2000, data files from DIGESA were unavailable at that time. New databases had to be developed from written records at DIGESA and given to the GIS contractor in February. However, some incomplete data could not be retrieved successfully. In total, over 1400 records (including dust, soil and blood samples) were geographically referenced (associating record value to a geographic position on the map). The task took two months, and the official presentation of the GIS to DIGESA took place on April 4, 2000.

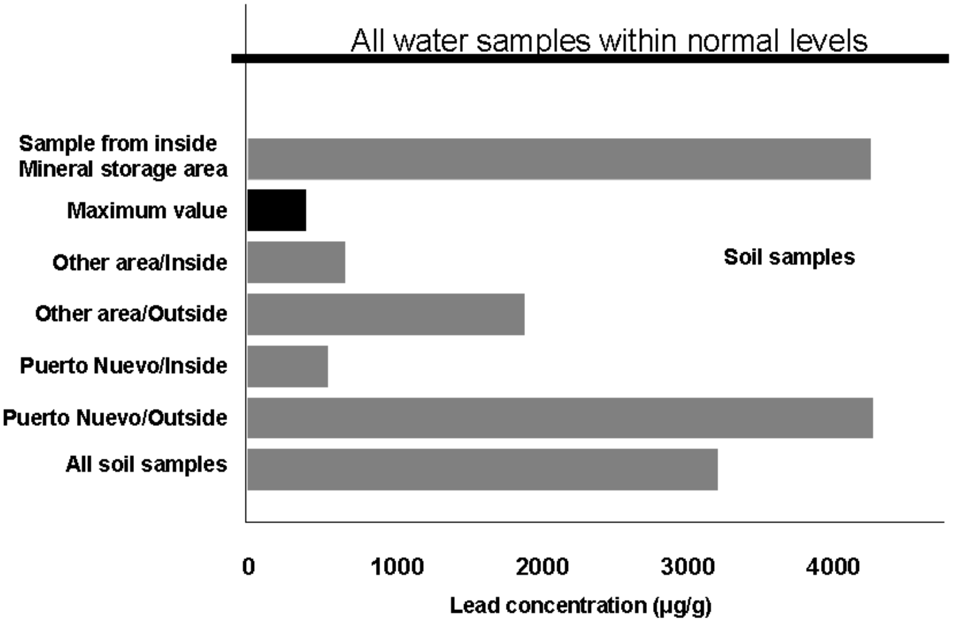
As a result of this activity, the contractor developed the following:

- A digital map of the Callao and La Perla districts, presented in blocks with street cartography.

- Theme layers, including schools, gas stations and green areas (parks).

- Geographic references for 1,410 registries from DIGESA's database to the digital map (Graph 5 and Figure 5).

The EHP consultant used this tool to confirm and present the characteristics of lead contamination in Callao in Activity Report 104 [6].



Graph 5. Lead concentration in soil and distance to nearest storage area.

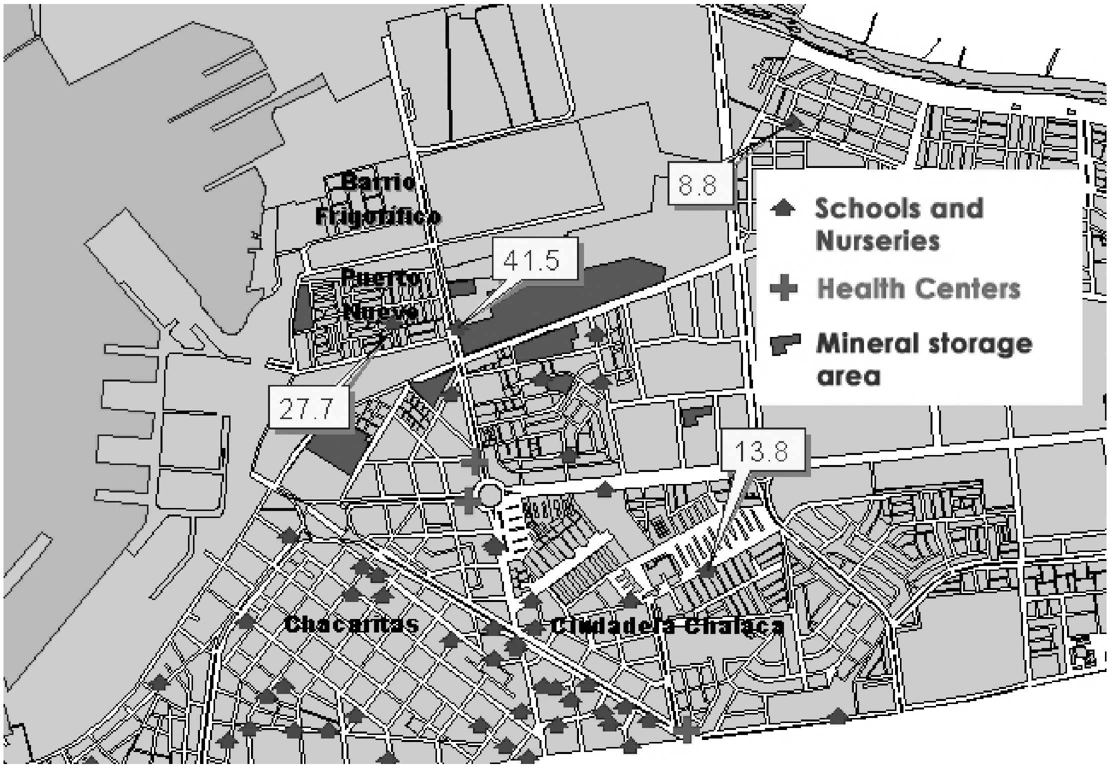


Figure 5. Average blood lead levels in children, grouped by school, 1999. Courtesy of Carlos Sanchez.

## 2.3. Assessment of Lead Exposure Pathways

Lead does not occur naturally in humans. Rural populations have low levels of lead intoxication or even none at all. Known sources for inhalation of lead particles include motor vehicle exhaust from leaded gasoline, smelters, lead manufacturing industries and battery recycling industries. Although inhalation is the most common pathway in adults, suspended particles eventually precipitate as dust on food and soil, where they can find their way into the humans by ingestion. Lead-glazed cookware, lead-based paint and herbal remedies have been described as other sources for ingestion of lead. Lead-soldered water pipes have been identified as a source for lead contamination in drinkable water.

The dry climate of the Pacific coastline of Peru and the lack of water pipes and paved streets in areas like Puerto Nuevo suggested lead in the environment might be concealed in the excessive amount of dust that is continually scattered by the wind, but the entire exposure pathway of lead particles in Puerto Nuevo was undetermined. The environmental sampling study was completed by June 1999, with 224 environmental samples of dust, soil and water collected in the vicinity of the storage areas in Callao for lead analysis.

The purpose of this study was to determine lead concentrations in different sources of lead exposure in Lima and Callao and, as a result, be able to determine the relative contributions of water, soil and dust as sources of lead contamination. The expected results of the activity were as follows:

- Information from this activity would help to assess the relative contribution of dust, soil and water to the high blood lead levels observed in Callao.

- The demonstration that lead content is low in water but high in soils from Callao, while lead content in soils in other parts of Lima remain low, would support the hypothesis that the local mineral concentrate storage areas are the exposure source.

- Information would be used in a written scientific report that discounts water as a source of lead poisoning and supports soil and dust as major environmental pollutants.

### Summary of Activities

From the sample group who participated in the original blood lead survey, 54 children were selected randomly from the following three groups: (1) children with blood lead levels below 10 µg/dL, (2) children with levels between 20 and 40 µg/dL, and (3) children with levels over 40 µg/dL. These children were contacted, blood samples were taken by DIGESA personnel and the samples were sent to the CDC laboratory in September 1999 for blood lead determination. These blood samples also were tested for isotope lead composition at the CDC laboratory for Activity 1.2, Lead Isotope Composition of Environmental and Gasoline Samples.

DIGESA personnel conducted complete interviews with the selected children at their homes to determine common potential environmental and behavioral exposure sources. Prior to November 1999, 254 interviews had been conducted to identify risk factors. To complete the study, during November and December, parents of children from Maria Reiche School in Puerto Nuevo were interviewed by DIGESA personnel and asked to fill out environmental (109 children) and psychological (90 children) questionnaires. DIGESA prepared the data from the interviews and questionnaires for analysis by the EHP consultant during his trip to Lima in May 2000.

## 2.4. Lessons Learned

The activities conducted during Phase II resulted in the following conclusions:

- Overall data suggest that mineral lead is the source of lead contamination in Callao, but it also may contribute to a lesser extent to the lead found in the air in Lima. Lead in the air in Lima resembles a combination of the lead in gasoline and lead in minerals. These findings are important because they suggest that minerals may be contributing more to the lead found in the air in Lima than DIGESA originally expected.

- The huge piles that lie within the mineral storehouses represent the major source of lead contamination of the soil and of the population in the port area of Callao.

- DIGESA lacks authority to arbitrarily take samples in private companies except in emergencies.

- Lead in soil and dust that does not come from gasoline can be found in at least one other site outside Callao (the district of Comas). The possibility that lead contamination from minerals extends to other areas inland of Lima needs to be evaluated.

- Lead present in dust and soil is the most probable exposure pathway for children (due to their normal hand-to-mouth activity) living near the storehouses.

- Higher blood lead values were associated with living closer to mineral storehouses in Callao.

- Other zones around the mineral storage areas (like Ciudadela Chalaca) also have high blood lead levels and need further study (see Activity 2.1 in Appendix A).

- Water was discounted as a potential source of lead contamination since all water samples were below 7 ppm.

- Lead concentration in 42 dust samples was high, and 30% of these samples were above the 500 ppm maximum recommended value, with a 258 ppm geometric mean.[6]

- Dust lead concentration was higher inside houses close to the mineral storehouses.
- In the interviews, hand-to-mouth activity was associated with an increased blood lead level in the study population, especially among children under four years of age.

# 3. Estimating the Magnitude of the Problem

Important stakeholders in the reduction of lead exposure in Callao include both the local community (including residents of Puerto Nuevo, Chacaritas, Ciudadela Chalaca and Frigorífico) whose health is currently being affected and workers in the storage areas who do not live in Callao but who come to work every day, are in direct contact with the ore piles and may get the lead dust on their clothes or in their hair. High blood lead levels observed in the community during the initial baseline study suggested that workers at the storage areas also could be at an increased risk of exposure to lead. The first results from this study came out in March 1999, and by the end of that year some changes had taken place at the storage areas. Higher fences and covered and moistened ore piles, as well as filter masks for the workers (Figure 6) were the initial responses to the recently acknowledged environmental lead contamination problem, but these measures are not sufficient to contain the source or affect the lead that already exists in dust outside.

The activities associated with Lead Project Phase II that are described in this chapter were designed to clarify the extent of the problem while providing some baseline information for measuring the effectiveness of any later program. One of the activities proposed was an occupational assessment to survey workers at the storage areas and at the port facilities (where mineral concentrates are handled) for blood lead levels and occupational risk factors. The purpose of the study was to evaluate the occupational risk of exposure to lead for lead smelter workers while at the same time gain evidence that might further support the concept that these mineral concentrates are the major lead contamination sources for populations living near and working in the mineral storage areas and amplify the importance of their containment. Documentation of high exposure in this working population would add credibility to the hypothesis that manipulation of mining concentrates in the storage area is a source of exposure to lead intoxication.

**Figure 6. Storage area in May 2000, showing higher fences (1), covered and moistened ore piles (2), and workers in filter masks (3). Courtesy of Carlos Sanchez**

## 3.1. Identifying Neighborhoods at Risk

During the initial blood lead survey, concern was aroused when abnormally high values of lead were found in the blood of children living near mineral storehouses in Puerto Nuevo. A study questionnaire was prepared to determine the presence of mineral concentrate near dwellings. Children whose parents reported the presence of storage areas near their houses had, on average, blood lead levels in excess of 13 µg/dL. Current CDC guidelines recommend a public health intervention when blood lead levels reach 10 µg/dL[7] (see Appendix C). Living near these areas was associated with an 18-fold increase in the risk of having a blood lead level higher than 10 µg/dL.[6]

During meetings with the mayor of Callao and community representatives from other areas near the storehouses, it became clear to DIGESA that at least three other neighborhoods (Chacaritas, Frigorífico, and Ciudadela Chalaca) also could be affected by the same storage areas. Since DIGESA is in charge of blood and environmental sampling in these areas and given the potential for lead exposure, DIGESA decided to extend the blood survey to these communities.

In August, DIGESA collected blood samples from the various communities, including 104 samples from Chacaritas, 51 samples from Frigorífico and 100 samples from Ciudadela Chalaca, and sent them to the CDC for analysis. Results from this study were made available by DIGESA as a database and were fed to the GIS prepared by the contractor in the previous activity. Environmental sampling results and risk factors for these populations were also fed by DIGESA into the GIS for further analysis. Results of the sampling indicated that, with a blood lead median of 25.2 µg/dL, Ciudadela Chalaca, a neighborhood southeast of Puerto Nuevo that contains mineral storehouses, could be exposed to lead contamination at the same blood levels as Puerto Nuevo (Figure 7).

