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PRIDE Project in Development and the Environment

# Proyecto Ecoriesgo: Ranking Environmental Health Risks in Metropolitan Lima, Peru


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## PREFACE AND ACKNOWLEDGMENTS

This report summarizes the findings of a project conducted in 1996 and 1997 for the U S Agency for International Development (USAID) mission in Peru The project evaluates the environmental problems facing Metropolitan Lima, Peru, and develops two rankings of the problems 1) in order of their relative severity in posing health risks, and 2) in order of the priority that should be given to addressing each problem The project's priority judgments were developed by committees representing the key institutions involved in environmental management in Lima The improved understanding of Lima's environmental problems and broad consensus on priorities resulting from this project provide a good foundation for continuing future work in managing the most serious problems

Many people contributed to this project It was conducted under the auspices of the Project in Development and the Environment (PRIDE) a USAID project operated by Chemonics International Inc and its associates Stuart Sessions (Environomics, Inc ) was the team leader Anna Zucchetti (Oficina de Asesoria y Consultoria Ambiental, OACA) was the coordinator of the project team in Peru and she with Marcos Alegre (OACA) and Augusto Lanao (OACA) made up the Lima team of environmental consultants Lynette Benson (Environomics, Inc ) and Jorge Otero (Chemonics International) were additional U S -based team members Milagros Bello (OACA) provided administrative coordination and support for the two project committees, as well as expert interpretation and translation Kathryn Steucek (Environomics, Inc ) contributed to data collection and the final report as a research assistant Laura Manthey and Cody Rice (Chemonics International) administered the overall project effectively, while the staff at OACA supported the activities in Lima Daniel Valle (CIPUR) served as technical facilitator for one of the committees

About 30 individuals from Lima participated as members of the Steering and Technical Committees for the project, representing key public and private sector institutions concerned with Lima's environment They graciously attended and contributed in many committee and subcommittee meetings, reviewed materials, assisted with data collection and gave their advice Raoul Tolmos (Consejo Nacional del Ambiente, CONAM) was particularly helpful

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Many other people provided help, and the team is indebted to them even though we have not named them here The views expressed in this report, however, are those of its authors and do not necessarily reflect those of USAID, the Governments of Peru or Lima, or others who have assisted in the project

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# EXECUTIVE SUMMARY

## A Overview

This report summarizes the findings of a comparative risk analysis (CRA) of the environmental problems affecting Metropolitan Lima, Peru CRA is a systematic process that is especially helpful for setting priorities for a geographic area that faces many environmental problems but has insufficient resources for managing all of them In the CRA process, individuals representing a wide range of concerned institutions work together first to investigate, understand and rank the environmental problems and then to decide what to do about the most serious of them The first half of this process has been completed in Lima thus far, resulting in a detailed evaluation and priority ranking of the metropolitan area's environmental problems

The U S Agency for International Development (USAID) mission in Peru contracted for this study and directed it The project had two objectives

- Study Lima's environmental problems and the health risks they pose and use a systematic process to rank them in priority order, and
- Do this in a participatory manner, involving representatives of all the key institutions concerned with environmental management in Lima, thus encouraging a broad-based consensus on the resulting priorities and promoting future inter-institutional collaboration for addressing them

The project was performed in 1996 and 1997 by a project team of six Peruvian and U S environmental consultants and two committees (a Technical and a Steering Committee) of more than 30 representatives of Peruvian institutions concerned with environmental management in Lima The committees guided the work of the project team during several meetings along the project development The project team gathered existing environmental data for Lima and estimated the health risks likely to result from different environmental problems Using the project team's draft reports, the Technical Committee compared Lima's problems and ranked them by the relative magnitude of the adverse human health impacts they cause The Steering Committee considered the technical, economic and social feasibility of addressing each of the environmental problems and developed a different ranking indicating which of them should receive the most management priority

The following ranking developed by the Technical Committee indicates the relative degree to which the different environmental problems pose health risks to Lima's population (Table ES-1) The ranked problems were also subdivided into three risk categories high, intermediate and low risk, as shown below (Table ES-2)



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**Table ES-1 Relative Health Risks from Environmental Problems in Metropolitan Lima (listed in descending order of risk)**

| |
|---|
| Limited coverage and erratic service by the water supply system |
| Limited coverage of the sewerage system |
| Solid wastes |
| Contaminated surface water |
| Contamination and overexploitation of groundwater |
| Food contamination |
| Air pollution (outdoor) |
| Contamination of the sea |
| Toxic substances |
| Hazardous solid wastes |
| Air pollution (indoor) |
| Loss of agricultural land and green areas |

**Table ES-2 Ranking of Environmental Problems in Risk Categories**

| |
|---|
| ***High Risk*** |
| Limited coverage and erratic service by the water supply system |
| Limited coverage of the sewerage system |
| Solid wastes |
| ***Intermediate Risk*** |
| Contaminated surface water |
| Contamination and overexploitation of groundwater |
| Food contamination |
| Air pollution (outdoor) |
| Contamination of the sea |
| ***Low Risk*** |
| Hazardous solid wastes |
| Toxic substances |
| Air pollution (indoor) |
| Loss of agricultural land and green areas |

A detailed analyses of the anatomy and nature of each problem indicates that -- currently -- the impact on the health of Lima's population resulting from exposure to biological agents is far more



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important than exposure to chemical pollutants However, information on chemical contamination of different environmental media in Lima is very limited and often insufficient for conclusions about health risks

## B Anatomy and health risks of Lima's environmental problems

**1 Limited coverage and erratic service by the water supply system** This is the major environmental factor contributing to unsanitary conditions and high rates of infectious diseases in Lima Plentiful clean water in the home is critical to good hygiene About one quarter of Lima's population is without a direct water supply connection and nearly 40 % of the households served by the public system share a communal connection with multiple households Service is often intermittent and discontinuous Individuals with no or limited water service often must obtain water from sources of dubious quality and store it, providing further opportunity for contamination These individuals use very little water for sanitary purposes and must pay high rates for it Diarrhea incidence in Lima is estimated to be about 2 1 cases per person per year, corresponding to a total annual number of cases of more than 14 million At least 30 % of such cases are water-related, for a total of more than 4 million cases per year It is estimated that extending water connections to all Lima residents would reduce the annual number of gastrointestinal illness cases by about 1 4 million Further reductions would occur if more reliable services were provided to those already connected, but these could not be estimated

**2 Limited coverage of the sewer system** This is also a very important environmental factor contributing to unsanitary conditions and high rates of infectious diseases in Lima Only about 72 % of Lima's population is connected to the sewer system Others use latrines or septic tanks, or have no facilities at all In areas without sewers, human fecal material remains where it can be contacted by people or spread by animals and vectors, and where it can further contaminate food and water supplies Since many infectious diseases are transmitted by the fecal-to-oral route, conveying human waste away from where people are likely to come in contact with it will significantly reduce exposure As with water supply and service, deficiencies in sewerage contribute to a large fraction of the more than 4 million cases per year of diarrheal diseases in Lima that are water-related We estimate that extending sewer service to the entire population of Lima would avoid about 1 3 million cases per year

**3 Solid wastes** Health risks from solid wastes are concentrated in the poorer areas of the city with minimal refuse collection, but the entire population of Lima can be affected About 65% of solid waste is collected, but only 33 % of that is disposed of in one of the city's two sanitary landfills, leaving more than 70 % of Lima's solid waste discarded in streets, vacant areas, river banks and informal dumps Uncollected and improperly disposed solid waste supports vectors (rats, insects, dogs) that are important in infectious disease transmission However, transmission of infective agents by this pathway is judged to be less direct and significant than by other means, such as lack of water and sewers Informal burning of solid waste contributes about 10% of the particulate matter in Lima's air At least 10,000 individuals involved in collection, informal recovery and recycling of materials from solid waste face additional risks



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**4 Contaminated surface water** The Rimac river provides 61% of the water supply for the SEDAPAL system (the remainder comes from wells), which serves approximately 75% of the population At the SEDAPAL treatment intake point, the Rimac has high bacterial and metal contamination from upstream communities and mining, and water quality approaches that of sewage as the river moves further through the city Treated water shows low and acceptable levels of most pollutants and good levels of chlorine residual Assuming that tap water quality is similar, we estimate minimal risks to Lima's population from drinking this treated surface water Thus, even though the river is highly contaminated, its highest volume use -- for drinking water -- results in little health risk A risk of 20 8 additional cancer cases per year due to arsenic in the water and 1 75 additional cases related to trihalomethanes were calculated Significant risks from contaminated river water come from other routes of exposure using it directly for drinking, washing, preparing food or cleaning implements, irrigation of food crops, recreation, or washing clothes Contaminated river water may also affect ground water through percolation and recharge, or it may infiltrate through cracks into pipes carrying treated drinking water No data are available on the extent to which these direct exposures to contaminated surface water occur, but the Technical Committee thought them to be important

**5 Contamination and over-exploitation of ground water** Perhaps half of Lima's population relies on underground water, either through SEDAPAL (which obtains 38% of its water from underground) or through several hundred community and private wells used by most of the population not connected to the SEDAPAL system Most of SEDAPAL's wells have acceptable bacteriological water quality and are chlorinated, but risks may be associated with non-SEDAPAL wells, about which little is known Non-SEDAPAL wells are often poorly constructed and their water is rarely disinfected before use, so microbiological contamination is likely common In 1996, total morbidity for water-related infections in Metropolitan Lima was estimated at 4,235,059 A quantitative estimate of the relative contribution of contaminated underground water to this morbidity total cannot be made, but we believe that it probably constitutes only a moderate proportion of the total number of cases Detailed information on chemical contamination of underground water is lacking Nitrate levels exceed the standard in some SEDAPAL wells, potentially leading to cyanosis in infants fed with formula made with ground water, but this is likely quite rare Of greater concern is the inference that if surface activities have caused significant contamination of ground water by nitrates, other surface pollutants that are typically not monitored for in ground water (pesticides, heavy metals, hydrocarbons) may also be present The Technical Committee was also very concerned about heavy use of ground water exceeding natural recharge, resulting in a falling water table, dry wells, increased pumping costs, and salt water intrusion in coastal areas In the future, large health risks will result if Lima's growing population cannot obtain the quantity of water needed for basic sanitary practices

**6 Food contamination** Food may be contaminated by biological or chemical agents Food becomes contaminated by biological agents through unsanitary preparation by street vendors and in the home, use of untreated sewage for crop irrigation, discharge of untreated sewage into the ocean, contaminating seafood, and washing food with contaminated water Most of the population of Lima likely faces health risks though eating contaminated food Studies carried out in different countries indicate that food contributes to approximately 70% of the total incidence of gastrointestinal infections Applying this evidence to Lima, we estimate that food could contribute to nearly 10 million cases per

year of diarrhea and other gastrointestinal illnesses annually in the city Despite the many cases of infectious disease transmitted through food, the Technical Committee believed that their prevalence should be regarded as a general problem of sanitation rather than specifically as a problem of food contamination While food may often provide the means by which an individual contacts the infectious agent, it is often the lack of water, the lack of sewers, contaminated water, uncollected garbage and vectors that create the unsanitary conditions in the first place Information on chemical contamination of foods in Lima is very limited and insufficient for conclusions about health risks Some data suggest high levels of metals in seafood and a need for further investigation of pesticide residues in food, which could exceed levels of concern A hazard index of 0 85 -- very near the level of concern -- was calculated for Aldicarb, one of the few pesticides which has been measured in some vegetables consumed in the typical diet of the population

7 **Air pollution (outdoor)** Lima's air pollution is mainly caused by motor vehicles and industry, with important additional elements such as burning solid waste Little attention has been given to this issue The available monitoring information in Lima is scattered, discontinuous, sometimes conflicting and thus insufficient to provide a confident picture of the typical ambient concentrations to which the general population is exposed The ambient concentrations of most of the air pollutants monitored in Lima exceed the health-base standards from World Health Organization (WHO) and the U S It is estimated that the contamination caused by suspended particles is probably responsible for 330 - 2200 premature deaths and an average loss of 0 9 - 5 6 days of productive activity per person per year Sulfur dioxide is probably responsible for between 320 - 2300 premature deaths per year and an average of 0 3 - 2 0 days of respiratory problems per person per year Lead in the air is also responsible for IQ level reductions of 0 6 - 1 6 points on average in children, as well as causing 212 - 588 premature deaths per year in Lima Air pollutant health effects estimates -- which seem to suggest that air pollution is among the highest risk environmental problems in Lima -- are regarded by the Technical Committee as highly uncertain The Technical Committee was also uncertain about the extrapolation to Lima of pollutant dose-response relationships developed elsewhere

8 **Sea pollution** Nearly all of Lima's domestic and industrial wastewaters are discharged untreated into the sea, which results in health risks through contaminated seafood (see food contamination) and swimming at contaminated beaches Peru's bacteriological swimming standards are exceeded at 30 - 40 % of Lima's beaches A study of swimmers along Miraflores Bay found increased risks of gastrointestinal and respiratory illnesses A very rough extrapolation of relationships found in studies in other countries suggests that contamination at Lima's beaches may cause between 50,000 - 150,000 cases of gastrointestinal and other illnesses each summer

9 **Hazardous solid wastes** Hazardous solid wastes are produced by hospitals, industry and households Virtually no quantitative information is available on the volume, treatment or destiny of hazardous wastes in Lima However, it is estimated that hospitals produce around 30 tons/day of hazardous waste, of which 15 4 tons is contaminated with biological materials Solid waste generated in the households of the whole city includes 37 5 tons/day of biocontaminated residues Hazardous chemical waste is mainly generated in industrial activities but there are no confident estimates of volumes produced or final destiny Some hazardous waste is sent to one of the two sanitary landfills,

a small fraction of hospital wastes is incinerated, and the rest meets a fate similar to non-hazardous solid waste We expect that hazardous waste primarily affects individuals who collect, transport, work with or recycle solid wastes, as well as those living near dump sites Although hazardous waste may contain very toxic or infectious substances, its relatively small quantity and the limited exposure to it probably result in modest health risks across the entire population

**10 Toxic substances** Existing data on toxic substances in Lima are scattered and limited In most instances where metals or pesticides have been measured, they occur at levels that are not expected to cause significant health effects Levels of the following toxic substances appear in concentrations potentially of concern metals in seafood, the pesticide Aldicarb in several foods, arsenic and disinfection byproducts in drinking water Lead is a toxic substance of special concern Three small blood lead studies in Lima suggest significant health problems (premature mortality among adults and impaired mental development among children), but the studies are neither recent nor necessarily representative Lead in Lima's ambient air often exceeds WHO and U S standards

**11 Air pollution (indoor)** Essentially the air indoors is outdoor air, with additional contributions from some domestic activities that require fuel burning (food preparation, heating, lighting where there is no electricity) and habits such as smoking Indoor air pollution is not expected to pose high health risks in Lima largely because most dwelling units are well ventilated and not fully enclosed Several housing characteristics can increase risks, though overcrowding, shops and workshops in dwellings (approximately 60 thousand), use of kerosene for cooking and lighting, candles used for lighting, and smoking Some preliminary studies about indoor pollution in Lima , have found that the concentration of gases (CO, $NO_x$ and $SO_2$) were within recommended levels, but particle concentrations often exceeded standards accepted by the international scientific community The most serious aliments claimed as relating to indoor air quality questions were headaches, insomnia, fatigue, throat irritation and respiratory infections These effects may have been due to external conditions (such as outdoor pollution, noise, vehicle traffic, dustfall, humidity and temperature) rather than specifically to indoor sources In Lima, lung cancer incidence is very low (250 cases per year) and smoking is a lesser contributor to indoor pollution than it is elsewhere