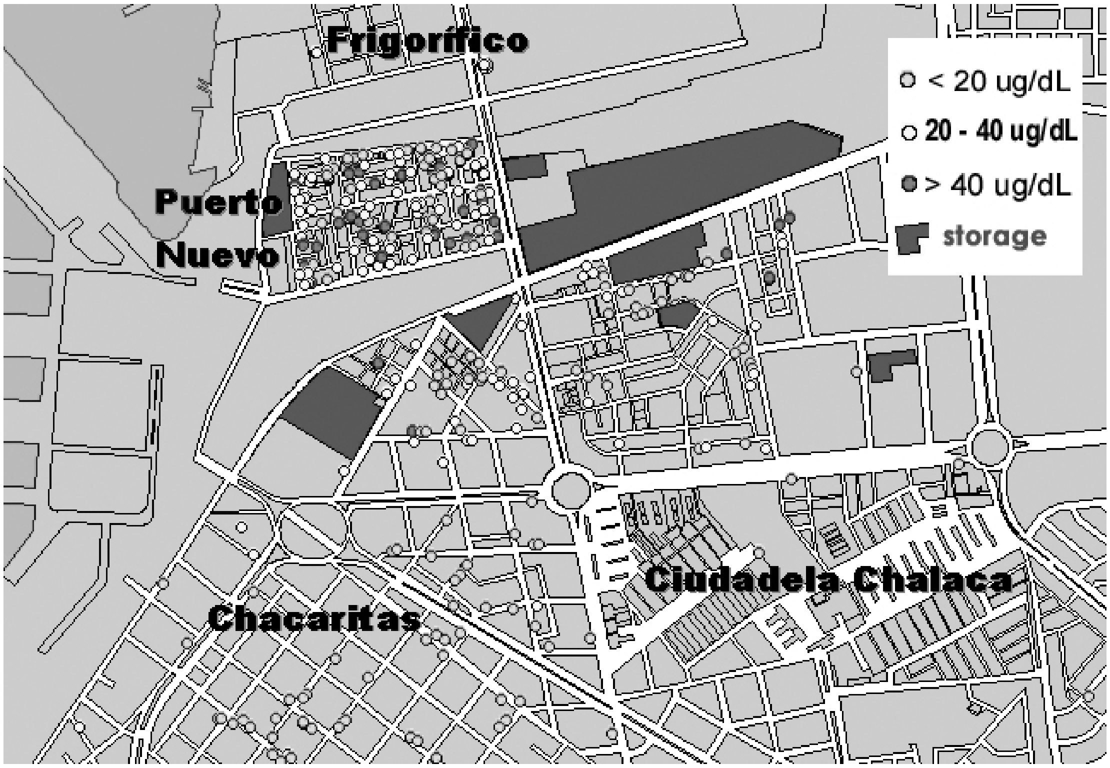


**Figure 7. Blood Lead Levels in Children, by Home Address. Courtesy of Carlos Sanchez**

## 3.2. Determining Occupational Exposure

In the 18th, 19th and 20th centuries, the worst outbreaks of lead poisoning of adults were occupational in origin. It became common knowledge that to work in an industry where lead was handled was certain to make a person sick or worse. These workers absorbed lead from inhalation of fine lead dust or fumes, from contaminated food eaten at the workplace, or by absorption through the skin. Charles Dickens describes in his essay "Star of the East" the horrible effects of lead poisoning on a woman working in London's infamous white lead mills: "[H]er brain is coming out her ear and it hurts her dreadful…." In 1763 Benjamin Franklin wrote about the "dry gripes" (colic) and "dangles" (wrist drop), which affected tinkers, painters and typesetters.[3]

While the national mean blood lead level in the United States has declined significantly in recent years, occupational exposures can still be found, but severe intoxication is rare. In developing countries, however, occupational exposure to lead remains a big problem.

One of the activities during the Lead Project Phase II was to study the risk of exposure to lead for workers in storage areas. The activity was supposed to involve an occupational assessment that would survey workers at the storage areas and at the port facilities (where mineral concentrates are handled) for blood lead levels and occupational risk factors. However, the DIGESA Occupational Health Division had little field experience with lead-exposed workers. Private enterprises are not obliged to allow DIGESA inside their facilities unless an outbreak (an emergency) occurs, so few companies would actually open their doors to government officials to perform studies on their workers. DIGESA made several attempts to contact mining companies that used the mineral storage areas with little success. USAID/Peru proposed to get the ILMC involved in this process, since many local companies were actually representing larger international enterprises.

It was under these difficult circumstances that DIGESA chose to support an occupational study on lead contamination that the CDC was crafting in Peru. In 1999, the CDC conducted a study called “Evaluation of a Portable Blood Lead Analyzer with Occupationally Exposed Populations,”[8] which aimed to prove that a portable electrochemical lead analyzer called LeadCare could be used effectively in a population exposed to high concentrations of environmental lead (for example, smelter workers), provided that venous (as opposed to capillary) blood is used.

LeadCare was originally designed as a fast, simple, and cost-effective method to survey inner-city children exposed to lead. It analyzes finger stick blood, which is an advantage in working with children but is an approach that supposedly cannot be used in populations exposed to high concentrations of environmental lead because the skin can become heavily contaminated and throw off the blood lead value.

The first phase of this study took place in July 1999 in a battery-manufacturing facility in the state of Missouri. LeadCare analysis of venous blood in these Missouri workers found that the workers had blood lead values between zero and 42 µg/dL. Comparison of the LeadCare results with the gold standard laboratory lead analysis proved the instrument to be accurate within this range. The next phase was to validate LeadCare analysis of venous blood in workers with higher blood lead levels. Because it is difficult to find such populations within the United States, the CDC contacted the Doe Run Perú laboratory to conduct the study in the company’s smelter in La Oroya (four hours west of Lima, in the Andes). The CDC selected 235 workers for the study based on their previous blood lead values recorded by the Doe Run laboratory.

DIGESA supported the CDC study with the aim of testing the possibility of using portable equipment to monitor highly exposed workers. Its support of the study did not directly affect the Lead Project’s work in Callao, but the study findings on LeadCare could have an effect on future studies and monitoring for DIGESA. Two divisions within the CDC teamed up to study lead-exposed workers: the National Institute for Occupational Safety and Health (NIOSH) and the NCEH, which designed a study to validate the use of the LeadCare instrument in this highly exposed population.

It was anticipated that the project's local lead coordinator would review with CDC the design of the study protocol for future occupational studies. DIGESA would then propose to the mineral companies a study protocol for an occupational evaluation based on the CDC experience.

In January 2000, DIGESA senior staff (including the deputy director, technical advisor and director for ecology and environment) and staff from USAID/Peru met at DIGESA with the executive director and director of environmental affairs for Doe Run and the ILMC program adviser and environmental consultant to review possible ILMC involvement in the Lead Project and to identify assistance mechanisms that ILMC might provide. ILMC offered to support DIGESA in many activities (donation of chelating agents, provision of experts on acute intoxication in children, implementation of proven dust control strategies) and also offered to conduct further studies in the Callao area (environmental risk assessments) at its own expense. Since the ILMC acts upon invitation from governments, it requested a formal letter from DIGESA, which it received in February inviting it to cooperate with DIGESA in assessing the lead problem in Callao.

The environmental consultant in charge of the ILMC program stayed in Lima in March, contacting local stakeholders and reviewing all potential efforts in the area of Callao to coordinate activities for risk reduction. At the same time, ILMC worked with representatives from the mining industry (SONAMINPET) to develop a follow-up program to monitor blood lead in their workers. Doe Run was already running such a program, taking samples twice a year in its smelting factory in La Oroya.

The first meeting between representatives of the Peruvian Ministry of Health (represented by DIGESA's deputy director), the mining industry (represented by SONAMINPET), and other stakeholders took place on May 12 in SONAMIMPET offices, with ILMC representatives acting as moderators. This new committee, called the Round Table because it encouraged participation from all the attendees, agreed to continue meeting periodically to follow up on any measures taken to improve the health of the local community. The community was not included in this initial meeting. During this first meeting there did not seem to be a complete consensus that the mining sector was responsible for the community problem of lead exposure. The mining companies decided individually when they would monitor their workers for lead intoxication, but they made no commitment, not all companies agreed to do so, and they did not offer to share the results with DIGESA. After the first meeting, ILMC drafted a memorandum of understanding to obtain formal (though not legal) commitments from the various stakeholders to work together to resolve the lead exposure problems. This memo, however, allowed any party to leave the table at any moment. This was the closest DIGESA could get to assigning responsibility, but it was not enough.

ILMC met with DIGESA staff once more on May 20, presenting the memo of understanding signed by ILMC and SONAMIMPET representatives. The second Round Table meeting took place on June 19, and by then the lead problem had gone public. This time the mining industry showed more interest in periodically monitoring workers, and it proposed that DIGESA be in charge of the occupational blood lead monitoring program. With this in mind, DIGESA turned to the CDC study. The objective from NIOSH was to look at blood lead levels in workers at the smelter in La Oroya using the LeadCare portable analyzer. If the LeadCare analysis proved successful for workers with high blood lead values, it could mean a more cost-effective approach to monitoring occupational blood lead values in Callao.

In July 2000, a NIOSH team, supported by DIGESA, conducted a study on selected workers at the smelter in La Oroya. The team took venous blood samples from 242 workers, and a LeadCare analysis conducted on site gave blood lead levels between six and 62 µg/dL. The mean blood lead concentration for the LeadCare analyzer was approximately 32 µg/dL. Months later, the mean value at the CDC laboratory using graphite furnace atomic absorption spectrophotometry was 46 µg/dL. There was discordance between the tested instrument and the gold standard. The portable analyzer continued to prove effective in moderate lead exposures,[8] but as the blood level increased (especially after 40 µg/dL), the analyzer had a growing tendency to underestimate. Whether this was caused by the lead in blood or by physiological adaptations of the human organism to high altitude remains to be explained.

DIGESA had been evaluating workers from some mining companies during the latter half of 1999, but it had limited staff and supplies to continue monitoring hundreds of workers for an adequate period. DIGESA's director for ecology and environment eventually declined sole responsibility for monitoring blood lead in occupational workers and suggested individual financing from each company. At consecutive Round Table meetings, members discussed other funds to continue monitoring the workers. Since the portable analyzer was no longer an option at this point, the idea of doing an occupational study within the Lead Project was abandoned.

## 3.3. Summary of Findings

Despite the difficulty in obtaining accurate blood lead exposure information, these activities resulted in several useful findings:

- Few mining companies adopted periodic blood lead evaluations of their workers.
- In moderately exposed populations (blood lead levels below 42 µg/dL), the LeadCare analyzer proved useful and accurate using venous blood[8] (see Appendix B).
- For highly exposed populations (over 42 µg/dL) in La Oroya, underestimation increases directly with the blood lead value.
- Funds to monitor health effects of high exposure on workers must be a continued responsibility of the mining company.

- Although ILMC and other mediating institutions funded by multinational mining companies are generally not trusted by the government sector, they have proven to be crucial in establishing communication with mining groups in Peru.

- Zones near the port of Callao containing mineral storage areas have high levels of environmental lead contamination associated with high levels of lead in the blood of their populations.

- With a blood lead median of 25.2 µg/dL, Ciudadela Chalaca could be exposed to lead contamination at the same blood levels as Puerto Nuevo.

# 4. Interventions to Reduce Lead Exposure

## 4.1 Range of Interventions Needed

Puerto Nuevo is a heavily lead-contaminated zone for children. High blood lead levels among children living close to mineral storage areas located near Puerto Nuevo made it clear that action was urgently needed. Based on the conditions that existed in Puerto Nuevo at the time of the study and the daily practices of its residents, Lead Project participants determined that parents, teachers and children in Puerto Nuevo needed an educational program. It was clear that professionally trained individuals would need to intervene to increase awareness of the routes of lead exposure in children and to promote behavior changes among residents to improve their personal hygiene practices and cleaning activities.

The following activities addressed both short-term and long-term measures to control and reduce exposure to lead. Short-term interventions included actions to define the roles and responsibilities of various stakeholders on reducing lead exposure, community educational programs to reduce individual exposure and actions to reduce the absorption of lead by improving the nutritional status of iron and calcium.

### 4.1.1. Hiring of Local Coordinator

The Lead Project Phase II required a full-time professional who would coordinate all intervention activities. Severe budget constraints compelled DIGESA to request complementary funding from USAID/Peru to hire a non-staff professional for this position. EHP was to contract this professional as a consultant. The new professional's duties as local coordinator would involve coordinating activities on a day-to-day basis, serving as a liaison between USAID and DIGESA, identifying all potential stakeholders to define their roles and responsibilities and effectively engaging the stakeholders in the process of defining the objectives and actions for the program to reduce lead exposure in Callao. DIGESA selected candidates based on their technical capabilities and USAID/Peru selected the local coordinator from these candidates. The local coordinator was expected to establish communication links among USAID, EHP, DIGESA and other stakeholders involved in the Lead Project.

### 4.1.2. Interventions to Reduce Ingestion of Soil Contaminated with Lead

As long as the dust in a child's environment remains contaminated with lead, the child will be at risk of chronic intoxication. Children (especially those under five years of age) are highly exposed to lead in dust and soil primarily because of their natural habit of putting fingers, toys and other objects that may be contaminated with dust or soil into their mouths. As early as the 1980s, it was well known that focused dust-control programs could reduce blood lead levels more efficiently than standard lead removal in the home.[9]

During the initial lead study in Peru, interviews with the parents of tested children revealed information regarding behaviors that increased the risk for individual lead exposure. Investigators inquired about children's habits, such as deliberately consuming soil or clay, chewing or sucking pencils, crayons or toys, placing their hands in their mouths and washing their hands regularly. Children who were reported to exhibit any behavior suggesting high hand-to-mouth activity had higher blood lead levels, although only those reported to eat soil and chew or suck on pencils had significantly higher blood lead levels after adjustment for other variables. Eating soil was associated with a mean increase in blood lead concentration of 0.90 µg/dL, and chewing or sucking on pencils was associated with an increase of 0.54 µg/dL.[2] For other children (outside Callao), chewing or sucking on pencils was an important factor only for children living or attending school in Lima, whereas eating earth and washing hands remained significant factors for children living in Callao after adjusting for other important variables. Overall, 12% of parents from Callao indicated that their children ate soil, and this group of children had blood lead levels 3.7 µg/dL higher than those of other children in Callao. Children whose parents indicated frequent hand washing had lower blood lead levels, and frequent hand washing was also associated with an average reduction in blood lead of 1.9 µg/dL among children living in Callao, though no significant difference was observed regarding frequent hand washing for children living in Lima.

Experience has shown that no single activity can effectively reduce a community's exposure to lead. (This was one of the most important conclusions reported during the EPA Lead Remediation Effectiveness Symposium, held May 2000 at Coeur d'Alene, Idaho.) Soil remediation, increased cleaning, access to running water, behavior change and other efforts work more efficiently when they are coordinated. Although controlling the sources of lead contamination, providing access to running water and improving cleaning efforts in the classrooms and homes can reduce lead exposure, community-based interventions also can have important beneficial effects reducing individual exposure. Furthermore, until other measures are implemented, community-based programs may be the only effective intervention.

One of the authors who participated in proposing activities for the work plan[5] for the Lead Project Phase II later outlined to DIGESA the main strategies to be considered and emphasized the value of creating a local advocacy group of volunteers for children in Puerto Nuevo (there was no local NGO operating in Puerto Nuevo at the time). Nearly 300 families in Puerto Nuevo had children less than five years of age. It appeared that there was little essential information available on the health effects of lead in these children. If a trained volunteer group visited these families, it could forge a valuable link between DIGESA and the community, while gathering important information, first to develop and later to monitor a behavior change program.

### 4.1.3. Role of Behavior Change Specialist

A baseline study was necessary to obtain current information about the community in Puerto Nuevo and therefore design an effective behavior change program. Unfortunately, the questionnaire that DIGESA drafted to survey the community failed to provide the needed information. DIGESA needed technical assistance to design this activity and perform the study. As a result, EHP behavior change experts drafted a scope of work to hire a consultant who could assist DIGESA as a behavior change specialist.

EHP proposed a sociologist who was a full-time employee of the Manoff Group—a firm that specializes in behavior change and is part of the EHP consortium—and a native Spanish speaker. The candidate had previously worked with the Peruvian Ministry of Health on behavior change related to nutrition (funded by the World Bank), with positive results, and he was well qualified for the assignment.

The behavior change specialist came to Lima three times during 2000-2001. On the first visit, in August 2000, a multidisciplinary team consisting of physicians, psychologists, a nutritionist, biologist and others from DIGESA was assembled by DIGESA's technical advisor to work with the specialist on the behavior change program. This 12-person team attended daily meetings with the behavior change specialist as he laid the groundwork for formative qualitative research—a methodology that includes surveys, questionnaires, focus groups, one-on-one interviews and field observations to assess the best way to communicate with the community. This methodology emphasizes fully understanding the community before attempting to modify its behavioral patterns. Selection of behaviors to target for change must include consideration of possible barriers (characteristics, such as lack of running water, that constrain the adoption of certain behaviors) and resistance (attitudes, such as tradition or misinformation, that work against the behavior change), as well as media, and must arise from analysis of a previous study of the community, usually on a smaller sample group.

The purpose of this trip was for the behavior change specialist to train the DIGESA team on how to obtain the available information from the Puerto Nuevo community (with appropriate instruments), using surveys, personal interviews and observation of community members' habits, motivations and concerns, as well as their current knowledge regarding lead issues, while recording community resources and identifying potential leaders. It was DIGESA's responsibility to collect and process the information from the sample group and initiate the development of a field manual, guides for interviews, surveys, questionnaires and focus groups.

The behavior change specialist visited DIGESA in January 2001 to assist in the analysis of data collected, review conclusions from the sample study (lists of behaviors, concepts and activities to be promoted, and instruments and materials to be used in the community) and design a draft baseline study that would allow DIGESA to monitor the effectiveness of the campaign in the future. This time DIGESA took its conclusions and ideas to Puerto Nuevo and, using trials of improved behavior, proposed instruments and materials to the community to select those whose implementation and integration into the general strategy for change appeared most feasible. A local artist was hired by EHP to make sketches according to on-site suggestions from the community for drawings to be included in printed materials. This activity proved highly relevant because the artist took ideas regarding colors, settings and framing directly from the community. The purpose of these activities in Puerto Nuevo was to validate the materials and instruments for the community (Figure 8). During this second trip, the behavior change specialist also was able to give a presentation at the fifth Round Table meeting (described above), where he introduced the advances and needs of the behavior change program to the mining representatives.

**Figure 8. Behavior change specialist and artist validating material with the community. Courtesy of DIGESA.**

The final design and production of materials was the responsibility of the DIGESA team, which was now reduced to four people (three psychologists and one social communicator from the original team). The DIGESA team was to finish the visits for the trials for improved behavior, develop educational materials with the local artist, pretest the materials with a sample group and conduct coordination for the baseline study. DIGESA had to continually postpone these activities, however, because of its limited staff, and the team also had to repeat the trials for improved behavior because the original trials were not performed correctly.

The purpose of the behavior change specialist's final trip to Lima in June 2001 was to review new information collected by DIGESA and make final adjustments in the design of the baseline study, the campaign and its follow-up. This process included the training of a community counseling and education team, made up of local residents who would visit families periodically and provide follow-up on the behavior program. Blood lead monitoring and future evaluation would measure any impact on lead exposure in the community. By then, running water would be available in some parts of Puerto Nuevo, and increased hand washing might reduce lead intake in children.

The behavior change specialist was also asked by DIGESA to assist with developing a presentation for the Round Table meeting on August 22, 2001, where the new Lead Poisoning Prevention Program for Callao would be presented to the mining industry, the community and government officials. DIGESA intended to use this presentation to acknowledge the need for additional resources and to seek support from the government and the mining companies represented by SONAMINPET. DIGESA also intended to submit a written proposal to SONAMINPET to explore the possibility of replicating the intervention at La Oroya—a smelting town in the Andes with a severe lead-poisoning situation. The results of these intervention conversations, however, occurred outside the timeframe of this report.

### 4.1.4. Lead-Screening Capabilities for Local Health Centers in Affected Areas

A second intervention involved strengthening DIGESA's capability to respond to local communities' requests for blood lead screening and increasing lead-screening capabilities outside DIGESA.

Blood lead is currently considered the best biological marker for lead exposure. The severity of symptoms associated with lead exposure correlates directly with increased blood lead levels. The goal of screening is to identify children who need individual interventions to reduce their blood lead levels. While the 1991 CDC edition of "Preventing Lead Poisoning in Young Children" called for virtually "universal" screening of children 12-72 months of age, the 1997 edition called for "targeted" (selected) screening as a more efficient secondary prevention activity.[7]

To achieve adequate monitoring of the health status of an exposed community, blood lead screening must be available for all families who wish to have their children tested. Inner-city children in some states in the United States are required to have at least one blood lead test before entering school. Blood lead levels are critical to the success of the educational and counseling programs because family counseling and household interventions are typically based on these blood lead levels. The CDC has set a level of concern at 10 μg/dL and recommends testing children at their one-year checkup or at six months if the child is at risk of high-dose exposure.[7] In Peru, monitoring changes in blood lead levels would be a powerful tool to evaluate the impact of community- and school-based interventions.

USAID technical cooperation in 1999 included training DIGESA laboratory personnel in the use of the LeadCare portable analyzer by AndCare, the company that originally developed the product in collaboration with the CDC. The original concept was that this knowledge could be transferred from DIGESA to local health centers of the Peruvian Ministry of Health so that they could implement their own blood lead screening programs where needed. However, expertise must be accompanied by infrastructure, and this would mean dispersing DIGESA's few portable analyzers with no guarantee that they would be used efficiently. Another possibility would be to set up a reference hospital to which all patients with a given disease or diagnosis would be transferred for treatment. In this case, a lead screening unit could be set up in one location, physicians would be trained to use it, and lead intoxication cases would be referred to this place.

The National Child Health Institute (formerly known as the Children's Hospital) in Lima currently holds the status of reference hospital for severely burned children. Its status in the area and the fact that children are more affected than adults by lead intoxication provided logical arguments for the institute to become the reference hospital for lead-intoxicated children. Between 1984 and 1998, this hospital had seven confirmed lead intoxication cases; in 1997 it had 158 cases of diagnosed nonspecific "intoxication" and 180 such cases in 1998. Measuring the current incidence of lead-intoxicated children at this hospital could be the beginning of establishing lead-screening capabilities, but for this to happen DIGESA would first have to train the physicians in the proper diagnosis of lead intoxication.

Since the chelating agents used to treat lead intoxication are rarely available, Peruvian experience with lead intoxication treatment is scarce and sometimes contradictory. Thus the expertise needed to train local doctors would have to be found elsewhere, but the Lead Project did not have a budget to hire a consultant for this activity. Further funds to train physicians and develop lead screening guidelines, as mentioned in the work plan, were not assigned by USAID. Finding other funds would be the responsibility of DIGESA and the local lead coordinator.

The activity required that DIGESA do the following:

- Identify a candidate to become a reference hospital for lead intoxication in children
- Establish a blood lead screening unit at the reference hospital
- Train doctors from the reference hospital in lead intoxication diagnosis and chelation therapy
- Release the blood lead screening unit to be managed by the hospital.

## Summary of Activities

Following receipt of a letter from DIGESA, the general director of the National Child Health Institute met with the technical advisor from DIGESA to appoint representatives from both institutions for future coordination. The two agreed that DIGESA would initially analyze all suspected cases of lead intoxication to estimate the incidence of lead intoxication for the hospital and would later establish a blood lead screening unit inside the hospital.

In January 2000, DIGESA began to analyze patients from the National Child Health Institute. The local lead coordinator, accompanied by a laboratory specialist, would go to the hospital whenever a possible case of lead intoxication arrived. Out of 29 children diagnosed with probable acute lead intoxication and sampled through

May 2001, only 13 had blood levels above 10 µg/dL, and only seven of these had levels high enough (over 65 µg/dL) to explain severe neurological impairment. Most of the cases therefore were not caused by lead intoxication, and most of those that were had a previous lead intoxication diagnosis. At the same time, another laboratory in Lima measured the blood lead levels of some of these same patients and found high blood lead levels (over 50 µg/dL) in patients whom DIGESA had determined had values within the normal range (less than 10 µg/dL). Activity 4.3, Training to Improve Laboratory Quality Control, examines this contradiction.

By May 17, 2000, the institute had a new director who agreed to sign a formal letter with DIGESA to initiate the baseline study and the training activities. It was agreed by both parties that the letter of understanding between DIGESA and the Child Health Institute would be valid only until August 31, 2000. This agreement included the creation of the blood lead screening unit and further cooperation between the two institutions. DIGESA initially planned to store all the analyzing units and supplies on its premises to better control handling of the equipment, but upon further consideration decided to leave the instruments at the hospital for quicker and permanent access.

While the Child Health Institute was reviewing DIGESA's baseline study protocol, two laboratory personnel from DIGESA and the local lead coordinator opened a temporary screening station inside the hospital, using portable equipment and supplies. Beginning on September 18, the station was open every morning for two weeks to screen children with symptoms that could be caused by lead intoxication. Although DIGESA was in constant contact with the Epidemiology Office of the Child Health Institute, few physicians had been informed of the screening service and even fewer physicians considered it important to screen for lead intoxication. The result was that few children were screened and not one lead intoxication case was diagnosed at the temporary screening station.

In September, DIGESA's technical advisor gave a sparsely attended presentation for physicians on lead intoxication differential diagnosis and treatment at the Child Health Institute. The presentation included a review of the lead problem in Lima and current information on symptomatology and chelation treatment. During that same week, laboratory technicians from the Child Health Institute received an introduction to the use of the LeadCare analyzer by laboratory personnel from DIGESA. In light of the lack of interest from the hospital medical staff, the training was redesigned for physicians from other hospitals and relocated to DIGESA. Eventually, the ILMC funded a chelation treatment workshop at DIGESA (Activity 3.7) on May 20 and 21, 2001, attended by 34 physicians from several hospitals in Lima. Doctors from the National Child Health Institute were invited, but none attended the workshop.

The baseline study finally took place in March 2001. Since the study needed physicians to refer suspected cases, pediatricians from two hospital departments (general medicine and neurology) were personally approached and informed of the study and of symptoms to look for in patients who would be referred for screening. It was expected that outpatients with cognitive impairment, a common symptom of chronic lead intoxication, would be referred from the Neurology Department. These patients seldom require blood sampling, so their participation was completely voluntary. Whether it was the parents or the doctors who were not willing to cooperate, the end result was that no patient from this group was sampled. Another possible group for lead intoxication was patients who arrived at the General Medicine Department with some form of underdevelopment, but this also failed to materialize. The study lasted one week longer than originally scheduled, but the number of children sampled was too low (fewer than 60) to make any attempt to calculate incidence. Inconsistencies in blood sample analysis by the laboratory at the hospital compromised what little data had been collected, and DIGESA terminated the study.

The results of this activity were the following:

- During the 16 months of surveillance, seven cases of acute lead intoxication were diagnosed at the Child Health Institute.
- Fifty-three laboratory technicians from the Child Health Institute were trained in the use of the LeadCare analyzer.

It can be concluded from this activity that physicians at the National Child Health Institute do not commonly consider diagnosing lead intoxication in severely impaired children, and parents are reluctant to allow venous sampling of their children.

### 4.1.5. Nutritional Interventions to Decrease Lead Absorption and Treat Iron Deficiency

Health agencies, schools and eateries should emphasize overall nutrition, since it is an intervention that would be more sustainable in the long run. It is also believed that nutritional interventions that are food-based are more successful than those based on iron or calcium tablets or pills. For a child with a high blood lead value where malnutrition is known to be a problem, increased consumption of calcium- and iron-rich foods in a low-fat diet would prove to be very important. This is probably true for children living in Puerto Nuevo as well, but additional information and work were needed to develop and outline potential interventions. As a result, an activity was designed through the Lead Project Phase II to study the effects of iron and calcium supplements on lead absorption. It was expected that through this activity DIGESA would learn appropriate nutritional expertise to design the nutritional interventions needed and identify potential funding mechanisms for their implementation.

The general idea is that children should benefit significantly in the short term from administration of calcium and iron supplements. Epidemiological and experimental evidence suggests that adequate dietary calcium intake decreases lead absorption in the gastrointestinal tract. Lead, calcium and phosphorus share common receptors for their absorption and must compete in the intestinal tract for their individual absorption.[10] If a receptor is occupied transporting one of them, it will not transport the other. Several studies have documented inverse associations between iron status and blood lead levels, suggesting that iron deficiency increases lead absorption. Most nutritional interventions are based on evidence of increased lead absorption when children are iron or calcium deficient; hence, improving their iron and calcium uptake should discourage lead from entering the body.