**12 Loss of green areas and agricultural zones** Agricultural land within metropolitan Lima has disappeared at a rapid rate, declining from 90% of the area in 1940 to 5% in 1992 At the current rate of conversion, agricultural land will totally disappear by 2010 Parks and green areas are similarly limited Lima has now 1 9 square meters of park land per inhabitant relative to the internationally recommended value of 8 square meters per person Despite these deficiencies, loss of green areas and agricultural zones has only a small and indirect effect on health Loss of these areas reduce the capacity for attenuation of air pollution, and reduces the rate of recharge of ground water (irrigation of these areas is a major source of ground-water recharge) Their loss also makes the landscape less attractive and reduces the opportunities for recreation, thus decreasing the general quality of life in the city On the other hand, the reduction in agricultural lands may improve the health of the population by reducing agricultural pollution- pesticides, nitrates and pathogens on foods that have been irrigated with sewage

## C Priority Ranking of Environmental Problems in Lima

The Steering Committee developed a priority ranking of problems to reflect the relative level of management attention that should be given to each (Table ES-3) The Committee considered not only the severity of each problem in terms of the health risks it poses, but also weighed a range of factors relating to current abilities to address the problems economic, socio-economic, political and institutional, technical and scientific

**Table ES-3 Priority Ranking of Environmental Problems**

| |
|---|
| Limited coverage and erratic service by the water supply system |
| Contaminated surface water |
| Limited coverage of the sewerage system |
| Solid wastes |
| Food contamination |
| Contamination and overexploitation of groundwater |
| Contamination of the sea |
| Air pollution (outdoor) |
| Hazardous solid wastes |
| Toxic substances |
| Air pollution (indoor) |
| Loss of agricultural land and green spaces |

This priority ranking is very close to the health risk ranking of the problems developed by the Technical Committee The top priority problems are a set of interrelated issues concerning water supply, water contamination and management of human wastes In addition to health risks, these problems cause significant diminution of the quality of life in Lima Limited, unreliable and unclean water supplies represent not only a sanitation problem, but also high cost, inconvenience and worry for many families The only problem ranked more than one place differently in the health risk and priority rankings was contaminated surface water It was considered to warrant more attention than its health risks alone might suggest for two reasons the close interconnection between surface water contamination and many other problems (improving surface water quality will help to solve other problems), and the intensive effort needed to coordinate the multiple institutions in Lima and upstream that affect river water quality

The Steering Committee emphasized that the priority ranking represents the overall level of attention that should be given to each problem now, but does not necessarily reflect how additional or future environmental management efforts and resources should be allocated A survey should be conducted of environmental management institutions in Lima to determine the status of current and planned activities in each of the problem areas This would identify 1) problems that, even though they

are high priority, are receiving adequate attention currently, and 2) problems that might be somewhat less pressing, but which are receiving virtually no attention currently Environmental trends will also be important The risk ranking and priority ranking reflect the current status of problems in Lima Over time, control efforts will lessen some problems while pressures of population and economic growth will worsen others Risk management activities in Lima should include a component to identify important trends and recognize opportunities to alter, adapt to or profit from these trends

## D Ranking of Aggregate Problems

The Project team and the two Committees considered that a separate ranking of aggregate problems should also de developed After all, environmental problems are strongly inter-related and the resulting risks are also tightly interdependent (Figure ES-1) For example, limited coverage and erratic water supply services, limited coverage of sewers and sanitation systems, contaminated surface and underground water, and food pollution are very tightly inter-related To different extents, they all contribute to the high incidence of gastro-intestinal diseases in the population of Lima

In addition, the relative ranking of problems is also influenced by their operational definition and categorization Aggregating them according to their nature could change the weight of the overall health risk and result in a different ranking The ranking of aggregated problems as developed by the project team is shown in Table ES-4

**Table ES-4 Ranking of Aggregated Environmental Problems**

| |
|---|
| Limitations in coverage of water and sewerage infrastructure |
| Contamination of waters (surface, groundwater, sea) |
| Food contamination |
| Air pollution (outdoor and indoor) |
| Solid wastes (domestic and hazardous) |
| Toxic substances |
| Loss of agricultural land and green areas |

## E Recommendations Regarding Risk Management

This project intentionally concentrated on assessing Lima's environmental problems in order to provide a firm foundation for future efforts to manage them effectively The project has not included a risk management phase, such intensive management planning efforts will likely be the subject of future projects funded by a broader range of supporters The Steering Committee recommends that remaining project funds be used to develop background information useful for a full risk management planning effort that would continue the multisectoral, participatory process begun in this project The planning effort should consider both narrowly focused initiatives addressing key parts of high priority



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problems and broader measures to improve the environmental culture of the city that address multiple problems simultaneously Some broad initiatives might include improving environmental education, improving the efficiency of water use, and improving the quality and availability of environmental information

## F Recommendations Regarding Environmental Information

In the course of this project we searched for and assembled existing information on each environmental problem in Lima Some significant information gaps became apparent In some cases these gaps might be addressed by one-time sampling efforts or studies, and in other cases a more expensive, ongoing, long-term monitoring program would be necessary Recommended monitoring would include 1) a systematic air quality monitoring network, and 2) an improved and expanded summer monitoring program at swimming beaches Additional studies might focus on 1) sampling to characterize the levels of lead in the blood of Lima's population, 2) characterize the quality of indoor air in households of different socio-economic sectors, 3) investigating the level of toxic substances in food and drinks, 4) collecting information on the sources and quality of household drinking water for those not served by SEDAPAL, 5) studying quality of water at the tap for a wide variety of households, 6) developing an inventory of major industrial pollution sources, and 7) better understanding the generation and disposition of hazardous wastes in the metropolitan area

In addition, it is critical that complete information on the quality of Lima's environment be available to its citizens Successful environmental management efforts depend on public support which in turn depends on the public's knowledge about environmental conditions, problems, risks and potential solutions Governmental organizations and NGOs should seek to raise public awareness and knowledge on environmental issues and increase public involvement in environmental decisions Means should be developed to ensure that environmental information is accumulated, maintained, and made available to the public



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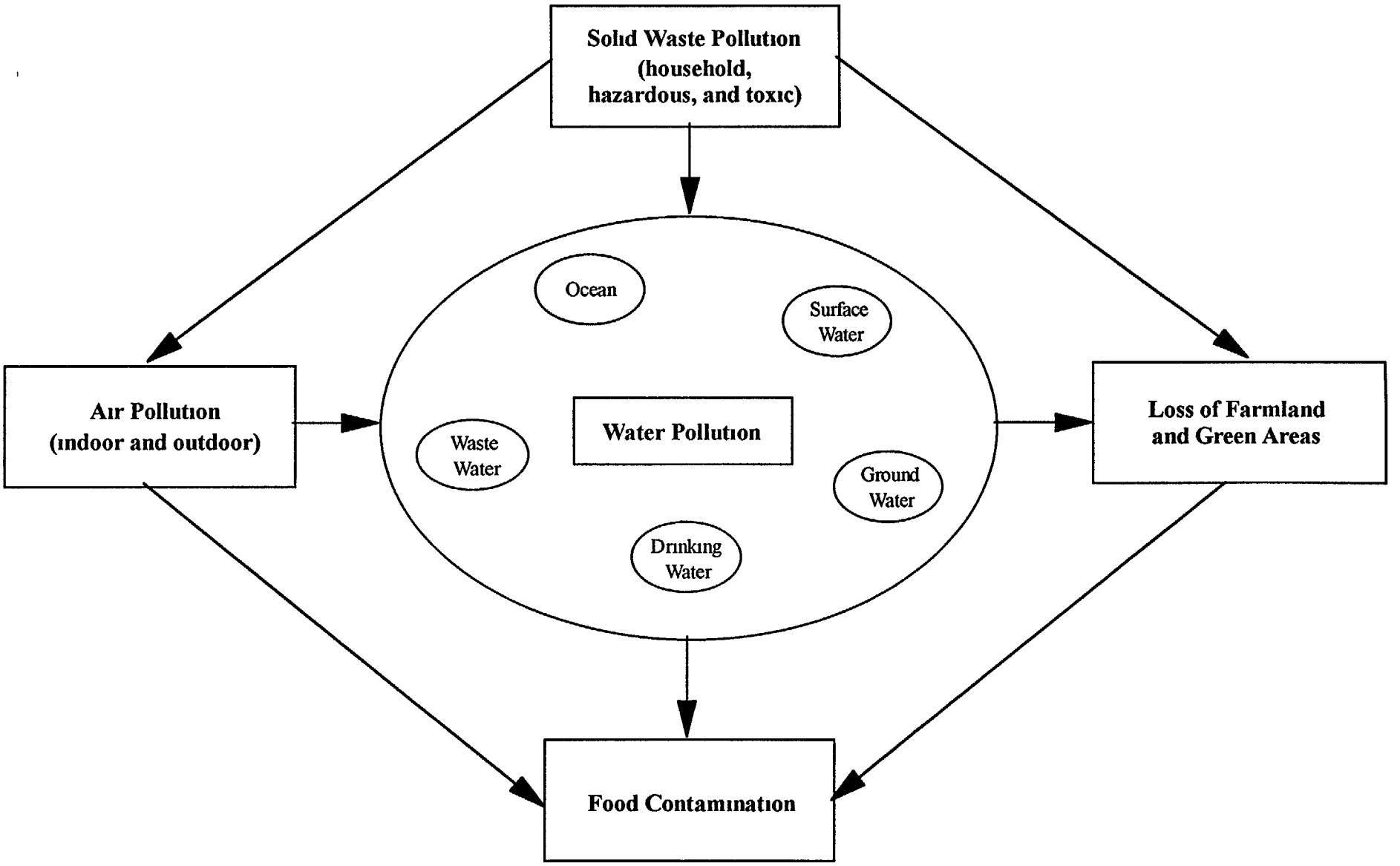
**Figure ES-1 Interrelationship of Environmental Problems**



# SECTION I
# INTRODUCTION

This report is the result of a comparative risk analysis (CRA) project carried out in Metropolitan Lima, Peru CRA is a systematic process that can help in setting priorities for a geographic area that faces many environmental problems but has insufficient resources for managing all of them In the CRA process, individuals representing a wide range of concerned institutions work together first to investigate and understand the environmental problems and then to decide what to do about them This report summarizes the conclusions of the first half of the CRA process in Lima, which has resulted in a detailed evaluation and priority ranking of the metropolitan area's environmental problems

## A Background

Lima in many ways is typical of other large capital cities in developing countries Commercial and industrial growth has increasingly concentrated in the country's primary city Perceived economic opportunity in the capital has drawn great numbers of immigrants from poorer rural areas Since 1961, the population of Metropolitan Lima has grown at an annual average of 3 9 %, while that of the remainder of the country has grown at only 2 6 % annually, about 2/3 as rapidly Lima now encompasses 29 % of Peru's population, but more than half of the country's economic activity and 65 - 70 % of its industry

The concentration of population growth and economic growth in Lima has produced in the city a paradoxical combination of both some environmental problems stemming from poverty and others caused by increasing affluence

Much of Lima's population growth has occurred in numerous informal new settlements (called *pueblos jovenes*, or "young towns") on the barren hills on the city's periphery, where development of environmental infrastructure -- piped drinking water, sewers, garbage collection and disposal -- has not kept pace with needs Overall, 25 % of the city's population is without direct water service and another 30 % of the population relies on communal connections shared with other households 28 % of the population is not connected to the sewer system, and virtually none of the city's sewage is treated before discharge to rivers, the sea, or agricultural fields Only about two thirds of the solid waste generated in Lima is collected and only about one third of that is disposed in sanitary landfills, leaving about 80% of solid waste on streets or in informal dumping areas This lack of basic sanitation services contributes to high rates of infectious diseases In 1991 and 1992, for example, roughly 40,000 cases of cholera were reported in Lima in the most serious outbreak of this disease in several decades

Uncontrolled pollution from economic growth in Lima causes different sorts of problems Lima's growing industrial sector is virtually unregulated, discharging nearly all of its wastes into the air, water or land without treatment Vehicle traffic and emissions are increasing sharply, with the vehicle fleet increasing by 23 % during the period 1993 - 1995, while population increased by only about 6 % As a result, the levels of suspended particulate matter in Lima's air are more than double the standards

prescribed by the World Health Organization (WHO) Airborne sulfur dioxide, lead and carbon monoxide also now exceed WHO standards in many parts of the Metropolitan area

Population and economic growth together are combining to strain Lima's natural resource base Lima has a desert climate, with rainfall averaging only 7 - 10 mm per year Nearly 100 % of the water from the three rivers in the metropolitan area is withdrawn and used, leaving the rivers as trickles when they flow into the sea The remainder of the city's rapidly growing water needs are met by ground water Pumping of ground water significantly exceeds natural recharge, causing a decline of the underground water table by about two to four meters per year and increasing the extent of salt water intrusion into formerly fresh water aquifers Rapid urbanization is also consuming Lima's green and agricultural areas -- necessary for crop production, recreation, ground-water recharge and aesthetics -- at an alarming rate Over the last fifty years, the percentage of the metropolitan land area devoted to farming has decreased from 90 % to 5 %

Fortunately, it is now widely recognized in Lima that this increasing environmental degradation threatens continued and sustainable economic development Pollution causes serious health damages among the population, reducing their quality of life and economic productivity Pollution and mismanagement diminish the resources that are needed by important sources of jobs and incomes industry, agriculture, tourism and fisheries Pollution degrades the aesthetic quality of life in the city, with garbage, dirt, odors, reduced recreational opportunities, noise, and fear of diseases from exposure to pathogens and toxic chemicals Recognizing these damages, local, national and international organizations are all taking important steps to improve the management of Lima's environment For example

- The municipalities of Lima and Callao within the last few years have established environmental management departments In January, 1996, Lima completed a comprehensive three-year plan for the environmental recovery of the metropolitan area The city has prepared a major project for environmental infrastructure, monitoring and management in the historic center area, and is now seeking bank loans to implement it

- The national government of Peru created at the end of 1994 a National Council on the Environment (CONAM) charged with formulating, coordinating, directing and evaluating national environmental policy With assistance from USAID, CONAM is now developing a system of norms and standards for the economic sectors responsible for the bulk of pollution in Peru Several national agencies (e g , Ministry of the Presidency, Ministry of Health, National Meteorology and Hydrology Service) have developed special projects focusing on aspects of Lima's environment For example, the Ministry of the Presidency is implementing the PROMAR project to eliminate pollution of the coastal waters and beaches along most of Lima's shoreline

- International donor and lending agencies are focusing an increasing portion of their assistance to Peru on urban environmental issues USAID/Peru in its 1995-96 Action Plan adopted for the first time explicit objectives involving urban environmental problems USAID/Peru has begun implementing a 5-year project for Sustainable Environmental and Natural Resources

Management (SENREM) SENREM includes several components that will contribute to better environmental management in Lima 1) establishing an improved legal, regulatory and policy framework, 2) expanding public awareness on environmental issues and strengthening private sector advocacy organizations, and 3) supporting small environmental improvement demonstration projects The World Bank and the Inter-American Development Bank conduct at least four major urban environmental loan programs in Peru, totaling several hundred million dollars The European Union, Japan, Germany and other countries also provide assistance

- Numerous local non-governmental organizations have been established in Lima devoted to environmental issues -- community activist groups, consulting firms, research institutions, development groups Their growth is partly because of popular concern for the environment, partly due to the need for environmental consultants to contribute to industrial and infrastructure development projects, and partly because of a demand for Peruvian environmental experts to implement foreign assistance projects

In view of the numerous serious environmental problems affecting Lima and the rapidly growing set of institutions that can contribute in addressing them, there are two critical needs in order to organize future activities effectively

1 A rigorous, careful decision on environmental priorities Available resources are very far short of what would be needed to solve all of Lima's environmental problems Choices must be made Which problems are most serious and deserve the most attention? What exactly should be done about them?