Questions remain as to whether it is appropriate to provide iron supplements to children without testing for iron deficiency. In Callao, however, in the absence of iron fortification programs, the socioeconomic characteristics of the affected area and the high prevalence of chronic malnutrition in school children suggested that children there would benefit substantially from such an intervention. In addition to decreasing lead absorption, iron supplementation would alleviate the adverse health effects associated with anemia caused by chronic lead intoxication.

A nutritional intervention, as described above, would require the following activities:

- The local lead coordinator must develop a study protocol.
- The local lead coordinator will need to identify the two study groups (lead exposed and nonlead exposed) and secure delivery of daily supplements for two to three months.
- The local lead coordinator will need to collect and analyze data from the study.
- The local lead coordinator should write a report on the cost-effectiveness of providing iron and calcium supplements to decrease blood lead levels.

## Summary of Activities

In December 1999, DIGESA approved a case-control study design (presented by the local lead coordinator) to determine the effects of iron and calcium supplementation in the children of Puerto Nuevo. Two groups of children had to be identified: one exposed to lead (children in Puerto Nuevo) and another not exposed (children in a different part of Lima but with similar racial and socioeconomic characteristics). The second group would be selected from students of a school in the district of La Molina where the baseline blood lead survey had found the lowest blood levels.[1] This control group would provide the “normal” reaction to the intervention. Both groups would receive iron and calcium supplementation for at least two months, and DIGESA would test blood lead levels every month to monitor changes. Ideally, DIGESA would be able to compare the blood lead values and the iron and calcium blood status of the exposed and control groups at the beginning of the study with blood values from both groups after they had received supplementation.

Because USAID funding was not available for a nutritional study within this activity, DIGESA postponed the study pending the availability of resources to buy the necessary iron and calcium supplements. In June 2000, during a meeting with the executive director and the program adviser of ILMC, DIGESA asked ILMC to finance this study. In response, the ILMC executive director reported that an unpublished study conducted in China had found an *increase* in the blood lead levels of undernourished children who were given nutritional supplements. In that study, subjects' average blood lead levels rose from 20 µg/dL to 25 µg/dL. The explanation could be that the metabolism of a child who does not receive adequate nutrition slows down to cope with the inadequacy. Studies of vitamins have shown that a sudden improvement in intake elevates the metabolism, stimulating appetite, promoting anabolic processes and potentially increasing absorption, including lead particles. The blood lead levels of undernourished Peruvian children living in Puerto Nuevo average 45 µg/dL. According to CDC guidelines, this is a borderline level that defines the need for chelation treatment because of the high risk for seizures and coma. If supplementation were to raise this level by only 5 µg/dL, this risk would be greatly amplified. Although the above-mentioned study on Chinese children had not yet been published as of August 2000, there was concern within DIGESA that this intervention might increase risks for the study subjects.

In November 2000, the municipality of Callao initiated its own program to provide daily calcium supplements to school children in Puerto Nuevo. However, the supplementation was politically oriented and short-lived, and it ended after only two weeks. DIGESA never found funds for the supplements and was clearly having second thoughts on this intervention.

By the end of January 2001, one of the authors of the work plan recommended food-based nutritional interventions as being more successful than those based on iron or calcium tablets and put an end to the hesitation. Nutrition would definitely receive emphasis in the behavior change program (Activity 3.2, Interventions to Reduce Ingestion of Soil Contaminated with Lead) but would not constitute an activity on its own. DIGESA was to promote consumption of iron- and calcium-rich foods (along with positive behaviors), and blood lead values would be tested before and after the intervention.

### 4.1.6. Interventions to Control Lead Sources

Information from the first phase of the Lead Project indicates that dust generated in the deposit areas settles less than 1 kilometer from the deposit area,[2] suggesting a site-related origin of contamination. In response to these findings, some mineral storage areas took quick (but not efficient) measures to control dust emission and public discontent. Such measures included raising fences up to 6 meters high, covering mineral piles with plastic and moistening the piles before transportation (Figure 9). Moistening was later abandoned since water increased the weight of the mineral product.

**Figure 9. Moistening and new fences at the CENTROMIN storage facility, May 2000. Courtesy of Jose Luis Quequejuna.**

Results from the soil sampling study and the high air lead concentrations registered in the vicinity of the storage site (5.3 µg/m³ near the storage site versus 0.4 µg/m³ in other areas of Lima) suggest that significant dust was generated, probably because the mineral piles were openly exposed, including during transport to and from the port area. Fences and covers would simply not be enough. Thus, interventions to develop efficient dust control programs were needed, including reduction of surface wind speed with windbreaks or source enclosures. The adequacy and applicability of each potential intervention to the local context will require more study and evaluation. For this reason EHP proposed that an ILMC soil remediation expert visit Puerto Nuevo and work with DIGESA and CENTROMIN on the development of alternatives for dust control in storage sites.

Funds for a consultant with expertise in dus0t control were assigned to this activity in the original work plan, but they were later reassigned by USAID. When representatives of ILMC and DIGESA met in January 2000, DIGESA expected ILMC to be a major participant in this activity. The ILMC executive director offered to work with SONAMINPET to apply ILMC's experience in the control of contamination sources in other parts of the world. The first meeting between DIGESA and the mining industry took place on May 12, with ILMC as a coordinator. These initial meetings served to get all stakeholders acquainted and to accustom them to working together for the implementation of proven dust control strategies.

DIGESA's technical advisor was invited to present the Callao experience at the EPA Lead Remediation Effectiveness Symposium later that month, and at the same time, acquire information on alternatives for remediation. Experience from around the world in dealing with lead remediation approaches was presented at this symposium. The program adviser from ILMC and Doe Run officials also were to attend the symposium and return to Lima with alternative ideas that could be applied in Callao. Approaches ranged from using lead decomposing bacteria to the complete removal of the surface layer of dirt. It was DIGESA's idea that, given the close proximity of the

Puerto Nuevo mineral piles to the local population, a completely sealed environment (roof and walls) would be the only solution that could guarantee emission control. The belief is that only after emission control is achieved can the outside soil be assessed (probably by pavement) since lead easily persists in the environment for decades.

During the fourth Round Table meeting, on October 24, 2000, where the technical advisor represented DIGESA, the members from the mining industry reviewed all their investments aimed at controlling dust emissions to date (including fences, covers, protective equipment for workers, etc). The ILMC proposed a budget to improve the conditions in the school in Puerto Nuevo (located next to the biggest mineral storehouse), and it was estimated that each company could provide a monthly contribution of U.S.$1,000 to maintain a continuous cleaning program of the area (including the school and the streets in Puerto Nuevo). However, no commitment was made, and this proposal was never put into practice.

By January 2001, a new calculation quantified the efforts each company would have to take to diminish lead emission, with a price tag ranging from U.S.$80,000 to U.S.$544,000 to cover piles, raise fences and wash the tires of trucks before they leave the storage areas. It was in this meeting that the behavior change specialist presented the behavior change program as DIGESA's long-term contribution to preventing the lead-contamination problem.

By the end of July 2001, none of the proposals had elicited a commitment, and DIGESA assumed the mining companies were not seriously considering containment structures.

### 4.1.7. Assessment for Soil Rehabilitation

Results from the environmental sampling study of the first phase of the Lead Project strongly suggested that soil in residential areas located near storage centers was contaminated with lead. Because lead is persistent in the environment, once the primary source is controlled, additional remedial actions will likely be necessary to prevent exposure to lead remaining in the soil.

Various technologies and remedial actions are available to mitigate the risks posed by lead in soil. Soil removal or paving of unpaved streets in residential areas may be necessary. The costs and the decision level required to take these actions were beyond the scope of the activities constituting the second phase of the Lead Project, and this activity was withdrawn from the work plan. This is a decision more likely to be made by the municipality of Callao. During the Round Table meetings between DIGESA and the mining industry, it was acknowledged that once the sources of lead were controlled (in the next five years), the removal of soil or pavement would be considered to control further exposure.

## 4.1.8. Medical Treatment for High Lead Levels

Lead intoxication in children is a silent disease. Upon its entry into the organism (generally by hand-to-mouth activities in children living in a contaminated environment or by the inhalation of fumes from melting lead), lead exhibits great affinity for proteins (altering their structure) and bone tissue (where it replaces calcium). Thus, the lead is stored for a long time before the body becomes saturated and symptoms start to arise. Anemia and growth impairment are common complications from chronic lead intoxication, but they are seldom diagnosed in Peru because they are also caused by other common factors in that country, such as poor nutrition. The effect on the nervous system is the most remarkable symptom associated with acute lead intoxication and is also the most life threatening.

As mentioned above, blood lead levels are significant for the severity of intoxication. However, lead in blood is in constant movement. High lead values in the bloodstream can account for lead on its way to storage in bone or nervous tissue when a child is first tested, or it may be on its way from those tissues to excretion after chelation therapy. Anytime in between, the levels vary between the daily intake and excretion. Thus, the blood lead level after treatment could remain high (over the 10-µg/dL limit) for some months while the lead is removed and the body detoxifies itself, even if the treated child is no longer exposed to lead. After treatment, the tendency (increasing or decreasing) of the blood value may be as important as the value itself. This is why medical treatment with chelating agents is contraindicated if the child is to remain in contact with the original lead source or to return to a high-lead environment. Several studies have documented that children who receive chelation therapy and then return to high-lead environments recover their original high blood lead levels within weeks, increasing the risk for acute lead toxicity. The current recommendation by the American Academy of Pediatrics is that children with blood lead levels higher than 45 µg/dL receive chelation therapy and be removed from the lead source.

In Peru, clinical expertise in the treatment of children with high blood lead level is scarce, and lead intoxication is not considered a major public health problem. The limited number of laboratories that can actually measure blood lead levels hampers physicians' ability to diagnose lead intoxication, and the lack of chelating agents restricts them from giving appropriate treatment. Lead sources go largely unidentified and uncontrolled because the reporting of lead intoxication cases to environmental authorities is not mandatory. Therefore, no environmental investigation is conducted among the rare cases that are diagnosed. The combination of these factors has limited clinical experience in treating pediatric lead poisoning.

### 4.1.8.1. DIGESA's Role in the Activity

The original purpose of Activity 3.7, Medical Treatment for High Lead Levels, in the work plan was to increase the local medical community's awareness of lead intoxication. This activity was to include USAID sponsorship for the participation of a chelation treatment expert from the United States in a seminar on relevant issues regarding lead poisoning during the National Congress of Pediatrics in October 1999.

However, no presentation on the lead problem was given at the National Congress meeting, and the local lead coordinator was hired a month after the meeting. As a result, the funds were reassigned and the activity had to be revised.

DIGESA reinterpreted the content and purpose of the activity to stock DIGESA with medication for lead intoxication emergencies. With no USAID funds available, DIGESA would have to buy the chelating agents. DIGESA contacted the Division of Pharmacy from the Peruvian Ministry of Health to purchase the medication, but this was not in the ministry's budget. At the same time, there was some concern among DIGESA officials about taking on the role of treatment providers as opposed to coordinators, and this concern eventually convinced the directorate not to get involved with the purchase of treatment. Since chelating agents would remain unavailable for intoxicated children, DIGESA and the local lead coordinator sought other funding options.

Other activities within the work plan required the establishment of communication links with the ILMC. Both of the rejected components of Activity 3.7 (treatment and training) were suggested to the ILMC, and its participation proved vital to the success of the activity.

In May 2000, the ILMC executive director donated 10 bottles of 100 pills each (Figure 10) of dimercaptosuccinic acid (DMSA or succimer) to DIGESA, enough to treat 15 children weighing around 15 kg. DMSA is taken orally and is as effective as other parenteral chelating agents but with less severe adverse effects. It was approved in 1991 for treatment of children with lead intoxication levels over 45 µg per deciliter. Treatment with succimer lowers blood lead levels but does not improve scores on tests of cognition, behavior or neuropsychological function, according to a 36-month follow-up with children with blood lead levels below 45 µg per deciliter.[11]

**Figure 10. DMSA at DIGESA. Courtesy of Norma Rodriguez.**

Doe Run Peru was to hold the donated DMSA until DIGESA had a formal request for treatment of a specific case. Conflict stirred again within DIGESA concerning the directorate's role: Should they provide treatment directly or should they facilitate contacts between physicians and suppliers? In the meantime, three cases of acute lead intoxication occurred in Lima, and DIGESA was being asked for DMSA. It was not until January 2001 that DIGESA accepted (still without formal request) eight bottles of DMSA, while Doe Run Peru kept the remaining two bottles. By then two children had benefited from the donation, and a third would soon benefit. These three cases, which illustrate common problems with treatment and diagnosis of lead intoxication in Lima, are described below.

#### 4.1.8.2. Cases of DMSA Treatment

In November 2000, two-year-old Gianxel Pizarro Castillo arrived at Cayetano Heredia Hospital in a semi-comatose state. After learning that the family recycled batteries at their home—a process that included melting lead and lead fumes—doctors made the diagnosis and began to search for the chelating agent since it was not in stock at the hospital. Eventually they called DIGESA, unaware of the donation of DMSA it had received, and DIGESA arranged with the Environmental Affairs Chief at Doe Run Peru to give one bottle of DMSA to the hospital. DIGESA confirmed a blood lead value of 96.9 µg/dL and the doctors initiated chelation treatment. For a child weighing around 10 kg, treatment consists of three tablets a day for five days, followed by two tablets a day for 14 days, for a total of 43 tablets. Since the tablets are given orally, the first five days of the 19-day course require supervision at a health institution, but the next two weeks can be done on an outpatient basis, provided there is confidence that the patient will continue treatment at home. Moreover, after the initial favorable response to treatment, it is hard to keep a child with no apparent illness confined to bed in a hospital, and the risk of the child contracting other diseases there has to be considered as well.