2 Consensus among the institutions involved in environmental management in Lima on the priorities and an action plan Given the wide dispersal of environmental responsibilities among different institutions (no institution has a lead role), it is critical that all participants share a common vision of what should be done and who should be responsible for implementing the different portions of the plan

This CRA project is designed to contribute to meeting these two specific needs In so doing, it is intentionally somewhat different than other recent environmental planning efforts relevant to Lima (e g , the municipality's plan for environmental recovery, the Peruvian National Environmental Action Plan) The CRA aims to make choices about priorities among environmental problems rather than to develop a lengthy list of recommended actions for every problem The CRA process involves participants from a wide variety of institutions in a democratic, consensual process rather than being directed by a single organization

## B Project History

This CRA of Metropolitan Lima was carried out under contract with USAID/Peru Funding was provided by USAID's Environmental Initiatives for the Americas program, intended to contribute to environmentally sustainable development throughout the hemisphere The work was directed by USAID/Peru's Office of Rural Development, Alan Davis, Vice Director and Edilberto Alarcon,

Environmental Officer USAID/Peru developed the project to help in determining cost-effective environmental policies and programs in Lima and perhaps more generally in other urban areas in Peru for both USAID and Peruvian governments

Representatives of many Peruvian institutions, including the public and the private sector and local, regional and national governments, participated in the study The institutions committed to support the study by providing policy officials and technical experts to serve on the study's Steering and Technical Committees and by providing whatever relevant data they had available The study is not, however, the responsibility or the product of any of the participating Peruvian institutions None of the institutions have formally reviewed or approved the study's conclusions, although we expect that the institutions would be likely to agree with the conclusions given the participation of key individuals from each institution The study thus represents a product contracted for by USAID/Peru that was developed with extensive support from the Peruvian government and other groups, but the study does not necessarily represent the policies or judgments of any of the groups

The study began in May, 1996 in Lima A project team of three U S and three Peruvian environmental experts worked to define the approach, a work plan, and the list of information needed for evaluating Lima's environmental problems Two committees were established to guide the project, consisting of individuals from institutions with responsibilities and expertise on environmental management in Lima The Steering Committee was charged with directing the project generally, making decisions about its scope and methods, resolving issues, facilitating contributions from the institutions that the members represented, and ultimately ensuring that the project would be as useful as possible The Technical Committee was charged with identifying data sources, making judgments about issues when data was lacking, and producing the eventual ranking of the relative severity of Lima's environmental problems Individuals were hired to serve as administrative coordinator and as technical facilitator for the committees An environmental non-governmental organization (the Oficina de Asesoria y Consultoria Ambiental, or OACA) was retained to provide administrative and logistical support for the project

From June through November of 1996, the committees met approximately monthly and the project team collected and analyzed data on the environmental problems The data and analysis were reported in a set of 10 papers covering the problems Based on the information in the papers, the Technical Committee then developed a ranking of the problems in order of their relative severity and the Steering Committee developed a somewhat different ranking of the priority that should be given in addressing each problem The project team drafted this summary report, presenting a profile of Lima's environmental problems and describing the rankings and recommendations of the committees The draft report was circulated for comment and suggested revisions to USAID, the committee members, and a panel of environmental experts in Lima who had not previously been involved in the project Several outreach activities will conclude the project during 1997, including a large public meeting to present and discuss the project's conclusions

The project thus concludes with a thorough and widely shared understanding of Lima's environmental problems and a preliminary ranking of the priority that should be given to addressing each problem This constitutes essentially the first half of the CRA process The remainder of the process --

deciding what to do about the most serious problems -- remains to be completed USAID hopes that the successful work to date in evaluating the problems and the cooperative relationships that have characterized this work will provide a persuasive foundation for continuing the CRA process Following the public meeting concluding this project, USAID will convene the participating institutions and other potentially interested donor agencies to determine how to formulate and evaluate specific strategies for ameliorating the highest priority environmental problems in Lima

## C Organization of the Report

This report consists of two parts In the first part, following this Introduction (Section I) is a section which presents the key findings and recommendations of the project This second section ranks Lima's environmental problems according to the health risks they pose, presents a priority ranking of the problems, and provides recommendations regarding environmental information needs and future steps in risk management Section III then describes the comparative risk analysis methodology as it has been applied in the past and here in Lima

The second part of the report includes 12 papers Two introductory papers provide background on the city and on the institutions involved in the city's environmental management Ten papers then cover the environmental problems in Lima, providing for each problem a summary of the available information and an analysis of the health risks it poses We have also included an appendix describing in more detail the health risk analysis methods from the United States Environmental Protection Agency (EPA) that were used in this project Bibliographic references for some papers are included in the relevant sections and in other cases they are compiled into a summary at the end of the report

## SECTION II
## FINDINGS AND RECOMMENDATIONS

In this project, we have compiled information on the current environmental problems in Lima. We have then analyzed it with the aim of estimating the health risks that each problem poses Papers summarizing these investigations were presented to two committees of experts (a Technical and a Steering Committee) They represented the institutions involved in environmental policy development and management in Lima. The committees developed two rankings from the project

- **A risk ranking** Lima's environmental problems were ranked in order of their relative severity This was measured by the extent to which they pose potential health risks

- **A priority ranking** This ranking considered both the severity of the environmental problems and the degree to which each might successfully be addressed The priority ranking indicates the relative level of management attention each problem should receive

The two rankings are presented and discussed in this section of the report In addition, we provide several broad recommendations for future environmental management in Lima.

### A Ranking of Lima's Problems According to Health Risks

For each environmental problem in Lima, we acquired data on the emissions and ambient concentrations of relevant pollutants and on human exposure to them These data for Lima have been combined with information from international sources on how these pollutants affect human health Estimates were developed of the number and type of adverse health impacts likely to result from each problem. The Technical Committee then ranked the environmental problems based on the magnitude and severity of these adverse health impacts

Although grounded in science, comparative risk analysis also depends strongly on qualitative and subjective judgment Available information on both levels of pollutants and their potential effects is limited and uncertain The Technical Committee's summary judgment on each environmental problem involved combining information about magnitude and severity with an understanding of the quality and biases of the underlying data.

Table II-1 summarizes the Committee's ranking of environmental problems in Lima based on the health risks they pose The ranked problems were also subdivided into three risk categories high, intermediate and low as shown below (Table II-2)

**Table II-1· Relative Health Risks From Environmental Problems in Metropolitan Lima**
(Listed in descending order of risk)

| |
|---|
| Limited coverage and erratic service by the water supply system |
| Limited coverage of the sewerage system |
| Solid wastes |
| Contaminated surface water |
| Contamination and over-exploitation of ground water |
| Food contamination |
| Air pollution (outdoor) |
| Contamination of the sea |
| Hazardous solid wastes |
| Toxic substances |
| Air pollution (indoor) |
| Loss of agricultural land and green areas |

**Table II-2. Ranking of Environmental Problems in Risk Categories**

| |
|---|
| ***High Risk*** |
| Limited coverage and erratic service by the water supply system |
| Limited coverage of the sewerage system |
| Solid wastes |
| ***Intermediate Risk*** |
| Contaminated surface water |
| Contamination and over-exploitation of ground water |
| Food contamination |
| Air pollution (outdoor) |
| Contamination of the sea |
| ***Low Risk*** |
| Hazardous solid wastes |
| Toxic substances |
| Air pollution (indoor) |
| Loss of agricultural land and green areas |

A detailed analysis of the nature of each problem indicates that the impact on the health of Lima's population resulting from exposure to biological agents is far more important than exposure to chemical



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pollutants However, information on chemical contamination of different environmental media in Lima is limited and often insufficient for conclusions about health risks

The most important factors determining the ranking of each problem are discussed below More detail is provided in the papers included in Sections VI - XV of this report They describe each problem and how its health risks were estimated

## B. Health Risks from Lima's Environmental Problems

**Limited coverage and erratic service by the water supply system.** This is the major environmental factor contributing to unsanitary conditions and high rates of infectious disease in Lima. A plentiful supply of clean water in the home is critical to good hygiene practices This will reduce the transmission of both water-borne diseases (e g , diarrheal diseases and cholera) and a wide range of other infections

There are several gradations in the extent to which households in Lima face limited water service

About 25% of the population of Lima, overwhelmingly in poorer areas, is without a direct water supply connection These individuals have to use water from public standpipes, tanker trucks, shallow wells and neighbors Water from these sources is typically more expensive and of lower quality than water from the public system. Transporting water from these sources to the home and storing it is inconvenient and costly It is also likely to result in further contamination Individuals not served by the public system usually use only 5 - 20% as much water per day as individuals with a domestic water connection

Among the population with connections, 39% share a communal connection with multiple households They also must deliver water to the home and store it

Most of the population connected to the water system (including the 61% with a direct connection in the home) face low water pressure and intermittent service Storing water is therefore necessary once again

Storing water, whether in the home or outside, is likely to lead to its contamination Informal storage containers are often open and not protected against dust, insects or animals In many cases, they are not equipped with taps for sanitary extraction of water Pumps installed to fill water storage containers can create negative pressure in the water distribution system, sucking in sewage, waste water and contaminated surface water

Quantifying the risks from inadequate water service in Lima is exceedingly difficult This is because of the many ways in which lack of water or contaminated water can affect health and the multiple factors that can contribute to infectious disease Diseases whose transmission is strongly affected by the quantity and quality of water supplies include diarrheal illnesses, scabies, trachoma and more We estimate the annual number of diarrheal illnesses in Lima to be about 2 1 episodes per person per year, for an annual total of more than 14 million cases At least 30% of such cases (more than 4 million per year) are water-related In addition, water-related limitations in hygiene are responsible for at least 23,530 reported cases per year of scabies and trachoma. Based on estimates from studies around the world, we estimate that

extending water connections to Lima's entire current population would reduce the annual incidence of gastrointestinal illness by about 1 4 million cases Further reductions in disease incidence would result from providing more reliable service to those with water connections already, but we were unable to develop a numerical estimate of the benefits of such an improvement

**Limited coverage of the sewer system.** Approximately 72 % of Lima's population is connected to the sewer system. The rest of the population uses pit latrines, septic tanks or has no facilities whatever

In areas without sewers, human fecal material is deposited where it can come into contact with people or be spread by animal and insect vectors It can thus contaminate food and water supplies Many infectious diseases are transmitted via the fecal-oral route Conveying human waste away from where people are likely to come in contact with it by using toilets and sewers will significantly reduce exposure to infectious agents Provision of toilets and sewers has been found to be a major contributor to reduction in the incidence of diseases transmitted by the fecal-oral route However, its impact is slightly less than providing in-house water supplies

It is not possible to calculate the exact health risk associated with inadequate sewerage The types of diseases resulting from inadequate sewerage are those associated with poor sanitation generally It is difficult to separate effects due to deficiencies in any one aspect of sanitation Inadequate sewerage however, contributes to a high proportion of the more than 4 million cases per year of diarrheal diseases in Lima that are estimated to be water-related Applying estimates from studies around the world of the effectiveness of sewers in reducing illness, we have calculated that extending sewer service to the entire population of Lima would avoid about 1 3 million cases of diarrheal disease each year

**Solid waste** Health risks from solid wastes are concentrated in the poorer areas of the city which have minimal refuse collection The entire population, however, can be affected Approximately 65% of solid waste is collected, but only 33% of this is disposed of in one of the city's two sanitary landfills This leaves more than 70% discarded in streets, vacant areas, river banks and informal dumps The health risks from solid waste cannot be estimated quantitatively The organic portion of solid waste that is uncollected or that is collected and improperly dumped supports many vectors (rats, insects, dogs) that are important in the transmission of infectious disease Transmission of infective agents via this pathway, however, has been judged to be less significant than pathways involving lack of water and sewers Informal burning of solid waste is responsible for about 10% of the suspended particles in Lima's atmosphere, contributing to premature mortality and respiratory illnesses associated with air pollution The practice of using untreated garbage as food for raising pigs contributes further health risks through the consumption of pork products Other risks are concentrated among the 10,000 or more individuals involved in collection and informal recovery and recycling of materials from solid waste

**Contaminated surface water** Of the three rivers in the metropolitan area, the Rimac is by far the largest and most important It provides 61% of the water supply for the SEDAPAL water system (the remainder comes from wells), which serves 75% of the population At the intake point for SEDAPAL's Atarjea water treatment plant, the Rimac is heavily contaminated with micro-organisms and heavy metals from upstream communities and mines As it passes through Lima, the river's quality approaches that of sewage

The Atarjea plant treats water through coagulation, sedimentation, filtration and disinfection to produce high quality drinking water SEDAPAL's monitoring data on the quality of the treated water shows acceptable levels of metallic, non-metallic and organic substances More than 99 % of the samples taken from the distribution system show good levels of chlorine residual Assuming that the quality of water at the tap is similar to this data, we estimate minimal risks to Lima's population from drinking treated surface water It is possible that there may be about 20 8 cases of cancer per annum due to arsenic and 1 75 related to trihalomethanes In effect, even though the river water is highly contaminated, its use as the source of drinking water for more than half of the population results in little health risk.

The Technical Committee, however, had two additional concerns The first relates to the concentration of heavy metals, such as lead, at the consumer's tap It is known that the Rimac is heavily contaminated by metals contained in tailings and sludges discharged by mining activities These concentrations vary with seasonal factors (especially rainfall) and mine production levels SEDAPAL provides data on pollutant levels in drinking water immediately following treatment at the water plant, but information on the chemical quality of the water the consumers ultimately receive is not available

A more important concern of the Technical Committee was that in many instances people are exposed to contaminated river water directly Although these other uses occur in a localized manner, they may produce significant risks for exposed populations The uses include

- Use of the river water for drinking, washing, preparing food or cleaning implements Many poorer communities along the banks of the rivers are known to do this,
- Irrigation of food crops with contaminated river water,
- Direct contact during recreational use or while washing clothes,
- Contaminated river water may affect well water used for drinking through percolation and recharge, or it may infiltrate through cracks into pipes carrying treated drinking water

No data are available on the extent to which these direct exposures to contaminated surface water occur, but the Technical Committee thought them important

**Contamination and over-exploitation of ground water** Ground water is the source for 38% of the drinking water provided by SEDAPAL (which serves 75% of the population) Most of the 25% of the population not served by SEDAPAL also relies on ground water Groundwater abstractions have increased by a factor of nearly 20 since 1955 With the absence of precipitation in Lima, recharge occurs only from the three rivers and through percolation of water used for irrigation and leakage Abstraction now significantly exceeds recharge rates and the water table is falling by 2 - 4 meters per year This results in dry wells, increased pumping costs, and salt water intrusion in coastal areas

There are approximately 1,000 wells in Lima. Most of SEDAPAL's 360 wells have acceptable water quality, i e , 95% of samples meet bacteriological standards In 1995 however, 17% of wells had nitrate levels exceeding the standard of 45 mg/L By our calculations, 1,000 - 1,500 infants fed with



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formula made with ground water may be at risk of cyanosis from such nitrate levels This disease, however, is extremely rare with no reported cases in Lima.