Gianxel's treatment started on November 7. The patient regained full consciousness three days later and continued treatment until November 23, two days before completing treatment (due to a request from his parents). Five days later, a control test showed a blood lead level of 47.8 µg/dL for the child. This value was still high and accordingly DIGESA emphasized the importance of prevention measures to the family. This advice apparently had little effect because the child returned to DIGESA for a control test on January 15, 2001, and was found to have a blood lead level of 69.7 µg/dL.

On January 4, 2001, one-year-old Abraham Sermeño Sánchez was fortunate to arrive at Daniel Alcides Carrion Hospital in Callao. The child was vomiting and numb in both legs before symptoms progressed to seizures. The physician in the emergency room (who also worked in Cayetano Heredia Hospital and knew about Gianxel's case) inquired about the family business and the answer—home battery recycling—confirmed his suspicions. The physician quickly called Cayetano Heredia Hospital for the remaining DMSA tablets and asked DIGESA to measure lead in the child's blood. DIGESA confirmed the diagnosis with a blood lead value of 87.2 µg/dL and supplied additional tablets for the hospital. Again the child presented a full recovery by the third day of treatment and was released from the hospital on January 18. Five days later, Abraham's control blood lead value was 49.1 µg/dL. As explained above, high lead values can still be expected after chelation treatment while the drug helps remove lead deposits in the body.

On February 14, 2001, José Inoñan Castillo entered the emergency room of Cayetano Heredia Hospital in a coma. His father, a longtime fisherman, used lead weights for his nets and melted them at home. DIGESA was called in and the child's blood lead value was beyond the maximum measuring level (100 µg/dL) of the portable LeadCare instrument. A blood sample was taken and sent to the laboratory while treatment was initiated on February 15. The child's dangerously high level was later determined by atomic absorption (still the standard for blood lead reading) as 219.9 µg/dL at DIGESA. The child completed the treatment course but his recovery was slow. The degree of central nervous system demyelination that takes place in such severe cases of lead intoxication is irreversible, and although children are usually able to get some of their neural activity back, it takes years.

When ILMC met with DIGESA in March 2000 and offered its resources to help with the lead problem in Callao, DIGESA suggested several activities in hope of obtaining needed funds. Training local physicians was a main concern for DIGESA, and ILMC agreed to sponsor a lead treatment seminar. At each subsequent meeting, ILMC repeated its offer to provide the training component for this activity. In January 2001, ILMC contacted two experts to come to Lima and train local physicians. One of the experts was a young physician who was working with children heavily exposed to lead in a smelter community in Torreón, Mexico; the other was an experienced faculty member in the School of Nursing at the University of Maryland in the United States, and both were fluent Spanish speakers. From May 20-21 they conducted a workshop at DIGESA on lead intoxication treatment using chelating agents (including DMSA, ethylenediamenetetraacetic acid [EDTA], dimercaprol [BAL], and penicillamine), lead exposure markers (zinc protoporphyrin/erythrocyte for acute or chronic differentiation, and aminolevulinic acid dehydrase in urine), and case studies. As many as 34 physicians from Lima hospitals attended this workshop, and although it was highly appreciated, there was concern from the audience about the practicality of applying CDC guidelines, which require a more effective health system than Peru has, in their communities.

## 4.2. Effectiveness of Interventions

The intervention activities resulted in the following:

- DIGESA identified a reference hospital for lead intoxication in children and established a blood lead screening unit at the reference hospital.
- Fifty-three laboratory technicians from the National Child Health Institute were trained in the use of the LeadCare analyzer.

- DMSA was made available to two hospitals for treatment of high lead intoxication cases.

- Thirty-four physicians, including three from Callao, were trained in proper chelation treatment and screening guidelines.

- The only people effectively trained in behavior change interventions were the social communicator from DIGESA and the coordinator for this activity.

- A revised behavior change plan will be presented in the following months.

What has been learned as a result of the intervention activities?

- The best way to approach and follow up with the community in Puerto Nuevo is through local advocacy groups (in this case, health promoters from the local center) who can reinforce with each visit the ideas presented during the campaign.

- DIGESA’s ability to apply participative methodology remains to be tested.

- DIGESA should focus on serving as a technical resource to the health centers (helping with educational materials and blood lead testing) rather than assuming the costs and effort of the whole campaign.

- Mining industry awareness and commitment is vital, not only for containing the sources of exposure but also for maintaining the education program.

- Monitoring and evaluation for behavior changes oriented to reduce blood lead levels in Callao should be implemented one year or more after the baseline study.

- New access to running water and initial dust control measures at the storage areas will make it difficult to isolate the contribution of the educational campaign if the blood lead values decrease in the coming years.

- Lead screening guidelines from the CDC must be adapted to the local reality and to the community’s ability to properly implement them.

- Physicians at the National Child Health Institute do not commonly consider diagnosing lead intoxication in severely impaired children.

- Treatment with DMSA is efficient in lowering lead levels in children with high blood lead levels.

- An outside professional placed within a government institution, such as DIGESA, has severe limitations in terms of both cooperation (no rank equals no authority within the institution) and infrastructure (resources are scarce and unavailable to an outsider).

- Resource independence from Peruvian government institutions is desirable.

# 5. Training and Capacity Building Needs

## 5.1. Training Objectives

DIGESA, as a government regulatory agency, responds to all environmental emergencies nationwide. As such, it needs to develop methodology and resources for adequate risk management programs to address problems occurring throughout Peru that are related not only to lead contamination but to other toxicants as well. As of 1999 DIGESA had no professional or technical staff with formal training in the investigation of environmental problems.

EHP used the lead expossure problem as a sample topic to develop training on key environmental health subjects and current capabilities at DIGESA. EHP's discussion with DIGESA officials concerning Phase I of the Lead Project resulted in the identification of technical areas where training was needed to improve and expand DIGESA's surveillance and regulatory capabilities.  Based on these discussions, DIGESA officials prioritized their current needs, and these became four of the activities of Phase II of the project.

USAID contacted CDC-NCEH to design a training event that would review lead contamination issues as well as the effects of other toxicants on human health. The NCEH medical officer in epidemiology developed a workshop in Spanish directed at professionals of different disciplines. The local lead coordinator secured an agreement between DIGESA and the NCEH on the content of the course and coordinate implementation of the course in Lima. The course was aimed at a multidisciplinary audience of scientists, health care providers and policymakers.

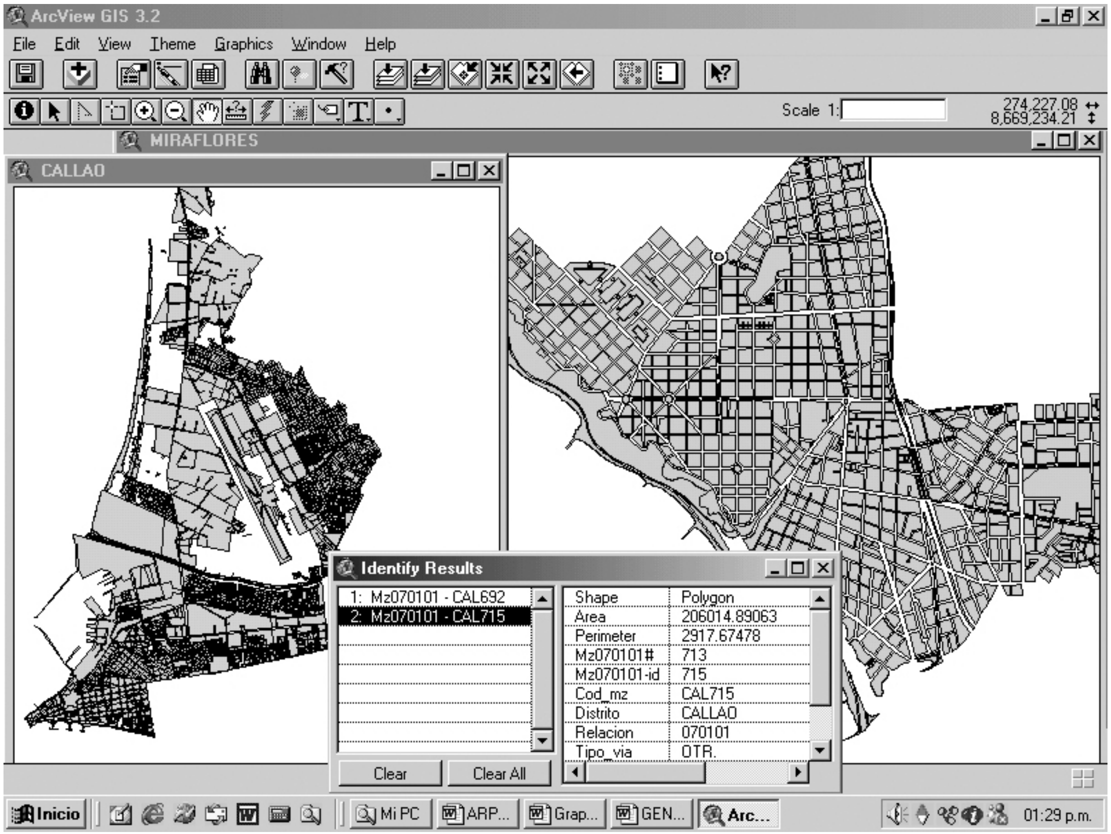
In addition to lectures, the workshop included interactive case studies on topics such as "Acute Renal Failure in Children (Tainted Medicine) in Haiti," "Insecticide Poisoning (Tainted Flour) in Jamaica," "Mercury Poisoning (Gold Mining) in Brazil," "Malaria Outbreak (Vector Control)" and "Epidemic of Acute Respiratory Disease (Industrial Air Emissions)" (adapted for Peru from a study conducted elsewhere). NCEH translated all printed material into Spanish, and EHP hired a translator to perform simultaneous translation for some of the presentations.

Instructors from NCEH conducted the training course on environmental epidemiology from March 20–24, 2000. Seven experts on environmental epidemiology from the Health Studies Branch of the Division of Environmental Hazards and Health Effects of NCEH visited Lima, including the acting chief, the senior environmental health scientist, the medical officer in epidemiology, three research chemists, and an Association of Schools of Public Health fellow. The lectures were practical and illustrative, and the participants' evaluation forms at the end of the workshop expressed their high appreciation of the course. A multisectoral audience of 29 participants from various divisions within DIGESA and 20 participants from DIGESA agencies around the country attended the workshop.

## 5.2. Training in the Use of Geographic Information Systems to Assess Environmental Problems

The application of GIS to the study of environmental problems is helpful in the analysis of relational and spatial data. GIS is a powerful tool used to support decision making, and DIGESA personnel needed training in the use of this tool. As a result, training in the use of GIS became one of the activities in Phase II of the Lead Project: Activity 4.2, Use of Geographical Information Systems to Assess Environmental Problems, which required the donation of software such as ArcView and S-PLUS.

ArcView is a type of GIS application software developed by Environmental Systems Research Institute Inc. It is easy to use and enables users to select and present geographic information rapidly and in a visual manner (see Figure 11). Another important GIS application is MapInfo, developed by MapInfo Corporation.



1: Mz070101 - CAL692
2: Mz070101 - CAL715

| | |
|---|---|
| Shape | Polygon |
| Area | 206014.89063 |
| Perimeter | 2917.67478 |
| Mz070101# | 713 |
| Mz070101-id | 715 |
| Cod_mz | CAL715 |
| Distrito | CALLAO |
| Relacion | 070101 |
| Tipo_via | OTR. |

**Figure 11. Theme layers for two districts of Lima on screen using ArcView software.**

While developing the work plan for the second phase of the Lead Project, the EHP consultant for the lead study proposed that National Institute of Public Health in

Mexico (INSP) collaborate in executing this activity so that DIGESA could profit from INSP's experience using GIS. The original course outline included a two-day introduction to GIS and eight days of using MapInfo software in different environmental settings; however, since ArcView software was more widely distributed within the Peruvian Ministry of Health, the outline was modified to specify training in ArcView. DIGESA approved the outline, and the INSP director of informatics, a specialist in GIS, was assigned by the EHP consultant to study the task of developing the course and taking it to Lima.

This activity was later divided into two components: one course would focus on using the ArcView program and would be intended for technical personnel at DIGESA; the other would be aimed at DIGESA decision makers and would focus on using GIS to study public health issues. The ArcView component of the activity would be conducted in Lima and would take place before the course on public health applications.

### 5.2.1. Workshop #1: Using the ArcView Program

The first part of this activity involved training in the use of the ArcView software program. DIGESA selected a local contractor with extensive experience using GIS to develop a 10-day course on the use of ArcView. DIGESA designated 15 staff members with diverse backgrounds to attend the ArcView course, which ran from September 18–29, 2000.

Although DIGESA had set 15 as the ideal number of attendees, in reality, DIGESA had trouble finding enough people who were sufficiently familiar with the Windows environment as most of the organization's personnel can barely manage word processors and e-mail. Once the contract was written for 15, trying to find this number of participants meant having to select several unqualified and unmotivated attendees who typically only participated for one or two days.

The ArcView course was given at the contractor's offices, and this involved travel for attendees. Classes often started late, and some of the attendees missed some classes, which severely handicapped them for subsequent classes. The end result was that only six of the 15 people (40 percent) who signed up for the ArcView course fully completed their training; the majority did not finish the course satisfactorily. In the final evaluation, the contractor ranked participants in the following categories: only one person qualified as "very good" at both levels of the course; five qualified as "good;" five others qualified as "good" at the basic level, but not at the advanced level; four persons who attended the course qualified as "needing more study;" and they were mainly those who had not attended the course regularly.

The six persons who satisfactorily completed the ArcView course should be able to perform the following tasks:

- Develop digital maps (theme layers) from printed maps

- Link databases to points on a theme layer

- Perform searches in a database and show results on the map

- Develop reports and presentations that incorporate these results.