Although the health risks from nitrates in ground water are small, contamination of ground water by nitrates from surface sources suggests a connection between surface activities and ground water If surface activities have caused significant contamination of ground water by nitrates, other surface pollutants that are typically not monitored for in ground water may also be present These include pesticides, heavy metals and hydrocarbons

The Technical Committee was concerned about the risks associated with the 640 non-SEDAPAL wells, as little is known about them Many are used for irrigation or industrial purposes, but they are also used for small community domestic water supplies and as sources of water for delivery tankers The wells are often badly constructed (e g , too shallow or without adequate casing and seals, thus allowing easy infiltration of contaminants from the surface) The water from them is rarely disinfected before use Microbiological contamination will be common and probably contributes to the total amount of water-related gastrointestinal illnesses (4,235,000/yr)

The Committee was also concerned about the use of nearly all of Lima's surface water and the overexploitation of groundwater Significant health risks will result if Lima's growing population cannot be provided with the quantities of water needed to support basic sanitary practices The measures being considered for increasing Lima's water supplies -- transbasin diversions and increased water use efficiency -- however, are complex and costly

**Food contamination** Food may be contaminated by biological (viruses, bacteria, helminths, protozoa) or chemical (primarily pesticides and metals) agents Practically the entire population of Lima is exposed through consuming food with significant levels of these contaminants Biological contaminants are of greatest concern. Chemical pollutants have not been studied in sufficient detail to fully quantify their importance

Many means exist by which foods in Lima become contaminated by biological agents These are

- Preparation of food for public consumption by establishments not meeting hygienic criteria, especially street vendors
- Irrigation of agricultural zones with untreated sewage or contaminated water Currently, virtually none of Lima's domestic sewage receives treatment but nearly 20% of sewage is used for crop irrigation
- Discharge of untreated sewage into the sea contaminates seafood 80% of sewage is discharged into the ocean Fish and shellfish are commonly taken from contaminated areas
- Washing foods, particularly vegetables, with contaminated water and then eating them raw
- Unsanitary conditions for food preparation in homes

Little quantitative information exists on the frequency with which foods become contaminated by each of these means Studies show that foods from markets and food stands in Lima are commonly contaminated microbiologically A 1995 analysis of market vegetables found that 37% of samples were contaminated with protozoa and 12% with helminths Sampling from 300 processed food vendors revealed 55% to have unhygienic conditions, as judged by unacceptable concentrations of fecal coliform bacteria. 4 - 8% of the foods sampled were also contaminated with pathogenic bacteria (*Salmonella sp , V cholera,* etc )

In Lima there are many cases of infectious disease transmitted through food or water, but their number is difficult to estimate because of multiple causes and substantial under-reporting of these illnesses Studies elsewhere have estimated that food is likely to be a route of transmission in 70% of all cases of diarrheal disease Applying this to Lima, we estimated that contaminated food could contribute to about 1 5 diarrheal episodes per person per year, totaling approximately 10 million cases annually Although such figures might seem to make food contamination one of the most serious environmental problems, the Technical Committee believed that the high rate of these infectious diseases should be regarded more as a general problem of sanitation than as problem specifically of food contamination While food may often provide the means by which an individual contacts the infectious agent, it is often the lack of water, the lack of sewers, contaminated water, uncollected garbage and vectors that create the unsanitary conditions in the first place

Information on chemical contamination of food in Lima is limited and insufficient to permit conclusions as to the degree of risk posed Data are available for a few heavy metals and one pesticide in foodstuffs but they cover only a small portion of the typical diet in Lima. What has been investigated, however, is sufficient to cause concern. Daily doses of several of these chemicals begin to approach levels of concern for possible health impacts For example, a hazard index of 0 85 (close to an index figure of 1, at which health risks may begin to exist) was calculated for the pesticide Aldicarb in some vegetables We suspect that, if information were available on chemicals in the entire diet, the daily dose of several chemicals could be found to exceed the levels of concern and adverse health effects could be possible The limited information suggests high levels of heavy metals in seafood and there is a need for further investigation of pesticide residues in food Even if the levels of chemical contaminants in Lima's food were known with certainty though, scientific understanding is quite limited regarding the health impacts of regularly consuming low levels of most of these pollutants

**Air pollution (outdoor).** Air pollution in Lima is caused mostly by motor vehicles, with industry as the second most important source There is an additional important contribution from the burning of solid waste The ambient concentration of most of the air pollutants monitored in Lima exceeds the health-based standards of the World Health Organization (WHO) and the U S

Dose-response relationships developed in studies elsewhere were applied to the concentrations of air pollutants in Lima in order to estimate the number of health effects likely to result among Lima's population We found

- Particulate matter (TSP) in Lima may cause 330 - 2200 premature deaths and 0 9 - 5 6 days of restricted activity per person per year



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- Sulfur dioxide is thought to cause between 320 and 2,300 premature deaths each year It is also considered to cause an average of 0 3 to 2 days per year of respiratory problems among the population

- High lead levels may cause 212 - 588 premature deaths per year and the loss of an average of 0 6 - 1 6 IQ points for each child

- Carbon monoxide levels vary widely but often exceed the WHO standard The expected health effects include fatigue, headaches and reduced visual perception This will occur on many days for the several hundred thousand highly exposed individuals in Lima. Sensitive individuals with cardiac problems may also more readily experience angina pain

- Other air pollutants for which data are available (nitrogen oxides and metals) generally occur at levels in Lima not expected to result in significant numbers of adverse health effects

The Technical Committee regarded these estimates of health effects from air pollution as being highly uncertain. They would seem to suggest that air pollution is among the most serious environmental problems Air pollution has received relatively little scientific or environmental management attention in Peru The available monitoring information is scattered, discontinuous and sometimes conflicting The data is not sufficient to provide a confident picture of the typical ambient concentrations to which most of the population is exposed

The Technical Committee was also uncertain about the extrapolation to Lima of air pollution dose-response relationships that have been developed elsewhere Two issues were important

- With a few exceptions (e g , Santiago, Sao Paulo and China), the relationships were derived from studies in developed countries where the air was significantly cleaner than in Lima and the population spends much more time indoors, and

- Some of the relationships predicted "premature mortality," which typically occurs among elderly individuals who are already in a vulnerable medical condition Cases of premature mortality are not directly comparable with estimates of deaths caused by other environmental problems, as these often strike younger and healthier individuals and result in significant losses in expected remaining years of life

In our view, air pollution in Lima needs more investigation Our estimates suggest that air pollution may be one of Lima's most serious environmental problems, but this assessment is very uncertain The Technical Committee's ranking of air pollution in the middle of the other risks represents a compromise

**Contamination of the sea** Nearly all of Lima's domestic and industrial waste waters are discharged untreated into the sea. This results in health risks when contaminated seafood is eaten (covered in the Food Contamination section) or during recreational use at contaminated beaches

Bacteriological contamination exceeds Peruvian standards for swimming at 30 - 40% of the beaches along Lima's coast An epidemiological study of swimmers at beaches along the Bay of Miraflores

in 1995 found increased risks of gastrointestinal and respiratory illnesses in comparison to the general population. An approximate extrapolation of relationships found in studies in other countries suggests that contamination at Lima's beaches may cause 50,000 - 150,000 cases of gastrointestinal and other illnesses each summer

**Hazardous solid wastes** Hazardous solid wastes are produced by industry, hospitals and households Virtually no quantitative information is available on the volume, treatment or destiny of hazardous wastes in Lima. It is estimated, however, that hospitals produce approximately 30 tons/day of hazardous waste, of which 15 4 tons is contaminated with biological materials Domestic solid waste includes 37 5 tons/day of biocontaminated residues A significant fraction of hospital and industrial hazardous waste is sent to Lima's two sanitary landfills A very small fraction of the hospital waste is incinerated The remainder of the solid hazardous wastes are mixed with household refuse Most is collected, but much of that is dumped informally rather than transported to landfills

Hazardous waste therefore mainly affects individuals who collect, transport, work with, or recycle solid wastes and those living near dump sites Although hazardous wastes may contain very toxic or infectious substances, its small quantity and the limited exposure to it is thought to result in modest health risks across the whole population. At least 10,000 people directly handle solid waste in formal or informal ways They may face significant health risks from contact with hazardous substances in the solid waste

**Toxic substances** There has been no systematic monitoring of toxic substances in air, water, food, or other media in Lima, nor has there been any extensive sampling conducted in human tissues For this reason, existing data on toxic substances are limited To provide an overview of toxic substances in Lima, we brought together all the information pertaining to specific substances (heavy metals and pesticides) that we had obtained when investigating the 11 other environmental problems This overview shows

In most instances where metals or pesticides have been measured in Lima, they occur at levels that are not expected to cause significant health effects Exceptions include

- Heavy metals appear in seafood in concentrations high enough to cause concern There is insufficient information on levels of metals in most of the remainder of the typical diet to allow a judgment as to whether total consumption of metals through foods is sufficient to pose a threat to health

- The pesticide Aldicarb has been measured in several foods at a level that suggests that total dietary intake may exceed the threshold of concern

- Arsenic and disinfection byproducts in drinking water may cause about 1 75 and 20 8 excess cancer cases per year

- Lead is of special concern Extensive recent research on lead has revealed important health effects at ever lower levels of exposure Three studies have measured the level of lead in the blood of individuals in Lima. These studies suggest levels of lead high enough to cause health problems in the general population and very high levels in highly exposed groups The studies had small sample sizes and were not designed to be statistically

representative of the entire city The monitored levels of lead in Lima's air often exceed WHO and U S standards We calculate the significant health effects from exposure to lead in this medium as 212 - 588 premature deaths per year and the loss of an average of 0 6 - 1 6 IQ points for each child Further research is necessary on exposure to lead in Lima and its sources, particularly for those working on the street and in traffic

**Air pollution (indoor)** In Lima, indoor air is essentially the same as outdoor air, with additional pollution from fuels burned indoors for domestic activities such as cooking, heating and lighting and from other indoor activities Indoor air pollution is not expected to pose high health risks in Lima largely because most dwelling units are well ventilated and not fully enclosed Some factors, however, can cause problems overcrowding and close contact can increase the concentration of infectious agents in the air, and the use of houses for productive activities increases contact with pollutants (Lima has approximately 60,000 houses used as workshops for small scale production )

Some preliminary studies on indoor air pollution in Lima have found that gas concentrations (CO, $NO_x$, $SO_2$) were within the recommended levels but particle concentrations were above the standards accepted by the international scientific community The most serious ailments were headaches, insomnia, fatigue, throat irritation and respiratory infections These effects may have been due to external conditions however, rather than specifically to indoor sources i e noise, vehicle traffic, dustfall, humidity and temperature

Tobacco smoking is often an important source of indoor air pollution in parts of the world where smoking is common and buildings have little ventilation In Lima, though, a smaller percentage of the population smokes than in nearly any other Latin American city The rate of lung cancer in the city as a whole is low, at about 250 cases per year

**Loss of green areas and agricultural zones** Agricultural land within metropolitan Lima has disappeared at a rapid rate, declining from 90 % of the total area in 1940 to 5 % in 1992 At the current rate, agricultural land will disappear by 2010 Parks and green areas are similarly limited Lima now has 1 9 square meters of park land per inhabitant The internationally recommended value is 8 square meters per person

Despite these deficiencies, loss of green areas and agricultural zones has only a small and indirect effect on health. Loss of these areas reduces the capacity for attenuation of air pollution, and reduces the rate of recharge of ground water (irrigation of these areas is a major source of ground-water recharge) Their loss also makes the landscape less attractive and reduces the opportunities for recreation, thus decreasing the general quality of life in the city

On the other hand, the reduction in agricultural lands may improve the health of the population by reducing agricultural pollution -- pesticides, nitrates, and pathogens on foods that have been irrigated with sewage

## C Interpreting the Rankings

Several points should be made in interpreting the ranking of environmental problems in Lima. These stem from choices made when establishing the methodology for this project

First, the ranking is based on human health risks A focus on other risks -- to ecological systems, economic losses or damages to quality of life -- would perhaps lead to a different ranking

Second, the rankings are intended to reflect the current risks from environmental problems The relative magnitude of the risks may change over time Environmental control programs take time to implement, and it will be important to re-examine the risks that remain as control programs progress The Steering Committee believes, for example, that the two most serious problems (limited water and sewer services) are being addressed as time passes Other problems -- food contamination, ground-water depletion and air pollution -- are being addressed to a much lesser degree, and may become relatively more serious Some researchers argue that large cities in developing countries will undergo a transition in the environmental risks they face Traditional problems like microbiological disease might decrease, but increased industrial and consumer activity will intensify problems such as air pollution, toxic emissions and hazardous wastes

Third, the rankings are based on an estimate of the health effects caused by the problems aggregated across the entire population of Lima. Severe effects of an environmental problem on a small sub-population are treated as less important than moderate effects on a very large population A problem that is geographically widespread and affects many people will rank high under this approach A problem that is localized and affects few people, even though it may affect them severely, will rank lower

Fourth, several environmental problems of potential importance to the health of Lima's population have not been covered in our analysis They include - problems that cannot be managed on a metropolitan scale (e g , global climate change), problems that relate more to public or occupational health than to environmental pollution (e g , malnutrition, food additives, worker safety and exposure to toxic substances, traffic accidents), and problems that are much broader social issues (overcrowded housing, crime, poverty, etc )

Finally, a ranking of problems according to their risk will not necessarily match the priority that should be given to control programs Management of environmental risks -- what one chooses to do about environmental problems -- will depend on many factors in addition to the magnitude of the risks Important factors that are not addressed in the risk ranking include the cost and technical feasibility of control measures, public opinion, political concerns, legal authority and institutional issues In setting priorities for control efforts, all these factors should be considered One might find that there are particularly good opportunities to reduce risks associated with a relatively low risk problem, while there is nothing that might be done about a higher risk problem. This broader question about the priority that should be given to each environmental problem is the subject of the next section of this report

## D. Priority Ranking of Environmental Problems in Lima

The Technical Committee developed a ranking of Lima's problems based on the health risks they cause As discussed above, this will not necessarily match the priority that should be given to each The seriousness of the risks posed by a problem is only one factor in determining the level of attention to give to the problem. In developing a priority ranking, the Steering Committee decided that several other factors were important

**Economic** The economic cost of the problem or its solutions The economic resources available for solving the problem.

**Socio-economic.** Whether the problem or the solutions affect social groups that are of special concern

**Political and institutional.** Factors relating to the institutions and organizations responsible for managing the problem, and public opinion regarding the solutions

**Technical and scientific** Factors relating to the scientific understanding of the problem and the technical efficacy of solutions

The Steering Committee weighed these factors and the level of risks posed by each problem and developed the following priority ranking of the problems

**Table II-3 Priority Ranking of Environmental Problems**
(Listed in descending order of priority)

| |
|---|
| Limited coverage and erratic service by the water supply system |
| Contaminated surface water |
| Limited coverage of the sewerage system |
| Solid wastes |
| Food contamination |
| Contamination and over-exploitation of ground water |
| Contamination of the sea |
| Air pollution (outdoor) |
| Hazardous solid wastes |
| Toxic substances |
| Air pollution (indoor) |
| Loss of agricultural land and green spaces |

This ranking represents the relative degree of attention that should be given to solving each of the environmental problems in Lima. The list is shown with the highest priority problem first The last four problems were all ranked together as generally of low priority No distinction was made between them

The priority ranking is similar to the Technical Committee's risk ranking The top priority problems are a set of interrelated issues concerning water supply, water contamination and management of human wastes The Steering Committee believed that the most severe problems deserved the most attention In addition to health risks, these problems cause significant diminution of the quality of life in Lima. Limited, unreliable and unclean water supplies represent not only a sanitary problem, but high cost, inconvenience and worry The only problem ranked more than one place differently in the risk and priority rankings was contaminated surface water The Steering Committee ranked it second while the Technical Committee ranked it fourth. The Steering Committee regarded surface water contamination as particularly important for two reasons

- The interconnection between surface water contamination and many other problems Cleaning the waters of the Rimac and other rivers would improve the quality of source water for SEDAPAL's drinking water; irrigation water, river water used directly for drinking, bathing or washing food or implements, ground water, and seawater used for recreation and seafood

- A large effort is needed to coordinate the activities of the many institutions affecting river water quality -- the governments of Metropolitan Lima, upstream communities, upstream agricultural, mining and industrial interests, several specialized river management groups, and the national government Many of the other problems involve much more straightforward institutional changes and require correspondingly less attention

The Steering Committee offered several general observations about their priority ranking First, the ranking represents the overall level of attention that should be given to each problem at the moment It does not necessarily reflect how incremental new environmental management efforts should be allocated, nor how resources should be allocated in the future For example, the first and third problems in the priority list -- water and sewerage infrastructure -- are receiving a good deal of attention An effective approach for dealing with these two problems is well known and under way SEDAPAL is expanding water and sewerage services to the unserved portions of the city and this is expected to be completed within a decade Other problems further down the priority list are receiving far less management attention -- food contamination, groundwater depletion, inefficient water use, and air pollution It would be worth concentrating new resources for environmental management on these under- addressed problems The Steering Committee recommended that further risk management should include a survey of environmental management institutions in Lima. This would determine what activities are under way or planned with respect to each of the problem areas Such a survey would identify

i) problems that, even though they are high priority, are currently receiving adequate attention, and

ii) problems that might be somewhat less pressing, but which are receiving virtually no attention

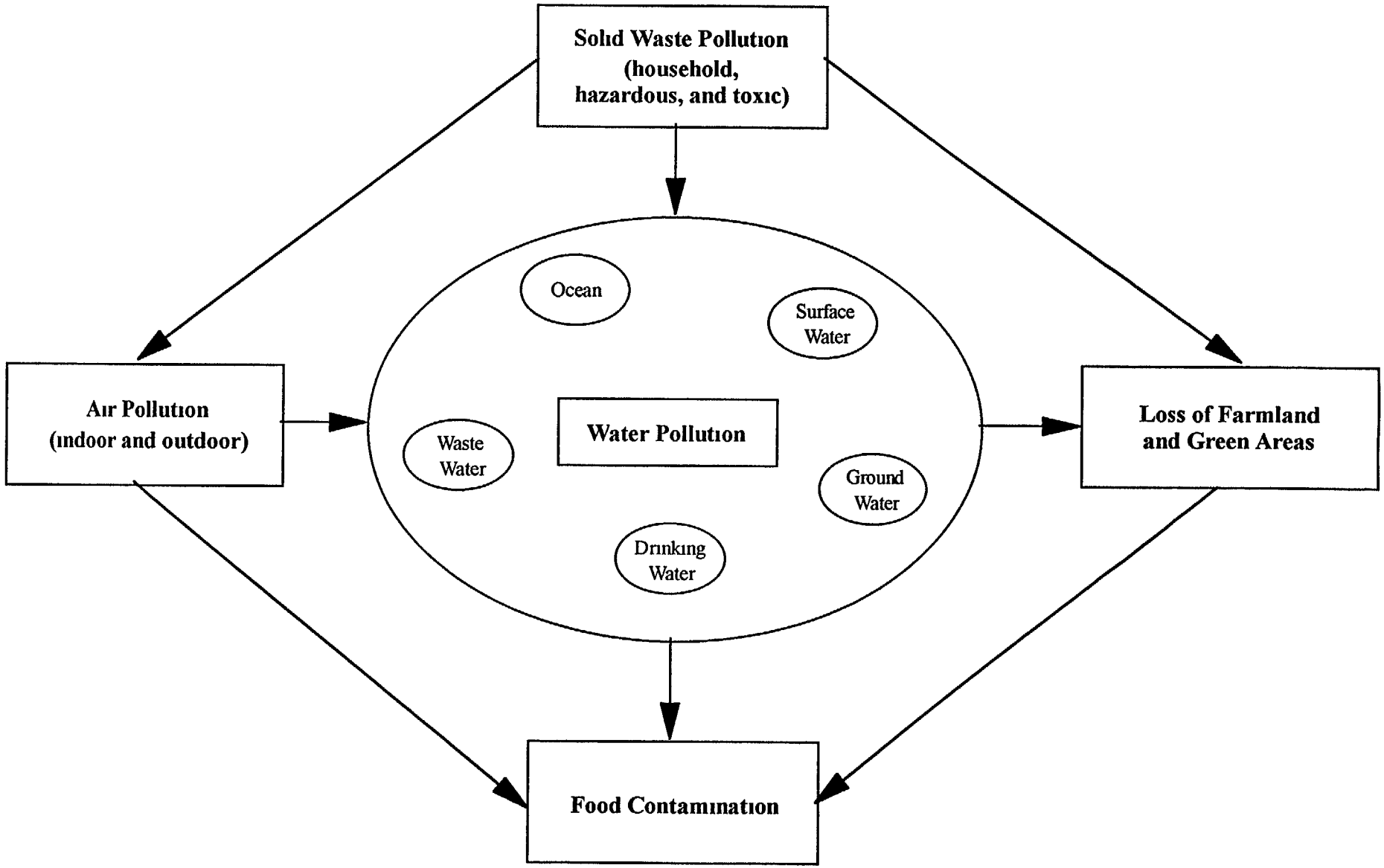
Secondly, the risk ranking and the priority ranking reflect the current situation As time passes, some problems in Lima will worsen. As environmental pressures grow and the population increases, industrial and vehicular pollution and ground-water depletion may intensify Other problems may lessen as efforts to mitigate them take effect The environmental situation in Lima will probably be different in a decade and priorities will shift over time The Steering Committee recommended that risk management activities under this or other projects should include a component to project likely future environmental

trends Effective environmental management policies should be both forceful in dealing directly with current environmental problems and visionary in recognizing opportunities to alter, adapt to or profit from future trends

## E. Ranking of Aggregate Problems

The Project team and the two Committees believed that an additional ranking of aggregated problems should also be developed Environmental problems are strongly inter-related and the resulting risks are interdependent (Figure II-1) For example, limited water supplies, insufficient sewers, contaminated surface waters, uncollected solid waste, and food contamination are a good example All

## Interrelationship of Environmental Problems



these factors combine to increase human contact with fecal material and other infectious agents, to different extents, they all contribute to the high incidence of gastrointestinal diseases in the population of Lima.

In addition, the relative ranking of problems is also influenced how we chose to define each problem Different schemes for defining the problems (for example, by source industry, vehicles, households, etc , or by pollutant metals, infectious agents, particles, etc ) could yield different sorts of rankings Aggregating the problems into larger groupings of related problems provides a perspective that is less influenced by the specifics of how we have chosen to define individual problems The priority ranking of aggregated problems as developed by the project team is shown in Table II-4

**Table II-4 Ranking of Aggregated Environmental Problems**
(Listed in descending priority order)

| |
|---|
| Limitations in water and sewerage infrastructure |
| Contamination of waters (surface, underground and sea) |
| Food contamination |
| Air pollution (outdoor and indoor) |
| Solid wastes (domestic and hazardous) |
| Toxic substances |
| Loss of agricultural land and green areas |

## F Recommendations Regarding Risk Management

Most of the effort in this project has focused on understanding and ranking the severity of the health risks posed by environmental problems in Lima. The Steering Committee has also discussed the priority that should be given to managing each of the problems But we have not begun the activities that are at the core of the risk management phase of the CRA process developing, analyzing and selecting initiatives to manage the most serious environmental problems and combining the initiatives into cost-effective action plans for environmental improvement

The organizers of this project intend that such intensive efforts to plan the management of Lima's environmental problems should be the subject of future projects with funding from a broader range of supporters than only USAID This project has intentionally concentrated on assessing Lima's environmental problems in order to provide a firm foundation for future efforts to manage them A small quantity of resources remains from this project that can support initial risk management efforts These will begin in 1997, at about the same time as this report will be finalized and published The Steering Committee developed several recommendations regarding risk management activities These include some activities to be conducted with the limited resources under this project and some activities to be the subject of future projects

**The remaining project funds should be used to develop background information that will be useful for a full risk management planning effort.**



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The background information might include

- An inventory of activities and plans that are already under way regarding each of the high priority environmental issues in Lima. Each of the institutions involved in environmental management would be interviewed and the results compiled into a profile of what is being done and what will be accomplished with respect to environmental problems This profile could be used to determine the key gaps in current management efforts

- A projection of how environmental health risks in Lima will change in the future The background papers and the Technical Committee risk rankings reflect the current nature of environmental problems As discussed previously, environmental management policies should have a longer term component -- one that recognizes trends and attempts to build on the positive ones and mitigate the negative ones

- A survey of lending, investing and donor agencies to determine what environmental management activities they may be interested in supporting This would provide an indication of likely funding for environmental improvements in addition to indigenous sources (e g , municipal or national government, project beneficiaries, the domestic private sector)

- If funds remain, the background information could include an initial list of possible strategies or initiatives for dealing with each of the highest priority environmental problems This would be developed through one or more "brainstorming" sessions with individuals knowledgeable about Lima's problems It also should reflect knowledge about what environmental measures have worked in other large cities in developing countries

This background information could provide a foundation with which to begin more detailed planning on environmental management This should cover what is currently under way regarding each problem, how the problems will change over time, what sources of financial support might exist for addressing each problem and some possible initiatives

**A future risk management planning effort should continue the multi-sectoral, participatory process begun in this project**

The collaboration of individuals from the entire range of institutions interested in environmental management in Lima has been very valuable The project's conclusions benefit from the diversity of expertise and perspective that has been available Its findings have been disseminated to and will be carried forward by numerous relevant institutions Future projects should continue the current structure or have other similar arrangements In particular it should include Steering and Technical Committees with several general meetings open to the public The technical steps in the risk management planning process should be those outlined in the general CRA methodology

i) Develop a list of promising initiatives for the highest priority environmental problems,
ii) Analyze the costs and benefits of the possible initiatives,
iii) Select initiatives in a participatory public process,
iv) Combine selected initiatives into coherent action plans, and

v) Implement the action plans

**Solutions to Lima's environmental problems should involve both narrow, focussed initiatives for individual problems and broad efforts to improve the environmental culture of the city**

The CRA process is analytical and reductionist It separates problems and asks which is most serious It then takes each problem apart to determine which portions of it cause the greatest risks This analysis is for the purpose of making choices as to which problems and which pieces of them most need solutions The process is helpful in generating narrow, targeted, cost-effective environmental initiatives addressing key parts of key problems

Environmental problems, though, are also highly interrelated A measure addressing one problem may contribute significantly to solving others In addition to sharply focussed strategies, broad strategies that address multiple problems will contribute to improving Lima's environment Environmental education, for example, can have widespread benefits Citizens who are informed about and concerned with their environment encourage environmentally responsible behavior among their friends and neighbors They also provide the critical impetus for political officials to give environmental issues higher priority

**The Comparative Risk Analysis process would also be helpful in setting environmental priorities for other major cities in Peru**

Sensible priorities for Lima's problems will probably be different from what is appropriate for Arequipa, Cuzco or other cities These cities have other patterns of environmental problems as a function of their different climates, settings, amounts of industry and traffic, water and sewer infrastructure, etc The CRA process has been found to be useful in Lima as a means for bringing together the institutions concerned with environmental management They have been able to organize existing data and create an environmental profile of the city with priorities for action. Following a similar process in other cities would be helpful in organizing their environmental agendas

**Good environmental information is needed for good environmental management**

Over the course of this project, we gathered and organized existing data on each of the environmental problems in Lima. Data sufficient to provide an understanding of a problem -- its magnitude, causes and consequences -- is a precondition to being able to manage that problem effectively Although more information is always welcome, in most instances we found that sufficient information has been generated to allow a reasonably confident understanding of Lima's environmental problems In some cases, though, we encountered significant gaps that left major uncertainties In view of the unusually broad and comprehensive scope of the information collection effort for this project, we thought it would be useful to provide an overview of what we believe to be the most pressing needs for further information These are discussed in detail in the next part of this section

## G Recommendations Regarding Environmental Information

We searched for existing environmental monitoring and sampling information for Lima from numerous sources government agencies, universities, industry, environmental organizations, and

individuals We found much information that was useful By highlighting the areas where more information is needed, we do not mean to criticize or demean the efforts that have occurred so far In fact, our strongest recommendation is not that more information should be generated, but that existing environmental information should be made more accessible it should be organized, maintained over time and disseminated to the public

### G1. Environmental Information Should be Disseminated to the Public

It is vital that information on the quality of Lima's environment be available to its citizens Ultimately, Lima's environment will only be as clean as its citizens want it to be The vigor and effectiveness of environmental management measures depend fundamentally on the extent of public demand for environmental quality All the entities that can play a major role in improving the environment rely on public support

- Government agencies that establish and enforce environmental requirements are subject to political control They will push environmental measures as far as there is political and ultimately public support for doing so

- Industries that are sources of pollution find it to be in their economic self-interest to meet environmental and other social goals to the extent that the public -- the industries' customers, workers and neighbors -- demands it

- Agencies that provide environmental infrastructure (water, sewer and solid waste management) can provide services only to the extent that the public is willing to pay for them

- And finally, individuals will practice environmentally responsible behaviors in their daily lives (e g , recycling, conserving resources, avoiding waste, preventing pollution) when they recognize the social desirability of doing so

In all cases, public support is necessary for significant environmental improvement In turn, public support for environmental quality depends on knowledge on the part of the public about environmental conditions and public understanding of environmental problems, risks and potential solutions An informed citizenry can be an active, effective voice for environmental progress An uninformed public will be indifferent

We have several recommendations for improving the level of public knowledge and awareness of the environment in Lima

- Citizens should have the legal right to know the condition of their environment This would mean that government agencies have the responsibility both to generate environmental information and to disseminate it to the public There should not be instances, such as we encountered in gathering information for this project, where a government agency has information about an environmental problem but will not divulge the information publicly for fear of embarrassment or charges of ineffective performance

- An appropriate institution should be charged with developing and distributing a "State of the Environment Report" or an "Environmental Atlas" for Lima. Such a document should portray in an easily readable and visually attractive manner the condition of the major features of Lima's environment. The document should also discuss what is being done or could be done about Lima's environmental problems While the Lima CRA gathered a large amount of environmental information on the city, it is different in important ways from the environmental atlas we envision The atlas would include information on more issues than are addressed in this largely pollution-related project They would include land use, climate, the visual environment, noise, traffic congestion, and recreational, historic and cultural resources An atlas would also discuss trends, possibilities and plans for environmental issues The atlas should be formatted to appeal to an interested member of the general public

- Government agencies should develop monitoring information and dissemination systems to inform the public about environmental pollution situations where the public could take action to avoid unhealthy exposures This might include monitoring and notification systems covering water quality at beaches (warning swimmers about times and beaches with high bacteria levels), instances when drinking water treatment systems fail or contamination is expected for other reasons (advisories to boil water), and days when air pollution levels are particularly high (suggestions to limit vigorous outdoor activities)

More generally, governmental and non-governmental organizations should seek opportunities to raise public awareness and knowledge on environmental issues and increase public involvement in environmental decisions There are many possibilities for doing so Curricula and course materials in environmental education could be developed for use at each level of children's schooling Community groups could organize local environmental action events, such as a campaign to clean up a neighborhood park or dump site, a recycling drive, or participation in an environmental sampling project Government agencies could make their environmental decisions in a more participatory manner This may be done by sponsoring open discussions with interested parties before developing plans or taking actions, establishing public advisory committees from which to obtain suggestions on major issues, and by conducting public hearings prior to any formal major regulatory decision

**A Way Should be Developed to Ensure That Environmental Information is Accumulated, Maintained, and Made Available to the Public**

Unfortunately, environmental information in Lima tends to disappear over time Studies are performed, then printed in limited quantities and distributed to individuals associated with or interested in the study at the time The individuals in charge of a study typically retain a small number of copies of it These are distributed to people who hear of the study Sooner or later, the copies of the study are distributed and further availability depends on finding a person with a copy and persuading that person to photocopy it The major problem in keeping information in such studies publicly available is that they are regarded as the personal property of the individual who has them When an individual changes jobs, that person takes his or her library of studies and information with them When a political administration changes, information is lost on a wholesale basis The senior departing officials from a ministry take with them the studies and information they have The institution itself is too often left with no record of the information it has generated

We see two reasonable solutions to this problem The first is to establish a public information function at important environmental institutions that is distinct from the individuals at the institution The public information unit should be provided with copies of all the studies, publications and data sources developed by the institution, and should then be responsible for cataloguing the information (e g , publications lists, indexed abstracts) and maintaining it for the public (e g , a library open to the public, photocopying service, summaries on the Internet) The institutions performing studies and generating environmental data would have to recognize the principle that they have a responsibility for making the information easily available to the public

The second possible solution is to establish and provide continuing funding for a central repository of environmental information The repository would seek to obtain all environmental information as it is generated and published It would then organize the information and make it available to the public A small fee might be charged to cover the costs of meeting any public request for special searches or compilations of information

**G2. Environmental Monitoring Needs**

Among the environmental information gaps that were encountered we would want to distinguish between those that would require a one-time sampling effort or study, and those that would require a more expensive, ongoing, long-term monitoring program In general, a one-time study is appropriate when the aim is to see whether a problem exists and to begin to understand its general character A full monitoring program is appropriate when a problem is known to exist and more detailed information is needed to help in managing the problem, particularly with regard to how the problem varies over time and across different locations