### 5.2.2. Workshop #2: Using GIS for Public Health Issues

For the second component of the activity, DIGESA approved INSP to conduct the GIS training because INSP had ample experience in its use for environmental and public health programs. No equivalent local Peruvian counterpart was identified. The INSP director of informatics and an INSP expert in risk evaluation (with a doctoral degree in epidemiology) were in charge of the training course in Lima. However, initial budget constraints from USAID and the unavailability of the INSP consultants caused the postponement of this part of the activity until March 2001.

Once the workshop was conducted, it included a basic review of GIS concepts and a case study of how GIS was used in Mexico to study malaria and demographic indicators, such as mortality trends. It was held at DIGESA to facilitate attendance, and 31 participants were expected to attend. In the end, only 15 people (50%) were present for all ten days. Some key decision makers were unable to attend. It was assumed they would be interested in this new tool, but these decision makers should have been approached beforehand to determine their interest. Of those who did attend, half had not been in the ArcView course and had serious trouble trying to use that program (and teaching them ArcView was not the objective of this course). While effective use of GIS in environmental problems does not necessarily depend on technicians who actually sit in front of the computer and work the software, attendees should have had a previous introduction to the software.

The 15 persons who satisfactorily completed the INSP course (Figure 12) should have acquired basic knowledge of the following:

- Geography and relevant geographic parameters involved in map generation and manipulation

- Construction of a GIS study area, using ArcView

- Data input, editing, and management

- Spatial data operations and manipulation (such as map overlaying and surface generation)

- Spatial statistics using the S-PLUS statistical software module for ArcView.

**Figure 12. INSP instructor giving a lecture on GIS. Courtesy of Carlos Sanchez.**

## 5.3. Training to Improve Laboratory Quality Control

Blood lead testing by atomic absorption—the standard for measuring lead in blood—is available at DIGESA. However, the equipment is old and requires a large sample volume (5 ml). Without adequate internal quality controls or participation in an external quality assurance/quality control program, the DIGESA laboratory's ability to obtain lead measurements with adequate precision is questionable. For example, laboratory personnel at DIGESA would empirically "expect" blood lead values obtained with the LeadCare analyzer to be 10 µg/dL below those obtained with atomic absorption; in other words, this would be "normal" to them. This need not be a serious concern, however, given that the range for the LeadCare analyzer is plus or minus 6 µg/dL and values were consistently below those expected. However, DIGESA verifies high blood lead levels found with LeadCare with the levels found with atomic absorption, so this procedure must be as close to infallible as possible.

The inconsistencies and undependability of the testing resulted in the development of Activity 4.3, Training to Improve Laboratory Quality Control, as part of Phase II of the project. The initial work plan for this activity called for the CDC to develop a course in Spanish on blood lead evaluation procedures for DIGESA laboratory personnel. However, the lack of a budget forced project planners to redesign the activity.

The CDC has a Blood Lead Laboratory Reference System (BLLRS) program running in several laboratories in the world, and this free program regularly distributes quality control sample materials for use in evaluating the accuracy of blood lead determinations as an external quality control mechanism. Internal quality control, of course, relies on the laboratory itself. The quality control materials CDC uses contain blood and lead: approximately 2 ml of bovine blood in a high-density polyethylene vial with a specific target value for lead.

Various analytical technologies (such as methyl isobutyl ketone extraction followed by flame atomic absorption, graphite furnace atomic absorption, or ESA 3010, or

3010B anodic stripping voltammetry) are currently available to measure lead in blood. At the NCEH laboratory, two separate procedures are used:

1. Measurement of the lead isotope ratios in blood by inductively coupled plasma isotope dilution mass spectrometry, which the CDC does only for special studies.

2. Determination of the total lead content in blood by graphite furnace atomic absorption spectrophotometry, which CDC does routinely.

The biochemical laboratory at DIGESA received two different sets of quality control material from CDC during the quality control program: one set of vials with unknown concentrations of lead, intended to evaluate how the laboratory was testing, and another set of vials with known concentrations that DIGESA could distribute among other laboratories to test their procedures. The local lead project coordinator was responsible for securing the arrival of the control blood samples by mail at the DIGESA laboratory.

USAID made the first contact with CDC for DIGESA's laboratory quality control program. Between March and November 1999, when the local project coordinator joined the lead project, the CDC sent four shipments of blood control samples, all of which were lost in the customs office in Peru.

Because the blood samples were animal-derived products, the Peruvian customs office required that an original export certificate accompany the samples. The CDC was unable to provide the original certificate because it ran the same program with other nations and apparently issued only one export certificate for the entire batch of samples. DIGESA in turn was unable to convince customs to accept a photocopy. The local lead project coordinator made an official request to the General Directorate of Animal Sanitation in the Peruvian Ministry of Agriculture on March 31, 2000, to accept a photocopy, and in April, the directorate authorized its office at the Lima airport to accept the photocopy for the vials. DIGESA has thenceforth been allowed to receive control samples by presenting only photocopies of their documentation.

Before the new authorization was tested, however, on March 18, 60 vials with five sample concentrations arrived at DIGESA with the NCEH team in Lima for the environmental epidemiology course (see Activity 5.1), and another five arrived through Federal Express. Apparently, Federal Express did not require authorization, but the CDC could not guarantee that they would send all samples through FedEx. DIGESA used these samples with known lead concentrations as its internal quality control for calibrating instruments.

In June 2000, a research chemist from the NCEH Division of Health Laboratory Sciences became DIGESA's new contact for the quality control program. When the research chemist came to Peru in July 2000 (see Activity 3.2), he brought 50 vials of seven different concentrations of BLLRS samples. Of the 50 vials, 36 remained at DIGESA and 14 (two of each concentration) went to the Doe Run Peru laboratory in La Oroya. On September 1, the research chemist sent one more shipment by Federal

Express: 36 vials (six samples of six different concentrations). The Federal Express approach ensured that the shipments arrived. In January 2001, the research chemist was promoted, and the new contact became the program leader for the BLLRS. She offered to send quality control samples, but DIGESA received none until the conclusion of the project in August 2001.

The other component of the quality control program was an external program intended to evaluate the precision with which DIGESA and other laboratories in Peru were reading lead levels in blood.

On March 30, 2000, the BLLRS office sent DIGESA 15 vials with three different unknown concentrations (through Federal Express) to be tested by DIGESA. The DIGESA laboratory processed the samples and sent its results to CDC on April 6. DIGESA closely estimated moderate blood lead values but had trouble quantifying traces of lead in blood (less than 1 microgram per deciliter). Table 1 summarizes the data.

**Table 1. Blood Lead Laboratory Reference System Results for the DIGESA Laboratory**

| BLLRS ID No. | Blood lead level (µg/dL) | | Difference: DIGESA Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
| | CDC Value | DIGESA Value | | |
| 0299 | 0.8 | 4.99 | 4.19 | 5.238 |
| 0699 | 20.3 | 20.23 | –0.07 | 0.003 |
| 2598 | 28.2 | 31.74 | 3.54 | 0.126 |

The BLLRS office sent a second set of blind samples in November, the results of which are still to be determined. Labs are encouraged not to process BLLRS samples separately but within normal batches of tests and on different days, if possible, to ensure they do not receive special treatment (which accounts for the extra amount of time needed to test all samples).

On June 8, DIGESA initiated sharing blind control samples with other laboratories to validate their procedures. The first contact was made with the Toxicological Information and Control Center (CICOTOX), a biochemical laboratory that works closely with the Pan American Health Organization offices in Lima and is located at the most traditional School of Medicine in Peru. CICOTOX returned results in August that showed very poor readings of the blind samples (Table 2).

**Table 2. Blood Lead Laboratory Reference System Results for CICOTOX Laboratory**

| BLLRS ID No. | Blood lead level (µg/dL) | | Difference: CICOTOX Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
| | CDC Value | CICOTOX Value | | |
| 1098 | 51.3 | 56.668 | 5.368 | 0.105 |
| 1196 | 32.9 | 35.265 | 2.365 | 0.072 |
| 699 | 20.3 | 38.708 | 18.408 | 0.907 |
| 1298 | 10.7 | 33.848 | 23.148 | 2.163 |
| 1299 | 5.6 | 39.188 | 33.588 | 5.998 |

Doe Run’s laboratory in La Oroya returned its results in September, which showed very good readings of the blind samples (Table 3). Unlike another laboratory that was thrown off by traces of lead in blood (like 0.4 µg/dL), the Doe Run laboratory’s procedure was to acknowledge a sample that was too small to be quantified and produces a simple “less than 1 microgram per deciliter” result.

**Table 3. Blood Lead Laboratory Reference System Results for Doe Run Laboratory**

| BLLRS ID No. | Blood lead level (µg/dL) | | Difference: DOE RUN Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
| | CDC Value | DOE RUN Value | | |
| 194 | 0.4 | <1 | Qualitative | - |
| 1299 | 5.6 | 3.8 | –1.8 | 0.321 |
| 1298 | 10.7 | 11.8 | 1.1 | 0.103 |
| 1098 | 51.3 | 55.3 | 4.0 | 0.078 |

In November, DIGESA delivered blind control samples to four other Social Security laboratories from the Occupational Health Division to validate their procedures. One of the laboratories was in a hospital in Lima, the other three were located in cities in Arequipa, Huancayo, and Trujillo provinces (Figure 1). Results were reported in July 2001 and are presented in Table 4 through Table 7.

**Table 4. Blood Lead Laboratory Reference System Results for the Occupational Toxicology Laboratory in Arequipa**

| BLLRS ID No. | Blood lead level (µg/dL) | | Difference: AREQUIPA Laboratory Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
| | CDC Value | AREQUIPA Laboratory Value | | |
| 1394 | 41.1 | 40.6 | –0.5 | 0.012 |
| 596 | 26.6 | 19.4 | –7.2 | 0.271 |
| 692 | 11.8 | 12.4 | 0.6 | 0.051 |
| 994 | 8.9 | 11.6 | 2.7 | 0.303 |
| 1299 | 5.6 | 10.5 | 4.9 | 0.875 |

While there were fairly good readings from the Occupational Health Laboratory in Arequipa, the measurements suggest that the lab is unable to give values under 10 µg/dL, and that could make all the difference in the general population.

**Table 5. Blood Lead Laboratory Reference System Results for the Occupational Toxicology Laboratory in Huancayo**

| BLLRS ID No. | Blood lead level (µg/dL) | | Difference: HUANCAYO Laboratory Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
| | CDC Value | HUANCAYO Laboratory Value | | |
| 1394 | 41.1 | 39.0 | –2.1 | –0.051 |
| 596 | 26.6 | 37.6 | 11.0 | 0.414 |
| 692 | 11.8 | 11.3 | –0.5 | –0.042 |
| 994 | 8.9 | 11.2 | 2.3 | 0.258 |
| 1299 | 5.6 | 10.1 | 4.5 | 0.804 |

The same observation occurred in Huancayo as for the previous laboratory.

**Table 6. Blood Lead Laboratory Reference System Results for the Occupational Toxicology Laboratory in Lima**

| BLLRS ID No. | Blood lead level (µg/dL) | | Difference: LIMA Laboratory Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
| | CDC Value | LIMA Laboratory Value | | |
| 1394 | 41.1 | 28.68 | –12.42 | 0.302 |
| 692 | 11.8 | — | — | — |
| 994 | 8.9 | 7.93 | –0.97 | 0.109 |
| 1299 | 5.6 | 14.96 | 9.36 | 1.671 |

No result was recorded for one of the samples for the laboratory in Lima. It apparently had been lost.

**Table 7. Blood Lead Laboratory Reference System Results for the Occupational Toxicology Laboratory in Trujillo**

| BLLRS ID No. | Blood lead level (µg/dL) |  | Difference: TRUJILLO Laboratory Value – CDC Value (µg/dL) | Ratio: Difference/CDC Value (error in µg/µg of sample) |
|---|---|---|---|---|
|  | CDC Value µg/dL | TRUJILLO Laboratory Value |  |  |
| 1394 | 41.1 | 37.9 | –3.2 | 0.078 |
| 596 | 26.6 | 35.2 | 8.6 | 0.323 |
| 692 | 11.8 | 10.3 | –1.5 | 0.127 |
| 994 | 8.9 | 10.5 | 1.6 | 0.180 |
| 1299 | 5.6 | 9.8 | 4.2 | 0.750 |

The laboratory in Trujillo, like the one in Arequipa, was not able to properly distinguish acceptable values less than 10 µg/dL.

At the time of this writing the quality control program between CDC and DIGESA was underway, with more samples expected in continuation of the program.

## Results

The results of the quality control program were as follows:

- DIGESA did not have an overall tendency to overestimate or underestimate lead in blood. The greatest errors per microgram of lead were found at concentrations of less than 1 µg/dL.

- Rather than give an incorrect or approximate value, minimal traces of lead in blood were reported as <1 µg/dL for the Doe Run Peru laboratory in La Oroya. The ratio of error per microgram of lead diminished as the lead concentration of the sample increased.

- CICOTOX had an overall tendency to overestimate blood lead concentration. At concentrations below 30 µg/dL, it added nearly 6 extra micrograms for every microgram of lead in blood.

- With low concentrations of lead in blood (less than 10 µg/dL), the Social Security laboratories from the Occupational Health Division had an overall tendency to overestimate the lead concentration, bringing it too close to the critical level of 10 µg/dL.

- DIGESA’s flame furnace for atomic absorption had difficulty measuring minimal concentrations, but not critical levels, of lead in blood.

- Doe Run’s laboratory at La Oroya measured blood lead concentrations correctly.

- CICOTOX had problems evaluating lead in blood and repeatedly overestimated the lead concentration.

- The Social Security laboratories from the Occupational Health Division made adequate readings of lead in blood at moderate concentrations. However, at lower concentrations they might fail to distinguish borderline cases.