**A systematic air quality monitoring network.** Existing air quality information for Lima is incomplete, but indicates that several air pollutants (suspended particles, sulfur dioxide, carbon monoxide and lead) commonly exceed internationally recognized standards for the protection of human health Our assessment of how serious the problems are is hampered however, by limitations in the existing data. Most air pollutants are monitored at only one site (CONACO) or occasionally a second (CAHUIDE or CONAGEN), for erratic and discontinuous periods For sulfur dioxide, for example, the available long term monitoring data in Lima shows concentrations varying by a factor of eight from well below the health-based standard to well above it We do not have enough information to determine whether this variation is real and due to time trends or differences in concentrations across monitoring sites, or whether it is misleading and perhaps due only to inconsistencies in analytical methods Sensible policies for managing air pollution cannot be developed in the face of this degree of uncertainty

Lima's air pollution problems appear serious enough to warrant a greater effort to understand them Air pollution will probably worsen as vehicle numbers in the city increase This may overwhelm whatever improvement occurs in vehicle emission controls An air pollution monitoring network for Lima should be modest but carefully designed It might include 3 - 6 sites chosen to characterize conditions in areas where the largest concentrations of the population lives At each site, at least 5 pollutants should be monitored suspended fine particulate matter (PM10 or PM2 5), sulfur dioxide, carbon monoxide, ozone and lead The monitoring should take place regularly throughout the year, and should continue for several years in order to establish a confident baseline and begin to assess trends



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**The program for monitoring swimming beaches in the summer should be expanded** Currently, DIGESA, IMARPE, DIHIDRONAV and the municipality of Miraflores all conduct some monitoring of water quality at Lima's beaches Our assessment of results from this monitoring (in combination with information about the likelihood of swimmers suffering illnesses as a function of bacteriological water quality) suggests that many cases of gastrointestinal, respiratory, eye, ear, and skin ailments result from pollution of swimming beaches Improvement of the current monitoring program could prevent many of these illnesses We have three suggestions

- The monitoring programs by different agencies should be coordinated so as to cover the entire length of Lima's beaches with regular monitoring (perhaps once per week) during the swimming season

- Monitoring currently focuses on fecal coliform as an indicator of water quality In studies elsewhere, various other easily measurable parameters (e g , total coliform, fecal streptococci) have been found to be better indicators of the presence of harmful levels of pathogens that cause illness The relationships between possible indicator parameters and the true sources of swimmer illnesses are site-specific and variable, and a study should be undertaken in Lima to determine which is the best indicator to use

- Monitoring results should be communicated to swimmers, so they can choose to swim only at beaches with satisfactory water quality A program of this sort that has been successful elsewhere has several elements During the swimming season each beach would be sampled early in the week. Beaches found to have unsatisfactory water quality would be re-sampled for confirmation later in the week. If the second sample at a beach is unsatisfactory also, a warning would be posted before the weekend suggesting no swimming at the beach The warning would continue until a satisfactory sample is obtained Swimmers would also be informed of unsatisfactory conditions by a recorded telephone message, updated each week, that indicates which beaches have acceptable water quality and which are unacceptable for the coming weekend The recorded message would be available by calling a widely publicized telephone number for beach water quality information Some variations could be added to this approach 1) Closing a beach when water quality is particularly bad rather than only posting warnings, and 2) Closing a beach for an extended period when water quality is consistently bad

### G3 Suggested High Priority Environmental Studies

Other needs for environmental information in Lima involve one-time studies that will be much less costly than ongoing monitoring programs In this section we recommend a prioritized list of studies that will be useful in better understanding of Lima's environmental problems Consistent with our emphasis in this project on risk assessment rather than risk management, we focus here on the information needed for assessing Lima's problems We do not now address the rather different set of studies and information that would be most important in managing the problems

Environmental information can never be truly complete There will always be additional questions that we would like to be able to answer Information needs must therefore be prioritized In our view, the

circumstances in which it is most important to acquire additional information are characterized by three criteria

i) The available information about an environmental problem is insufficient to permit a confident judgment as to its seriousness

ii) Limited information suggests that the problem may be serious (we would not consider it high priority if the limited available information on the problem suggested that it was unlikely to be serious)

iii) The desired information could be obtained through a study that would not be very costly nor complicated

The following suggested studies meet these criteria. We recommend these studies be carried out to provide the information that is most important in assessing and understanding Lima's environmental problems

**A study should be performed to determine the typical levels of lead in blood in children and adults in Lima.** Studies in other large cities like Lima -- with heavy automobile traffic and use of leaded fuel -- have found lead to be one of the most serious causes of environmental health risks Information on the level of lead in blood allows an understanding of the severity of the problem For Lima, we have been able to find only three limited studies of blood lead a 1995 30-person study of a highly exposed population living around a metal-working plant, an earlier study of 40 children in San Juan de Lurigancho, and a small sample study of adults throughout the city in 1987/1988 These studies suggest levels of blood lead high enough to cause health problems in the general population and very high levels in highly exposed groups The studies had small sample sizes, were not designed to be statistically representative and two are out of date We expect that lead levels have increased in the past decade as traffic has increased and leaded fuel continues to be used

**The level of toxic substances in food and drinks should be investigated.** We found very little information on the levels of chemical contaminants in food in Lima Three metals have been analyzed in a few samples of seafood, vegetables, fruits and potatoes Only one pesticide (Aldicarb) was sampled for, in potatoes, watermelons and lemons The foods that have been sampled are only a small subset of those consumed These types of food represent less than 1/3 of the typical diet The small portion of the diet that has been investigated, however, is sufficient to result in daily doses of some toxic chemicals that begin to approach levels of concern We suspect that if information were available on these chemicals in the entire diet, the total daily dose of many would exceed levels of concern Adverse health impacts from chemical contaminants in food may be possible among the general population of Lima

Several more specific questions are suggested from the limited data we have obtained as needing more investigation

- Aldicarb is a widely used but not extremely toxic or environmentally persistent pesticide If sampling of only a few foods finds Aldicarb to pose a potential health risk, investigation of other more dangerous pesticides should be a high priority Many other extensively used pesticides are



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more toxic (e g , aldrin, chlordane, diazinon, dieldrin, endosulfan, EPN), more environmentally persistent (e g , organochlorines), or able to concentrate by factors of thousands in certain foods (e g , DDT concentrating in fatty tissues in animal meat and fish)

- Limited information suggests that heavy metals are not found at risky concentrations in soils irrigated with sewage or in fruits, vegetables, corn or potatoes from irrigated fields If this can be confirmed, concern for the health impacts of irrigation using sewage might focus on pathogens, and protective measures addressing them alone might be reasonable

- Deposition of airborne metals on foods as they are displayed for sale in markets may not be a significant source of exposure to metals The available information suggests that the concentration of lead in foods at markets is often similar to the concentration in the fields where they were grown Such findings could limit the exposure routes that need to be addressed in managing environmental health risks

- The few samples of seafood that were analyzed for heavy metals showed very high levels By our calculations, seafood represents only 9% of the total daily consumption of the foods for which metals information was available, but provides over 80% of the estimated total intake of metals This raises several questions Are these samples of seafood representative and is it healthy to eat seafood? Can other contaminants that were not evaluated in this study also be found at threatening levels in seafood (e g , pesticides, PCBs, hydrocarbons, other metals such as mercury)? Does the level of chemical contamination in seafood depend significantly on where the seafood is obtained from?

**More information would be useful on the quality of drinking water obtained by households that are not connected to SEDAPAL's distribution network.** Households not served by SEDAPAL are thought to face high risks of sanitation-related illness for three primary reasons

i) They obtain water from sources that are much more likely to be contaminated (e g , from tanker trucks, public fountains and community ground-water wells),

ii) They typically have much lesser quantities of water available to them This is because of limited, inconvenient and discontinuous sources of supplies, higher water costs, and lower disposable incomes, and

iii) Because water is not continuously available, households need to store water, which increases the opportunities for contamination

Despite the higher risks that these households face, there is much less information available about their water supplies than about supplies coming from SEDAPAL Better information would be useful in developing targeted strategies to reduce risks Important information to gather would include

- How many households get water from each of the different sources tanker trucks, community distribution network from wells, public standpipes, etc?

- Where do each of these sources draw their water from?

- What is the quality of the source water? What protection is the water given before and as it is being distributed? Is the water chlorinated? What is the eventual quality of the water as delivered/consumed?

- What quantities of water are delivered from each of these sources to households, how reliably, and at what cost?

Answers to these questions would provide a better understanding of which of these non-SEDAPAL water sources entail the greatest risks and which should be highest priority for improvement

**A study of tap water quality could confirm that health risks are low from drinking water delivered by SEDAPAL** The quality of treated surface water as it leaves the Atarjea plant is good and SEDAPAL monitors its ground water wells to ensure that they are satisfactory The water from both sources is chlorinated Sampling throughout the distribution system indicates that an appropriate chlorine residual is nearly always maintained Although this information leads us to expect generally good drinking water quality at the tap, there are several means by which pollutants can increase in the distribution system infiltration of sewage or other sources of contamination through leaky distribution pipes, leaching of lead and copper from pipes, increase of disinfection by-products due to continuing reactions between chlorine and organic material, etc Sampling and analysis of tap water quality would provide a basis for concluding whether risks from any of these potential sources of contamination are significant

**A study should be performed to better characterize indoor air pollution problems in Lima.** Several initial studies on air quality inside Lima's homes found some reasons for concern involving emissions from cooking stoves and from home workshops However, risks were significantly mitigated by high rates of air exchange between indoors and the outdoors With little need for home heating or cooling, houses are typically well ventilated and not fully enclosed This is changing, however As incomes increase and housing quality can be improved, homes will become tighter to shut out outdoor noise and to allow efficient use of heating and cooling for occupant comfort Rising incomes will also involve greater indoor use of consumer services and products involving toxic substances, for example dry cleaning, hair sprays, nail polish, paints, solvents, etc These trends will worsen indoor air pollution in Lima, perhaps to the point where, as has now happened in the U S A., indoor air pollution is a much more serious problem than outdoor air pollution A study now to characterize the sources and risks of indoor air pollution in Lima might be able to find ways to avoid this projected growing threat

**An inventory of major industrial sources of pollution would help in identifying geographic areas and population groups that are subject to particularly high risks** Industrial point sources of air or water pollution or toxic wastes can cause significant risks to residents and workers in their immediate vicinity In this project, we have focussed on identifying broad risks to the general population of Lima. We have devoted much less effort to characterizing the variability of environmental conditions across the city in a way that could identify particular locations or groups that are exposed to unusually high levels of pollution



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Our choice to concentrate on city-wide environmental health risks results largely from a belief that broad environmental priority setting should be based initially on total risks to the entire population (the greatest good for the greatest number) High risks to unusually exposed individuals can then be addressed subsequently through fine-tuning of individual control programs Furthermore, the environmental data currently available for Lima are not extensive enough to show the pattern of differing levels of pollution to which people are exposed in different locations throughout the city

It is important as a matter or equity to ensure that no segments of the population are subjected to excessively high risks Addressing unusually high risks will first require identifying where they occur This can be done by developing an inventory of major point sources of pollution (these will mostly be industrial facilities, but can also include major refuse dump sites, locations of sewage outfalls, mines, etc ) It will then be possible to monitor emissions and ambient concentrations in the vicinity of the point sources to see if unacceptably high risks result



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# SECTION III
# METHODOLOGY

## A Introduction to Comparative Risk Analysis (CRA)

When a government faces numerous environmental problems and insufficient resources to manage them all, priorities must be set Comparative risk analysis (CRA) is a systematic technique that helps in setting environmental priorities for a geographic area (which may be a community, city, province, or country) The problems assessed can include ambient air and water pollution, indoor air pollution, food contamination, drinking water contamination, sanitation, toxic substances, pesticides, industrial and municipal solid wastes, and other environmental problems facing the geographic area

CRA is a participatory process involving representatives of a wide range of institutions concerned with environmental management in the area CRA includes two phases a risk assessment phase and a risk management phase

**Risk Assessment** In the risk assessment phase, the environmental problems facing the area are identified, evaluated, and compared in order to develop a ranking of problems in order of relative severity The ranking of environmental problems is based on (a) quantitative analysis to the extent possible of health and other risks caused by the problem, (b) expert judgment where data are not available

**Risk Management** In the risk management phase, initiatives or action plans are developed to address the highest risk, most serious problems Choices among measures are made based on the measures' cost-effectiveness in reducing risk Initiatives focus on the most serious problems, concentrating on aspects of the problems responsible for the bulk of risks

The two phases of the CRA process are intended to answer different questions 1) "What are the worst pollution problems that face us?" and 2) "How will we address these problems?" These questions are related to each other, but they can and should be answered separately To understand and rank the pollution problems facing an area, scientific information and judgements about problems are required To evaluate and select alternatives to mitigate the problems requires public officials to balance different information about the economic, technical, institutional, legal, and political nature of the alternatives, in addition to risk information Separating the two processes improves the objectivity and technical quality of the risk assessment phase It is important to obtain an understanding of the inherent severity of environmental problems without being influenced by the degree to which they are controllable or the political support that exists for solving them

This project has largely been devoted to the risk assessment phase, answering the question "What are the worst pollution problems that face us?" We believe that an objective assessment of



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the environmental risks facing Lima is a key precondition to successfully managing risks This project has also devoted some resources to risk management, and we expect that further environmental planning projects will be developed for Lima that build on this work

Environmental pollution poses several sorts of risks to people and natural ecosystems Analysts often consider three broad categories of risks human health risks, ecological risks, and risks to quality of life in general

- **Human health risks** include disease and injuries due to exposure to environmental pollutants Some of the diseases that can be caused by pollution include cancer, gastrointestinal illness, reproductive or developmental abnormalities, and adverse effects on organs such as the liver, kidneys, or lungs

- **Ecological risks** can include death of individual organisms, disruption of the processes governing interactions among species (reproduction and predation), and alteration of the factors controlling key activities within the ecosystem (nutrient cycling and climate) The severity of damages can be measured by the ultimate changes in the basic structure and function of the entire ecosystem

- **Risks to quality of life** from environmental pollution can include a broader set of adverse impacts to the well-being of individuals and society Some of these impacts are economic in nature and potentially quantifiable, such as the reduction in yield from a polluted fishery, the cost to treat contaminated water so that it can be usable, or the reduction in the productivity of an economy when some of the work force is ill Other impacts of pollution on the quality of life may be intangible and non-quantifiable, such as offensive odors or the effect of air pollution in reducing visibility

These different risks or damages from pollution overlap to some degree Illnesses from pollution represent both adverse human health effects and reductions in the quality of life causing medical treatment costs and loss of economic productivity A pollution problem that damages an aquatic ecosystem might also cause economic losses to tourism and fisheries Nevertheless, we believe that these three sorts of damages are generally distinct from one another For this project in the urbanized of metropolitan Lima, the project organizers decided to focus only on human health risks as the primary motivation for improving environmental conditions Ecological issues are less important than human health within metropolitan Lima As limited project resources would not permit full analysis of both health risks and quality of life risks, health risks were judged to be of greater concern

### A1 What Is Distinctive About CRA?

Other approaches exist to environmental planning CRA is distinctive in that it focuses on <u>risk</u> In both the risk analysis and risk management stages, risk is used to judge the severity of the



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environmental problems relative to each other, and risk reduction is used to judge the efficacy of possible solutions to the problems

Objectively comparing the disparate environmental problems facing a metropolitan area such as Lima is a difficult task Consider just two of Lima's problems air pollution from motor vehicles and discharge of untreated domestic sewage into the sea These problems involve different pollutants of concern, which affect different environmental media, and their impacts are different How is it possible to compare these two problems?