## 5.4. Strengthening DIGESA's Capabilities in Blood Lead Monitoring

Lead occurs in drinking water from two sources: (1) lead in raw water supplies, i.e., source water or distributed water, and (2) corrosion of plumbing materials in the water distribution system (corrosion byproducts). Most lead contamination is from corrosion byproducts. In the European Community, the Drinking Water Directive limits lead content to 50 µg/l. In the United States, EPA's Lead and Copper Rule defines a maximum of 15 µg/l in drinking water. The World Health Organization has recently proposed reducing its guideline value from 50 µg/l to 10 µg/l. The EPA Office of Water establishes drinking water standards in its National Primary Drinking Water Regulations with an action level at values greater than 0.015 mg/l in more than 10 percent of tap water samples. EPA has approved the Palintest Method 1001 (Differential Pulse Anodic Stripping Voltammetry) for the analysis of lead in drinking water. EPA's final rule regarding lead in drinking water (*Federal Register* Part V 40 Code of Federal Regulations Parts 141 and 143), effective on January 3, 2000, was published on December 1, 1999 (Environmental Protection Agency 1999).[12]

In 1999, USAID donated four LeadCare (used to analyze lead in blood) and Palintest (used to analyze lead in soil, dust, and water) analyzers with their corresponding supplies for the first phase of the Lead Project. Once the results of the lead in blood baseline study were known and the Callao problem area had been identified, DIGESA needed to implement further lead contamination studies and more equipment became necessary. As a result, DIGESA requested additional LeadCare analyzers and supplies and Palintest supplies for the second phase of the Lead Project and its replication in other cities in Peru.

### 5.4.1. Description of Lead Monitoring Supplies

#### 5.4.1.1. LeadCare Supplies

**LeadCare Analyzer**

AndCare Inc. (a Research Triangle Park–based diagnostic device company) and its marketing partner ESA Inc. (based in Chelmsford, Massachusetts) developed the LeadCare system with a grant from the CDC (Figure 13). In September 1997, AndCare and ESA received clearance from the U.S. Food and Drug Administration to market LeadCare, a portable, easy-to-use device for the quantitative determination of lead in whole blood, using a finger stick or venous sample. Clinical studies conducted at Boston Children's Hospital and rural pediatric clinics in Goldsboro, Sanford and

Lumberton, North Carolina, indicated that the test was reliable as an established laboratory test method for detecting lead poisoning.

**Figure 13. LeadCare Analyzer. From *http://www.esainc.com.***

The LeadCare system consists of a compact, battery-powered instrument and a single sensor on a disposable plastic strip. The handheld analyzer is portable and requires neither manual calibration nor refrigeration. Its gold electrode sensor contains no mercury or other toxic materials. In addition to being portable, its almost immediate results are an extra advantage, because shipping tests to central laboratories can take days or even weeks, and parents often have a harder time making return visits to a pediatrician's office to get test results and medical advice. DIGESA is therefore interested in adopting the LeadCare analyzer for use in rural areas in Peru.

### Analyzer Kit (ESA Part 70-3449)

The analyzer kit consists of a portable blood lead testing analyzer, a 50-µl pipette, an alternating-current adapter, a battery, a sensor holder, a training video, a quick reference guide, and a user's guide. The analyzer must be used with the test kit (70-2233) and the control kit (70-3440).

### Control Kit (ESA Part 70-3440)

The control kit contains one Level 1 blood lead control (2 ml), one Level 2 blood lead-control (2 ml), and water for reconstitution.

### Test Kit (ESA Part 70-2233)

The test kit (Figure 14) contains 48 sensors, 96 pipette tips, 48 tubes of treatment reagent, and one calibration button (lot specific).

**Figure 14. LeadCare Test Kit. Courtesy of ESA Inc.**

#### 5.4.1.2. Palintest Analyzer

### Palintest SA-1000 Scanning Analyzer

The Palintest model SA-1000 scanning analyzer (Figure 15), with a unique disposable electrode technology, is simple, precise (PRECISION : +/- 5% at 15 µg/l lead), and specific. Though not truly portable, in 1999 it was considered by DIGESA as a breakthrough in testing for lead in water.

**Figure 15. Palintest analyzer. From *http://www.palintestusa.com/*.**

The sample is first acidified before analysis and then neutralized. The scanning analyzer features a unique disposable electrode system that is immersed in the sample to be tested. The lead in the conditioned sample is determined by Differential Pulse Anodic Stripping Voltammetry (DPASV) using a precalibrated disposable sensor. The lead in the sample is concentrated by plating onto the working electrode of the disposable sensor and then it is stripped back into solution by raising the electrode potential. As the lead returns to solution, a peak of current is detected. The peak potential identifies the metal, and the peak height is proportional to the concentration of the lead; the software does the conversion. In this way the metals are separated and identified. The analyzer captures thousands of current and voltage readings from the electrode during the stripping phase. The processor interprets these readings to determine the exact metal concentration and displays the results within three minutes. In addition to the EPA-approved lead determination, the analyzer also gives a reading of copper (Range: Lead 2 - 100 µg/l / Copper 70 -2000 µg/l.) for guidance.

### 5.4.2. Obtaining Needed Supplies

In November 1999, EHP established the following contacts for this activity: the assistant activity manager for EHP, a salesperson from ESA Inc., and the local lead project coordinator for DIGESA. The local lead project coordinator was responsible for preparing and submitting the request for EHP to purchase needed equipment and supplies according to input from DIGESA officials. With EHP’s assistance, the local coordinator also coordinated the delivery of these supplies to DIGESA.

The project coordinator modified the first tentative request list once EHP received better prices from ESA Inc. ESA Inc., shipped the equipment to the Customs Division of the Peruvian Ministry of Health in December 1999, and most of it had arrived in Lima by January 2000. Unfortunately, one box never left Miami, so DIGESA put the process on hold until the shipment was completed. DIGESA needed a letter of donation from USAID detailing the precise contents of the shipment before customs would release the equipment. By the end of March, the shipment was still incomplete, and DIGESA retrieved the boxes already in customs. The last box finally arrived at DIGESA in May, but with different contents than specified. Apparently the first box was lost and ESA Inc., supplied a second box without knowing what items were missing.

The following list of supplies arrived at DIGESA:

- *LeadCare:*
  - Three analyzers, 27 test kits (with 48 tests) for blood samples, and three control kits
- *Palintest:*
  - 37 kits (with 10 tests) for dust samples, 19 kits (with 10 tests) for soil samples, 34 kits (with 10 tests) for water samples, 13 boxes of 100 capillary tubes, 13 boxes of 100 pistons, six boxes of 200 lancets, two boxes of 100 lancets, 25 boxes of 25 patches, and five bags of cotton balls.

## 5.5. Lessons Learned

The following are lessons learned as a result of training and capacity-building activities that occurred during Phase II of the project:

- DIGESA should select course participants far in advance of a proposed training course to ensure individuals' availability and commitment.
- USAID can effectively leverage available funds through interagency agreements (which may involve CDC and EPA) for further capacity building at DIGESA. The initial invitation for collaboration must come from DIGESA, but agreements between USAID and CDC (or EPA) will make these arrangements much more fluid.
- Donations must be carefully planned to ensure efficient shipment.
- Donation letters from USAID/Peru are necessary to exempt DIGESA from paying additional taxes. Such letters must provide detailed descriptions of the shipment that is delivered and must be translated into Spanish. If the letter is written before hand and does not match the material delivered, a new letter will have to be drafted and signed. Since these are legal papers, any inaccuracies could compromise USAID. Therefore, donation letters should be written only after the shipment has arrived in Peru.
- Any package for DIGESA received at the customs storehouse is charged a daily fee, which DIGESA must pay prior to removal of the packages. Thus, payment

can only be made once all parts of a shipment are ready, with the fees increasing in the meantime. DIGESA's Logistics Department, which is responsible for all transactions with customs, has not proven resourceful enough to avoid complications or speed up the process.

# 6. Issues and Recommendations

The purpose of the Lead Project Phase II was to clearly identify, through a more intensive study of the environment, the source of lead contamination in Lima and Callao, Peru. Providing stronger evidence of the sources of contamination would allow DIGESA to implement future regulatory and control activities to prevent lead exposure in Callao or other areas with similar exposures. This chapter discusses key issues and recommendations that resulted from that study.

One of the obvious results of the Phase II study was that the mineral storage sites located in the port area of Puerto Nuevo were identified as the primary source for lead contamination. At the same time, other affected areas in Callao were also identified as having high levels of contamination.

The environmental and population sampling conducted during this study clearly linked the lead of the mineral concentrates with that of the children with high blood lead values in Callao. Though less conclusive, the results also linked the isotope lead ratio in mineral concentrates with that of children with low blood lead values who do not live in Callao, implying that children outside Callao also had traces of mineral lead in their blood. Air filter samples analyzed by the CDC also gave valuable insight into the complexity of the problem. Lead in the air in Lima was found to resemble a combination of the lead in gasoline and lead in minerals, suggesting that minerals may be contributing more than originally expected to the lead in the air. The mineral isotopic pattern found in Callao more closely resembled that of mineral lead, while the city of Lima (as a whole) showed a mixture of both mineral and gasoline patterns.

To assist DIGESA in detecting blood lead contamination cases in the area, the idea of establishing blood lead screening capabilities in the contaminated neighborhoods was proposed. Early in the project, however, it was determined that maintaining a small laboratory at the local health centers or even maintaining portable equipment in the contaminated areas would not be a practical option. Rather, it was recommended to establish a lead detection center in a reference hospital and train hospital personnel to correctly diagnose lead intoxication cases. Although every attempt was made to set up this detection center, the only component of this activity that was eventually realized was the training of local doctors.

The last set of activities undertaken during Phase II of the study was designed to support DIGESA in its effort to deal appropriately with the environmental problems at hand. Through a workshop and other interventions, DIGESA personnel were trained in environmental epidemiology concepts and applications, introduced to the uses of geographical information systems to assess environmental problems, and given a means for receiving additional donated equipment and supplies to support current and future studies of lead contamination.

## Recommendations

Project activities resulted in the following recommendations:

- Solutions to the lead problem in Callao, as it relates to the mineral storage areas, need to be addressed, and working in cooperation with the ILMC appears to be one avenue that can be taken. The ILMC is in a position to facilitate cooperative arrangements with the mining industry regarding engineering solutions to the lead problem, and the actual health issues could be approached as a direct interaction between the ILMC and DIGESA. The industry is committed, through the ILMC, to work with governments, industries, and the international community to manage the risk of lead exposure.

- On an individual level, the best way to approach advocating changes in behavior and follow up with the community is through local advocacy groups (in this case, health promoters from the local center) who can reinforce the ideas presented during the health education campaign. During the initial lead study, interviews with the parents of tested children revealed information regarding behaviors that increased the risk for individual lead exposure. Decreasing the risk of lead exposure in children will require changes in behavior, such as improved personal hygiene practices and cleaning activities around the household. Community-based intervention programs can be effective in promoting such changes and may be one of few options available at this time. It was recommended that a trained volunteer group visit the families, forging a valuable link between DIGESA and the community, while gathering important information, first to develop and later to monitor a behavior change program.

- Soil removal or paving of unpaved streets in residential areas may be necessary to eliminate the problem of lead-contaminated soil in the affected communities. Once the sources of lead are controlled, the removal of soil or pavement would be considered to control further exposure. The decision to remove contaminated soil most likely will rest with the municipality.

## Conclusions

The following are the most important issues concluded as a result of Phase II of the project:

- The project results further supported the original hypothesis that mineral lead (and not leaded gasoline) accounts for the primary source of lead exposure in the population of Callao.

- Minerals may be contributing more than originally expected to the lead found in the air from Lima.

- Lead in soil and dust that does not come from gasoline can be found in at least one other site outside Callao, indicating a larger environmental lead contamination problem in the area than originally inferred.

- The possibility that lead contamination from minerals extends to other areas inland of Lima will require further investigation.

- Lead present in dust and soil is the most probable exposure pathway for children who live near the mineral storehouses.

- Community-based interventions that encourage behavioral changes and increase awareness of the routes of lead exposure in children can have beneficial impact on reducing individuals' exposure to lead. Until other measures are implemented, such programs may be the only effective intervention possible.

## Issues Remaining

The only pair of activities still pending by the time the second phase of the Lead Project was officially concluded in 2001 were Activity 3.2, Interventions to Reduce Ingestion of Soil Contaminated with Lead, and Activity 3.4, Nutritional Interventions to Decrease Lead Absorption and Treat Iron Deficiency. Activity 3.2 (The Behavior Change Program) was designed to reduce individual exposure to environmental lead, since the sources could not be immediately contained and the existing contamination could not easily be eliminated. This activity took much more time and funding than originally expected and its final stages are included in the new Environmental Activity that USAID initiated with DIGESA in 2001 following the Lead Project experience. Meanwhile, Activity 3.4, The Nutritional Supplement Study, which aimed to address iron and calcium supplementation to diminish lead absorption in children, had to be redesigned in March 2001 and eventually became part of the Behavior Change Program in the form of healthy nutrition guidelines that will be presented to the community. This change resulted from the discovery that supplementary nutrition is not the best way to deal with malnutrition issues in the long term.

DIGESA needs to improve the quality control of its blood lead screening to better detect contamination cases. To accomplish this, DIGESA suggested the need for technical assistance to upgrade its laboratory to international standards, but no budget had been assigned for such assistance in the work plan for Phase II. DIGESA instead joined the BLLRS standardization program of the CDC, which validates laboratory lead results by using blind random samples. By participating in this free program, DIGESA will be able to ensure that its measurements of blood lead are accurate and precise. The BLLRS program was expected to continue after the completion of the Lead Project.

Several of the activities were intended to support DIGESA in its effort to deal appropriately with the environmental problems at hand. USAID support included training of DIGESA personnel in environmental concepts, applications and necessary equipment and provided a means for donating further equipment and supplies to support current and future studies of lead contamination.