Several approaches might be used

- One might compare the two problems in terms of the degree to which each is appropriately managed Using this approach, one could look at the control measures for each problem that are available and typically implemented in other cities with relatively clean environments and ask how well each problem is managed in Lima relative to this standard Thus, we might compare the percent of the city's domestic sewage flow that is treated and the level of treatment attained against the extent to which controls on vehicle exhaust have been adopted (e g , the percentage of vehicles with catalytic converters)

- Alternatively, we might compare ambient levels of pollutants associated with each problem with national or international standards Here, we might compare how often ambient levels of air pollutants associated with motor vehicles (carbon monoxide, ozone, lead, nitrogen oxides) exceed Peruvian or World Health Organization standards against how often beaches exceed recreational water quality standards

One could also assess the relative severity of environmental problems by evaluating the quantities of pollutants emitted or associated with each problem, the number of people exposed to each problem, or other measures

All of these approaches for judging problems are unsatisfactory because they focus on aspects of the problems that fall short of the ultimate impact caused by the environmental problems Treatment plants for domestic sewage are not built merely to reduce discharges of pollution to surface water or to improve the quality of receiving water They are built to keep people from getting sick from contact with human waste or from drinking contaminated water, and to maintain the health of the aquatic ecosystem In contrast to methods that focus on intermediate goals, risk analysis addresses the impacts we ultimately care about risks Are people becoming ill? Are ecosystems endangered? Is quality of life being impaired? A basic premise of CRA is that assessing the actual risks to human health, the environment, and quality of life is the best way to judge an environmental problem Similarly, environmental management initiatives can be evaluated by looking at the degree to which they reduce risk

Risk is generally described as a combination of three elements the probability that an effect will occur, the magnitude of the effect (extent of the population or ecosystem that is affected), and

the severity of the effect All three of these elements should be taken into account when evaluating the risk associated with an environmental problem Making such evaluations will require varying combinations of data, analysis, and judgment depending on the environmental problem

CRA is particularly appropriate for use in priority-setting activities because it

- Addresses the impacts we ultimately care about

- Provides a common denominator for comparing disparate environmental problems by using measures that are comparable across problems (e g , the number of people suffering illness or injury, the amount of monetary damages) rather than non-comparable measures (different sources and pollutants)

- Allows sharper, more precise choices to be made between alternatives Other environmental planning processes tend to generate long lists of initiatives that are worth pursuing for each environmental problem facing an area CRA, by contrast, provides information useful in making a narrower choice as to which problems to address first and which to defer for later

- Generates information on the anatomy of risks caused by a problem, that is, information on which among the sources or pollutants or pathways by which damage occurs are most important The anatomy information helps to focus risk management initiatives more narrowly on key portions of a problem rather than on the problem as a whole

### A2 Procedural Benefits of the CRA Approach

CRA is intended to provide substantive results in terms of better environmental priorities for the geographic area of interest The process is also designed to generate procedural benefits The process typically involves a wide range of participants representing key institutions interested in environmental management in the study area agencies at several levels of government (local, metropolitan, regional, national), universities, the private sector, environmental NGOs, consulting firms, research organizations, community groups, and the general public The individuals participating in a CRA do so through an interactive process involving several committees and workgroups and multiple public and private meetings In contrast to relying on a small group of experts performing an environmental study, the CRA process should be broadly participatory and inclusive The specific process used in Lima is described later in this report

There are several reasons for conducting a CRA through a broad process involving local institutions and experts and reflecting local values and interests

- To facilitate the development of a consensus regarding environmental priorities among the key institutions and stakeholders involved in environmental protection, economic development, and the provision of urban infrastructure in the area,

- To ensure that the study is relevant and useful to environmental decision-making in the area, and

- To ensure that local knowledge and values provide the basis for the many assumptions, value judgements, and decisions that must be made throughout the course of the study

Furthermore, during the study process, CRAs often bring together parties that might not ordinarily work together to address environmental problems Participants are trained in risk assessment and develop a heightened cross-media perspective on environmental issues Participants address the full range of environmental problems in the study area rather than the one or two issues that they typically focus on in their normal professional activities Participants learn from their colleagues Thus, the CRA process helps to open up pathways across institutions for future cooperation on environmental issues

### A3 Historical Use of CRA

CRA has been used in the United States for about 10 years and has become accepted as a key element in environmental priority setting It has been used at the federal level, by more than half the states, and by more than 10 cities

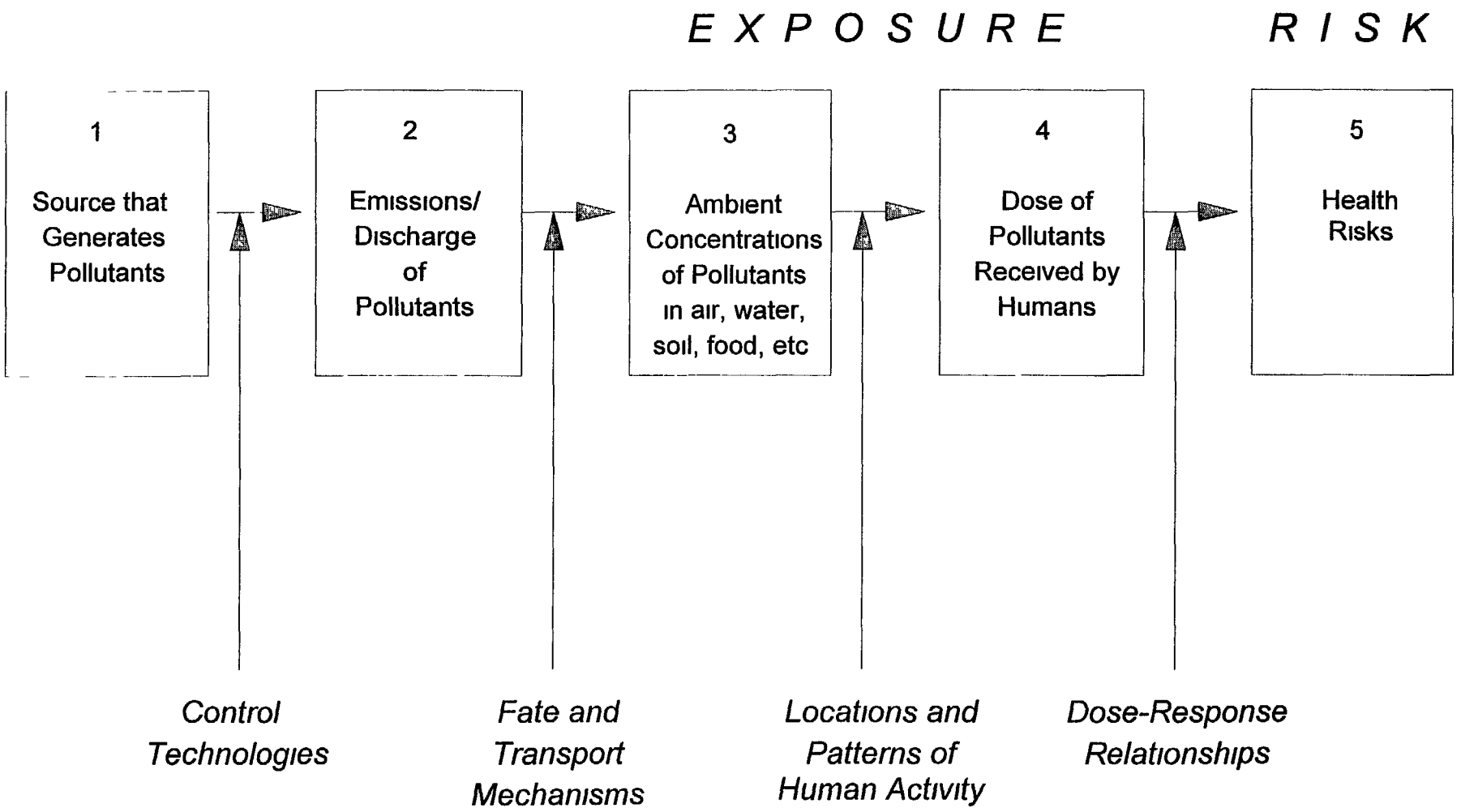
Since 1990, CRA has been successfully applied in several large urban areas throughout the developing world The first application of the process outside of the United States was in Bangkok, Thailand, in a project co-sponsored by the U S Agency for International Development (USAID) and the U S Environmental Protection Agency (USEPA) The use of CRA in setting environmental priorities continues to be strongly supported by both USAID and USEPA Other projects have been performed in Cairo, Quito, two cities in India, Eastern Europe, and the Central American region (excluding Mexico) The completed CRAs have had a significant impact on environmental management in the areas where they have been conducted

### A4 Analyzing Health Risks Posed by an Environmental Problem

The organizers of the Lima CRA decided to focus specifically on health risks rather than risks to natural ecosystems or quality of life generally Most environmental problems cause adverse human health effects through an identical series of five steps (see Figure IV-1)

1 **A source generates pollutants** For example, motor vehicles generate carbon monoxide, nitrogen oxides, hydrocarbons, particulate matter, lead, and other pollutants as fuels are burned The amount of pollutants generated depends on the characteristics of the source the type of vehicle, the way it is driven, and the fuels used

**Table IV-1 How Environmental Problems Cause Human Health Risks**



2 **Some of the pollutants are emitted or discharged to the environment** Control technologies may prevent the generation of pollutants or reduce the fraction of generated pollutants that are emitted or discharged Engine tuning, catalytic converters, unleaded gasoline, improved traffic flow, and other control measures can reduce emissions from motor vehicles

3 Those pollutants that are emitted or discharged undergo various chemical and physical processes in the environment, resulting in **ambient concentrations of the pollutants** Some of the smaller lead particles emitted by autos using leaded gasoline may disperse and remain suspended in the air Other larger particles may settle out of the air, perhaps onto foods displayed for sale in roadside stalls, or as dust on the surface of playgrounds, agricultural fields, and other areas

4 By breathing, drinking, eating, and other activities, **humans are exposed to these ambient pollutants** The degree of exposure or dose received by humans depends on how people use their environment and where they are located relative to the higher ambient concentrations of the pollutants For example, there may be little exposure to the lead dust on food at markets if the food is washed before it is eaten, while young children in playgrounds may have significant exposure to lead by playing in the dirt and mouthing objects

5 **Human exposure to a pollutant produces some likelihood of a resulting adverse health effect** For many pollutants, clinical, epidemiological, or toxicological studies provide an understanding of the adverse health effects that may be caused by exposure to a pollutant, as well as an underlying dose-response relationship A dose-response relationship is a mathematical relationship specifying the probability of a human suffering an adverse health effect as a function of the dose of the pollutant he or she has received

In assessing environmental problems, we are most interested in obtaining data on the ultimate impacts from the problems (Level 5 in Figure IV-1) Data at this fifth level can show how many cases of adverse health effects are caused by the problem Unfortunately, accurate direct measurements of the number of health effects from environmental causes are rarely available There are several reasons for this

- Available statistical measures are often inaccurate indicators of the underlying numbers of health effects Mortality and morbidity figures reported by doctors, clinics, and hospitals are subject to large errors from under-reporting (many individuals do not seek treatment), misdiagnosis, insufficient specificity, and uncertain catchment areas (the rate at which the illness is ocurring may be unclear because of uncertainty about the size and location of the population served by the health care facility providing the data)

- Few diseases are attributable exclusively to environmental factors For most diseases, pollution seems to be a relatively minor cause [1] Incidence of most diseases is strongly influenced by genetics, diet, smoking, personal hygiene, quality of medical care, and other factors

- Many diseases related to pollution appear only long after the exposure Current disease statistics, even if accurate, may reflect problems of long ago, and the impacts of today's problems may take many years to show up

Because of the lack of direct information at Level 5, we typically project the likely health effects from a pollution problem by estimating the dose of a pollutant to which people are exposed and then applying a dose-response relationship for that pollutant In effect, we collect available data at the levels on the left in Figure IV-1 and use models and other estimating techniques to estimate quantities further to the right that have not been measured directly Numerous uncertainties and likely sources of error are inherent in the two steps of estimating the dose and applying a dose-response relationship

In the first step, uncertainties derive from shortcomings in monitoring data in Lima and difficulties in modeling exposures based on these data We discuss the most important of these uncertainties later in this report in papers on each of the environmental problems in Lima

Uncertainties inherent in applying dose-response relationships are of a different sort Here we follow methods and use databases on health effects of chemicals that are approved by the USEPA However, there is scientific controversy about the choices EPA has made in its risk assessment procedures Some of the most difficult issues involve extrapolating the effects of chemicals observed in high-dosage animal experiments to situations in which humans are exposed to low doses Thorough discussions of uncertainties and suggestions regarding alternative health risk assessment procedures are available elsewhere (NAS, 1996, Finkel, 1990), and we will not go into this issue further here We have used EPA's methods, and our conclusions are thus subject to all of the associated uncertainties Appendix A provides a more detailed description of EPA's approach that we have adopted It includes an explanation of some of the different ways in which health risks are measured and expressed

For a few environmental problems, our process is the reverse of the typical left-to-right progression in Figure IV-1 Problems involving infectious diseases and sanitation such as insufficient or unclean water, inadequate domestic sewerage and treatment, and uncollected solid waste provide examples For these problems, statistics on health effects such as diarrheal diseases and typhoid may be available, but dose-response functions are not Risk analysis for these problems

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[1] For example, a small fraction of the incidence of cancer is attributable to environmental pollutants The major preventable risk factors for cancer that have been identified thus far are tobacco, dietary imbalances, hormones, and chronic infections (Gold, 1993)



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will involve a right-to-left progression in which disease statistics are collected and then adjusted to reflect the degree of under- or over-reporting and the contribution of non-environmental causes

The goal of the risk analysis portion of this project is to estimate the number of cases of disease or injury among Lima's population due to each environmental problem Often, different risk analysis procedures are used to estimate the impact of different components of the problem For the food contamination problem, for example, left-to-right procedures are used to estimate the health impacts of each of the chemical contaminants in Lima's food supply for which we have data, while a right-to-left process is used to estimate the number of cases of illness due to bacteriological contaminants in food The total health risks posed by a problem are thus the summed health risks posed by the various components of the problem For reasons having to do with data availability and ease of analysis, the problems we evaluate may have components related to different pollutants, different routes of exposures, or different sources

In many cases, insufficient data is available to allow us to estimate the number of health effects expected in Lima from an environmental problem The missing information may involve the ambient concentration or degree of exposure to a specific pollutant in Lima In other cases, knowledge is limited on the health effects of a pollutant, with no dose-response relationship yet having been developed for the pollutant In these instances where we cannot quantitatively estimate the number of cases of disease or illness from a component of a problem expected in Lima, we simply do the best we can by speculating on whether health effects are likely or unlikely and whether the number of cases is likely to be small or large

Once a quantitative or qualitative estimate of the number of adverse health effects occurring among Lima's population is developed, this information is combined with information on the severity of these health effects to arrive at a judgement on the relative seriousness of each environmental problem analyzed Finally, the environmental problems are ranked in order of the magnitude of the total health risks caused by each

## B Use of the CRA Approach in Lima

### B1 Introduction

The size and complexity of Lima's environmental problems point to the need to develop coordinated and concerted strategies and interventions for addressing these problems The haphazard intervention of numerous organizations with overlapping, duplicative and conflicting functions -- as currently characterizes environmental management organizations in Metropolitan Lima -- has proven to be ineffectual

With these considerations in mind, the ECORIESGO Project was developed openly and in a participatory fashion Its success in contributing to the task of defining Lima's environmental priorities was made possible by the effective participation of organizations and individuals with a firm commitment to achieving environmental progress



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The following groups and individuals were directly involved

- An international consulting group consisting of three Peruvian experts and three U S experts,
- Representatives from the organizations most responsible for environmental management in Metropolitan Lima, under the leadership of the National Environmental Council (CONAM), and
- The Office of Environmental Advisory and Consulting Services (OACA), an NGO in Lima specializing in environmental issues, which provided coordination and administrative support to the project

**B2 Two Committees Roles and Membership**

The primary goal of the participatory strategy was to obtain a consensus among the broadest possible range of institutions concerned with environmental management in Lima on priorities It was predicated on the creation of two committees a Directive Committee (DC) and a Technical Committee (TC), whose members provided continuing directive and advisory services to the consulting group during the course of the CRA