# Appendix A. Work Plan Activities

In April 1999, after several meetings with USAID/Peru and DIGESA, EHP assigned Dr. Mauricio Hernandez and Patricia Billig to prepare the work plan for the “Lead Project Phase II: Further Assessment of Lead Contamination, Pediatric Lead Poisoning, and Interventions to Reduce Lead Exposure in Lima and Callao, Peru.”[5] The present Summary Report is a direct product of this work plan and therefore maintains its original outline. The original work plan in April 1999 contemplated 18 activities, grouped below in four main strategies, each with their final status:

### 1. **Activities to clarify sources of lead contamination** (5 activities)

| | |
|---|---|
| 1.1 Environmental sampling study | completed |
| 1.2 Lead isotope composition of environmental samples and gasoline | completed |
| 1.3 Electronmicroprobe analysis of soil samples from Callao | withdrawn |
| 1.4 Geographical information system for Callao | completed |
| 1.5 Assessment of lead exposure pathways in Lima and Callao | completed |

### 2. **Studies to estimate the magnitude of the problem** (2 activities)

| | |
|---|---|
| 2.1 Blood lead survey in other populations at risk in Callao | completed |
| 2.2 Occupational exposure evaluation | withdrawn |

### 3. **Interventions to reduce lead exposure** (7 activities)

| | |
|---|---|
| 3.1 Hiring a full-time coordinator | completed |
| 3.2 Interventions to reduce ingestion of soil contaminated with lead | endorsed |
| 3.3 Lead-screening capabilities for local health centers in affected areas | completed |
| 3.4 Nutritional interventions to decrease lead absorption and treat iron deficiency | endorsed |
| 3.5 Interventions to control sources | withdrawn |
| 3.6 Assessment for soil rehabilitation | withdrawn |
| 3.7 Medical treatment for high lead levels | completed |

### 4. **Training and capacity building for DIGESA** (4 activities)

| | |
|---|---|
| 4.1 Methodology for investigation of environmental problems | completed |
| 4.2 Use of geographical information systems to assess environmental problems | completed |
| 4.3 Training to improve laboratory quality control | completed |
| 4.4 Strengthen DIGESA’s blood lead monitoring capability | completed |

The original work plan was still a draft at the time the local coordinator was hired in November 1999 (Activity 3.1: Hiring a full-time coordinator). One of the first tasks of the local coordinator was to revise and complete a Plan of Action based on the work plan produced in April 1999 and revised in September 1999. However, based on the original corresponding timeframe of six months to conclude the second phase (which actually took longer) and in order to achieve the desired results to the extent possible, some activities had to be withdrawn and others redesigned in their implementation while retaining their original purpose.

The only activity withdrawn in this initial revision was Activity 1.3, Electronmicroprobe Analysis of Soil Samples from Callao, since no local institution was identified that could perform the test. It was decided that the identification of the source would rely on Activity 1.2, Lead Isotope Composition of Environmental and Gasoline Samples, and that this activity should be enough to settle the issue.

Between November 1999 and July 2001, 12 of the 18 activities were completed. While the work plan contemplated that most of the activities would be sponsored by USAID, sponsors had to be found for some other activities.. As the second phase of the Lead Project progressed, six of these activities required outside funding. Three activities—3.3, Lead-screening Capabilities for Local Health Centers in Affected Areas; 3.7, Medical Treatment for High Lead Levels; and 4.3, Training to Improve Laboratory Quality Control—had to be redesigned to receive funding from other sponsors and were eventually completed, but the remaining three never got sponsors: 2.2, Occupational Exposure Evaluation; 3.5, Interventions to Control the Sources; and 3.6, Assessment for Soil Rehabilitation. These were withdrawn from the work plan in March 2001.

Activity 3.3, Lead Screening Capabilities for Local Health Centers in Affected Areas, originally called for establishing blood lead capabilities for the community living in the contaminated area, but maintaining a small laboratory or even portable equipment in the dangerous neighborhood was not practical. Accordingly, this activity was reconsidered and the decision was made to establish a lead detection center in a reference hospital and train hospital personnel to correctly diagnose lead intoxication cases. Although every attempt was made to set up this detection center, the only component of this activity that was eventually realized was the training of local doctors (sponsored by the ILMC).

Activity 3.7, Medical Treatment for High Lead Levels, was proposed so that DIGESA would have access to chelating agents (which are scarce in Peru) to treat emergency lead intoxication cases that might arise in the future. Although DIGESA was supposed to buy these agents as a precaution to treat life-threatening cases, DIGESA reconsidered its role as a treatment provider and concluded that it was not within its responsibilities to distribute treatment. In the end, ILMC donated the agent succimer to DIGESA, who then distributed it to several hospitals.

Activity 4.3, Training to Improve Laboratory Quality Control, was not well defined in the original work plan and had to be redesigned. The idea came from DIGESA's need to validate its blood lead results so that the results would not be questioned when presented. DIGESA suggested technical assistance to upgrade their laboratory to international standards, but no budget had been assigned for such assistance in the work plan. Instead, DIGESA joined the BLLRS program of the CDC, which validates laboratory lead results by using blind random samples. This program is expected to continue after the Lead Project is over.

The first two sets of activities—activities to clarify sources of lead contamination and studies to estimate the magnitude of the problem—were designed to identify the source of lead contamination in the area and the extent of the contamination. Activity Report No. 104[6] (Study to evaluate sources of exposure to lead in the constitutional province of Callao, Peru) is the product of the completion of four of these activities: 1.1, Environmental Sampling Study; 1.2, Lead Isotope Composition of Environmental and Gasoline Samples; 1.5, Assessment of Lead Exposure Pathways in Lima and Callao; and 2.1, Blood lead Survey in Other Populations at Risk in Callao. This activity report clearly identifies the mineral storage sites as the primary source for lead contamination, while at the same time identifying other affected areas in Callao besides Puerto Nuevo. Activity 1.4, Geographical Information System for Callao, was used to view geographically the relation between the storage areas and lead contamination and was a key tool for the assessment.

The last set of activities (Training and Capacity Building for DIGESA) was USAID's way of supporting DIGESA as an institution in its effort to deal appropriately with the environmental problems at hand. Activity 4.1, Methodology for the Investigation of Environmental Problems, was implemented first via a workshop developed by the CDC to train DIGESA personnel in environmental epidemiology concepts and applications. Next, in Activity 4.2, Use of Geographical Information Systems to Assess Environmental Problems, some of these professionals were introduced to the uses of geographical information systems to assess environmental problems. The last activity (4.4: Strengthen DIGESA's Lead in Blood Monitoring Capabilities) provided a means for donating further equipment and supplies to support current and future studies of lead contamination.

The only pair of activities still pending by the time the second phase of the Lead Project was officially concluded in 2001 were Activity 3.2, Interventions to Reduce Ingestion of Soil Contaminated with Lead, and Activity 3.4, Nutritional Interventions to Decrease Lead Absorption and Treat Iron Deficiency. Activity 3.2 (The Behavior Change Program) was designed to reduce individual exposure to environmental lead, since the sources could not be immediately contained and the existing contamination could not easily be eliminated. This activity took much more time and funding than originally expected and its final stages are included in the new environmental activity that USAID initiated with DIGESA in 2001 following the Lead Project experience. Meanwhile, Activity 3.4, The Nutritional Supplement Study, which aimed to address iron and calcium supplementation to diminish lead absorption in children, had to be redesigned in March 2001 and eventually became part of the behavior change program in the form of healthy nutrition guidelines that will be presented to the community. This change resulted from the discovery that supplementary nutrition is not the best way to deal with malnutrition issues in the long term.

# Appendix B. Calendar of Activities

| | | |
|---|---|---|
| **1999** | Mar | Initial Lead Survey: “Blood Lead Study in Selected Populations of Lima and Callao, Peru” becomes the first phase of the Lead Project. |
| | Apr | Workplan developed for second phase: “Further Assessment of Lead Contamination, Pediatric Lead Poisoning, and Interventions to Reduce Lead Exposure in Lima and Callao, Peru.” |
| | - | |
| | Sep | Blood lead Survey for second phase of the Lead Project. |
| | Oct | Blood lead Survey continued for second phase of the Lead Project. |
| | Nov | Activity 3.1 : “Hiring a full-time coordinator” begins; Local Lead Coordinator hired. |
| | Dec | Blood lead Survey expanded for second phase of the Lead Project. |
| **2000** | Jan | ILMC meets DIGESA.<br>Blood lead screening Unit for Activity 3.3 installed at Children’s Hospital. |
| | Feb | |
| | Mar | NCEH/CDC Environmental Epidemiology Workshop concluded for Activity 4.1: “Methodology for investigation of environmental problems.” |
| | Apr | Official Presentation at DIGESA of GIS database for Activity 1.4. |
| | May | Final database presented to DIGESA for Activity 1.4: “Geographical Information System for Callao.”<br>Supplies and equipment arrive for Activity 4.4: “Strengthen DIGESA's blood lead monitoring capabilities.” Consultant travels to Lima for environmental study. 1rst meeting of the ILMC Committee. |
| | Jun | Printed final CDC Isotope Report for Activity 1.2 arrives at DIGESA concluding Activity 1.2: “Lead isotope composition of environmental and gasoline samples.” 2nd meeting of the ILMC Committee. |
| | Jul | First Draft of Activity Report No. 107 for the environmental study arrives at DIGESA.<br>NIOSH-CDC Occupational Study. |
| | Aug | 1st Trip to Lima of EHP consultant for Activity 3.2 and the 3rd meeting of the ILMC Committee. |
| | Sep | |
| | Oct | Training in GIS ArcView software concluded for Activity 4.2: “Use of geographical information systems to assess environmental problems” and 4th meeting of the ILMC Committee. |
| | Nov | First acute lead intoxication case that receives succimer within Activity 3.7 (Gianxel’s case). |
| | Dec | Second acute lead intoxication case that receives succimer within Activity 3.7 (Abraham’s case). |
| **2001** | Jan | Printed Activity Report No. 107 of the environmental study concludes Activity 1.1: “Environmental sampling study.” Activity 1.5: “Assessment of lead exposure pathways in Lima and Callao” and Activity 2.1 : “Blood lead survey in other populations at risk in Callao.”<br>2nd Trip Lima of EHP consultant for Activity 3.2 and 5th meeting of the ILMC Committee. |

|  |  |  |
|---|---|---|
|  | Feb | Third acute lead intoxication case that receives succimer within Activity 3.7 (Jose's case). |
|  | Mar | Workshop on the "Use of GIS for environmental problems" finalizes Activity 4.2: "Use of geographical information systems to assess environmental problems."<br>6th meeting of the ILMC Committee. Baseline Study for Activity 3.3 concluded at Children's Hospital. |
|  | Apr |  |
|  | May | Chelation Treatment Workshop provided by ILMC for Activity 3.3: "Lead screening capabilities for local health centers in affected areas" is held at DIGESA, and chelating agent donation by ILMC is definitely stored at DIGESA for Activity 3.7: "Medical treatment for high lead levels." |
|  | Jun | Activity 3.2: "Interventions to reduce ingestion of soil contaminated with lead" is integrated to the new Environmental Activity. |
|  | Jul | Activity 3.1: "Hiring a full-time coordinator" concludes. |

# Appendix C. NIOSH Study Abstract

Lauralynn Taylor, Robert L. Jones, Lorna Kwan, James A. Deddens, Kevin Ashley, and Wayne T. Sanderson. 2001. Evaluation of a Portable Blood Lead Analyzer with Occupationally Exposed Populations. *American Journal Ind Medicine* 40:354-362.

**ABSTRACT**

Although the U.S. national mean blood lead level has declined significantly in recent years, occupational exposures to lead are still common in the United States. Since the severity of symptoms associated with lead exposure correlate directly with increased blood lead levels, a blood lead sample is considered the main biological marker for lead exposure. This project evaluated a portable electroanalytical instrument that rapidly analyzes blood lead levels in individuals using a fresh whole blood sample (venous or capillary). The instrument, which operates by means of anodic stripping voltammetry, was originally designed to provide a rapid, cost-effective technique to monitor lead exposures of pediatric populations. However, the instrument's ability to perform rapid analysis makes it potentially valuable to occupational health professionals for medical monitoring or on-site investigations. Therefore, this instrument was evaluated within a study population consisting of 206 employees from both a lead battery manufacturing facility and a lead smelting facility. Participating employees donated two 2.0 ml venous blood samples collected into "lead-free" evacuated tubes. One blood sample was analyzed on site using the portable field instrument while the second sample was analyzed by the CDC blood lead laboratory using graphite furnace atomic absorption spectrometry. Within the study population, venous blood lead levels ranged from 1.0 µg/dL to 42.0 µg/dL. A preliminary analysis indicates that the field instrument results have a slight positive bias overall, with less bias for blood levels above 10 µg/dL. The absolute mean difference between the field instrument and the laboratory results was less than 1 mg/dL. Age, smoking status, and gender had no effect on the field instrument performance relative to the laboratory-based analytical results. This tool can provide valuable rapid blood lead information for occupational health professionals in the field.

**Conclusions**

Within the blood range evaluated (1-42 µg/dL), the instrument performed adequately according to Clinical Laboratory Improvements Amendments (CLIA) proficiency requirements. The ability of the instrument to perform rapid analysis makes it potentially valuable to occupational health professionals for medical monitoring or on-site investigations.

# Appendix D. CDC Guidelines 1997: Comprehensive Follow-Up Services, According to Diagnostic* Blood-Lead Level

| **BLL (µg/dL)** | **• ACTION** |
|---|---|
| <10 | Reassess or rescreen in 1 year. No additional action necessary unless exposure sources change. |
| 10-14 | Provide family lead education<br>Provide follow-up testing.<br>Refer for social services, if necessary |
| 15-19 | Provide family lead education<br>Provide follow-up testing.<br>Refer for social services, if necessary.<br>If BLLs persist (i.e., 2 venous BLLs in this range at least 3 months apart) or worsen, proceed according to actions for BLLs 20-44 |
| 20-44 | Provide coordination of care (case management).<br>Provide clinical management (described in text).<br>Provide environmental investigation.<br>Provide lead-hazrd control. |
| 45-69 | Within 48 hours, begin coordination of care (case management), clinical management (described in text) environmental investigation, and lead hazard control. |
| 70 or higher | Hospitalize child and began medical treatment immediately. Begin coordination of care (case management), clinical management (described un text), environment investigation, and lead-hrzard control immediately. |

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