The DC was chaired by CONAM and included 13 representative officers from key organizations responsible for environmental management in Lima the Ministry of the Presidency, the Ministry of Health, the Municipalities of Lima and Callao, NGOs, the private sector, etc (see Annex A for full membership lists for all the project committees) The function of the DC was to provide direction to the project by assuming responsibility for the principal project design decisions The DC also provided institutional support in the area of project implementation, validated the work conducted by the consulting group and the TC, and participated in defining strategies based on the results of the project The DC also developed a priority ranking of the environmental problems through the application of economic, political, social and institutional criteria

The TC was comprised of 18 specialists with academic training in environmental and sanitary engineering, environmental chemistry, epidemiology, toxicology, medicine, microbiology and public health (see Annex A)

The role played by the TC was three-fold

- As **advisor** in technical matters the TC participated in drawing up definitions of problems and in selecting criteria for problem prioritization It also worked to ensure the quality and technical consistency of the analysis and report prepared by the team of consultants,
- As **facilitator** of the collection of information required for the study, and

- As **promoter** of the results of the study

Thus, the responsibility of the TC included conducting a technical review of the work performed by the project team and preparing the classification of environmental problems, which together culminated in the preparation of a ranked list of problems based exclusively on health risks

Additionally, in the final stage of the project a panel of nine experts met to conduct a final review of the draft reports, thus enriching the content and conclusions of the study The meeting of the panel made it possible to further expand the number of organizations participating in the study (see Annex A)

**B3 The CRA Process**

The CRA process consisted of the following three stages

***Stage I Establishment of the project team and issuance of an invitation to the environmental community of Lima***

The Peruvian consultants that would serve as counterparts to the PRIDE consultants were selected, an organization to provide logistic and administrative support was identified, and a broad-based invitation to participate in the project was extended to public and private organizations concerned with environmental management in the metropolitan area

During this stage, the organizations that would eventually be appointed as members of the directive and technical committees were identified

***Stage II Identification, selection and gathering of information***

The consulting team prepared a preliminary list of the environmental problems to be addressed, including problems related to environmental pollution and natural resource management The preliminary list was submitted for consideration by both advisory committees, which drew up a final version Next, all potential sources of relevant information at local, national and international levels were identified, and the project team proceeded to identify and collect the requisite information, with support provided by the organizations represented on the TC Several iterations were conducted as information was collected and reviewed, gaps were identified, and further efforts were made to find important missing information

***Stage III Information analysis Characterization of risks, classification and prioritization of problems***

The consulting team prepared detailed technical reports on each of the problems investigated, as well as comparative tables illustrating the health risks involved with each problem The reports were reviewed by members of the TC, who provided comments and the reports were revised accordingly The scientific information contained in the reports made it possible to conduct

a comparative analysis and ranking of the problems based exclusively on health criteria A subcommittee of the TC developed the procedure that was to be used in the ranking The ranking process was then carried out in two full meetings of the TC

During this stage, the DC also prepared a prioritized list of the environmental problems using economic, social, institutional and political criteria, resulting in a list of problems that was subsequently compared against the list prepared by the TC, an evaluation was then conducted of the areas of agreement

### B4 Ranking and Prioritizing the Problems

Two different methods were used for ranking and prioritizing problems

The TC used the method of pair-wise comparison to prepare a preliminary ranking of problems reflecting the relative degree to which they pose health risks to Lima's population This method involved the repeated comparison of pairs of problems after a number of repetitions, all of the problems had been compared to each other, resulting in a ranked list The TC then met a second time to consider adjustments to this initial ranking based on a comparative assessment of all of the problems simultaneously

- The 12 ranked environmental problems affecting Metropolitan Lima were discussed in order of their initial ranking

- Key summary information from the report about each problem was presented the nature of the problem in Lima, the means by which it causes health risks, the number of individuals exposed, and number of cases of health effects expected annually This information was complemented by other data available to members of the TC, and discussions were held with regard to problem interrelations Reference information on future scenarios was also included

- Once presented, each problem was compared against the previous problem or problems, thus quickly generating a new ranked list of environmental problems A problem for which it was not possible to obtain consensus on where it should rank was put to a vote by the TC members

To prepare the list of environmental problems ranked in order of their priority for management attention, the DC used a scoring method Each DC member submitted a form on which they had assigned individual scores pursuant to criteria that had been developed at a previous committee meeting, and the results were totalled, resulting in a total score and an overall prioritization (see Table III-1)

Finally, both rankings of problems -- the risk ranking and the priority ranking -- were presented and ratified in a plenary meeting of the TC and the DC In this and a subsequent meeting,

the committees developed plans for continuing the project work into risk management activities and for more public involvement However, these further activities are not covered in this report

### B5 Key Project Decisions

During the course of the project, the DC and CT made several key decisions regarding the scope and direction of the project

***Initial scoping*** Three key decisions were made

- The project should focus on the risk assessment phase, leaving the risk management phase for a second stage of work It was felt that it would be extremely important to begin by acquiring a full understanding of Lima's environmental problems, which would subsequently provide a solid basis for decision-making with respect to how the problems should be resolved A decision was made to leave a small fraction of the project resources and time for scoping out possible risk management activities

- The CRA should cover the entire geographical area of Metropolitan Lima, including the two provinces of Lima and Callao, and

- The project should focus on current health risks posed by the problems Although both economic and ecological impacts from environmental problems in Lima were clearly important, it was thought best to focus the project's limited resources on pressing health concerns And, in view of the newness of the CRA methodology and the limited data available on environmental conditions in Lima, the committees thought it best to concentrate on current, demonstrated problems and risks without diluting the effort by pursuing more speculative work on projecting future trends and future risks However, some of the follow-on work to be conducted in 1997 will address concerns about future environmental trends

***Selection of the problems to be analyzed and characterized.*** Both committees agreed to focus on problems of environmental pollution ("brown" issues) and only two major problems involving natural resource management ("green issues") in Lima (loss of green areas and decrease in the water table) Although they strongly affect environmental conditions, broader social issues (e g , poverty, malnutrition, rural-to-urban migration, overcrowded housing, inadequate medical care) were thought to be beyond the scope of the study Within the overall scope of issues to be covered by the project, the criteria used to define the specific problems to be analyzed included ease of analysis, minimal overlap, consistent level of aggregation, availability of information, and addressability, among others

***Definition of ranking criteria*** It was decided that the project should focus on essentially health impact issues The TC would prepare a *risk ranking* using strictly technical criteria, while the DC would prepare a *prioritization* using economic, political, institutional and social criteria

Initially, the Technical Committee discussed the viability of using a series of criteria such as number of cases (magnitude of impact), type and severity of effects on health, impact on vulnerable population groups such as children, women, the poor, time trend, uncertainty, etc Ultimately, a decision was made to assess the seriousness of the health risks posed by environmental problems by using only two key indicators magnitude of impact (number of individuals affected) and severity (type of disease, symptoms, etc)

The prioritization prepared by the DC was based on the ranked list drawn up by the TC using health criteria and involved the application of additional economic, political, social and institutional criteria, including the following

Economic criteria

***Definition*** The economic cost of the problem and/or the cost of the solution The economic resources available to solve the problem

***Indicators*** What is the economic impact of the problem (on tourism, fishing, productive time lost, medical expenses, etc )?

- Is there any economic alternative for solving this problem?
- Are resources available to solve this problem?

Socio-economic criteria

***Definition*** Factors that determine whether the problem has a specific impact on a particular population group

***Indicators*** Does the exposed population

- Have a low level of income?
- Contain a high level of vulnerable individuals (children, pregnant women, the elderly)?
- Exhibit a high degree of unemployment?
- Have adequate service coverage?

Political-institutional criteria

***Definition*** Institutional factors involving the organizations responsible for managing the problem, the interaction between them, and popular opinion with regard to alternative solutions

***Indicators***

- Are the current powers interested in solving the problem?

- To what extent is it possible to incorporate the solution to the problem into current policy?
- Will the solution to the problem encourage public participation?
- How many organizations must be involved in solving the problem?
- Have the institutions involved signed mutual cooperation agreements or do they have a history of collaboration?
- Is there both willingness and ability to comply with current or potential norms?
- Do adequate institutional resources (qualified individuals, training, autonomy) exist to solve the problem?
- Is there sufficient popular support to solve the problem?

Technical-scientific criteria

***Definition*** Factors related to the scientific understanding of the problem and the technical effectiveness of the solution

***Indicators***

- Is the relative ranking of the problem based on scientific fact?
- It is possible to adapt solutions that have been effective in similar contexts?
- Is there a solution that offers long-term benefits?
- Is there an adequate scientific understanding of the problem that will make it possible to reach an optimal solution?

***Strategy to be adopted in the risk management stage***

The DC determined that the risk management stage should include the following

- Conducting a more detailed analysis of the highest priority environmental problems,

- Generating a list of currently existing strategies and initiatives for addressing the principal environmental problems,

- Conducting an analysis of future scenarios (prospective planning) that would make it possible to visualize mechanisms for managing the principal environmental problems,

- Generating management strategies and action plans for the problems selected, including processes that would make it possible to generate appropriate socio-cultural skills and attitudes with regard to the problems selected

An agreement was reached to maintain the structure of the two committees and the consulting team for the risk management phase

***Dissemination strategy*** It was felt that it would be necessary to develop and implement a project dissemination strategy The committees agreed that such a strategy should focus on the following priority target audience the mayors of Lima and Callao, the National Congress's Commission on the Environment and the Amazon, the Council of Ministers and the general public, through the mass media

### B6 Summary of Activities Performed and Timeline

***Activities performed by the consulting group***

- Project initiation and establishment of committees
- Information gathering
- Organizing the information, additional efforts to fill gaps, and risk analysis
- Preparation of preliminary reports
- Assistance in preparating preliminary ranking
- Preparation of final reports

***Activities performed by the consulting group and the committees***

Five meetings of the CT

- Scoping meeting and initial decisions
- Meeting to provide CRA training and further decisions
- Meeting to analyze preliminary information and discuss ranking criteria and methods
- Meeting to prepare preliminary risk ranking using the pair-wise comparison method
- Meeting to develop final risk ranking

One meeting of the Technical Subcommittee to define final criteria

Three meetings of the DC

- Scoping meeting and initial decisions
- Meeting to review issues and progress and define criteria
- Meeting to develop priority ranking

One joint meeting of the Directive and Technical Committees covering comparison and validation of both sets of rankings, review of project accomplishments, development of plans for risk management activities

One meeting of the panel of experts to provide an additional, outside technical review of the draft reports

Presented below is a timeline of the activities conducted

**Table III-1 Individual Form for Priority Ranking of Problems by the Directive Committee**

| Initial Risk Ranking by the Technical Committee | | Criteria and Scores | | | | Total Score |
|---|---|---|---|---|---|---|
| Rank | Problem | Economic | Socio-Economic | Political-Institutional | Technical-Scientific | |
| 1st | Food contamination | | | | | |
| 2nd | Pollution from solid waste | | | | | |
| 3rd | Limited coverage of drinking water system and intermittent service | | | | | |
| 4th | Pollution of surface water | | | | | |
| 5th | Atmospheric pollution | | | | | |
| 6th | Limited coverage of sewer system | | | | | |
| 7th | Pollution of the sea and beaches | | | | | |
| 8th | Pollution of ground water | | | | | |

Observations _____

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**Table III-2 Timeline of Activities, 1996**

| ACTIVITY | JUNE | JULY | AUGUST | SEPTEMBER | OCTOBER | NOVEMBER | DECEMBER |
|---|---|---|---|---|---|---|---|
| Establishment of team and committees | | | | | | | |
| Information gathering | | | | | | | |
| Training in CRA | | | | | | | |
| Analysis of information collected | | | | | | | |
| Risk characterization | | | | | | | |
| Preliminary reports | | | | | | | |
| Initial ranking by the TC | | | | | | | |
| Further data collection and analysis | | | | | | | |
| Prioritization by the DC | | | | | | | |
| Final rankings, review of project and planning future activities | | | | | | | |
| Draft reports | | | | | | | |
| Panel of experts | | | | | | | |
| Final reports | | | | | | | |
| Committee meetings | Plenary | CT | CT,CD | CT,CD | CT,CD | Joint | |

**Annex A**

**Members of the ECORIESGO Project Directive Committee**

| NAME | ORGANIZATION | ADDRESS | TELEPHONE | FAX |
|---|---|---|---|---|
| 1 Adela Timoteo | Coordinator of the Metropolitan Committee of the Glass of Milk Program | Guillermo Dansey 936<br>Lima Cercado (alt cdra 6 Av Colonial) | 123 3456 | |
| 2 Miguel Angel Planas | President of the Environmental and Enterprise Commission<br>Chamber of Commerce | Gregorio Escobedo 398 | 461 8974-463 3434<br>271 3733 | 463 28 |
| 3 Ricardo Giesecke | Regidor Metropolitano<br>Municipality of Metropolitan Lima | J A Roca 154<br>Santa Beatriz, Lima 1 | 996 5517<br>433 0378 | 433 7446 |
| 4 Jorge Villena-Chávez | Director General DIGESA (Directorate General for Environmental Health) | Las Amapolas 350<br>Lince | 440 2340 | 440 6562 |
| 5 Lidia Oblitas<br>Alicia Chang | Superintendent, SUNASS Technical Secretariat | Bernardo Monteagudo 210-216<br>Magdalena del Mar, Lima 17 | 264 1440<br>264 1441 | 264 0116 |
| 6 Luis Consigliere | Technical Director<br>Metropolitan Planning Institute | Natalio Sánchez 220 Piso 12<br>Jesus Maria | 433 5526 | 433 5521 |
| 7 Arnold Millet | Municipal Directorate for City Services<br>Municipality of Lima | Los Tucanes 196<br>San Isidro | 946 4112<br>428 7077 | 427 2272<br>433 1550 |
| 8 Eduardo Salazar Monroe | Ministry of the Presidency<br>CORDELICA | Av Juan Pablo II 140<br>Bella Vista Callao 180 | 498 4525 | 498 4525 |
| 9 Charles de Weck<br>Alexandra Cugler | Executive Secretary<br>Peruvian Environmental Network | León de la Fuente 110<br>Lima 17 | 264 1317<br>446 9339 | 264 0128<br>438 7171 |
| 10 Marilez Orbegoso | Chief, National Institute for Environmental Protection (INAPMAS) | Pachacutec 900 Jesus Maria | 432 3014 | |
| 11 Julio Calderón | President, HABITAT NETWORK | Coronel Zegarra 426 Jesus Maria | 471 2034 | |
| 12 Antonio Bernales | SENREM - CONAM Project | Av Javier Prado Oeste 1121<br>San Isidro | 441 7333 | 441 7334 |
| 13 Edilberto Alarcón | USAID | Larrabure Unanue 110<br>Jesus María | 433 3200 | 463 7034 |

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## Members of the ECORIESGO Project Technical Committee

| NAME | ORGANIZATION | ADDRESS | TELEPHONE | FAX |
|---|---|---|---|---|
| 1 María del Carmen Gastañaga<br>Wellington Chumbe | Executive Director for Evaluation of Environmental and Occupational Risks<br>DIGESA | Las Amapolas 350<br>San Eugenio<br>Lince - Lima | 442 8353<br>440 0399 | 442 8353 |
| 2 Maribel Díaz Ching | Assistant Director, Directorate General for Environmental Quality<br>National Institute for Environmental Protection (INAPMAS) | Pachacutec 900 | 432 3014<br>423 2591 | 432 3064 |
| 3 Benjamín Marticorena | National Academy of Science | Alfredo Novoa 179<br>San Miguel Lima 32 | 464 2273 | 464 2273 |
| 4 Nora Salazar | Advisor in Community Participation<br>CEPIS | Los Pinos 259<br>Urb Camacho La Molina | 437 1077 | 437 8289 |
| 5 Carlos Gambirazio Carbajal | General Office of Epidemiology-Epidemiological Surveillance, Ministry of Health | Camilo Carrillo 402<br>Jesus María | 433 0081 | 433 0081 |
| 6 Nelly Nakamatsu<br>Margot Durán | Chief of the Quality Assessment Team<br>SEDAPAL | Av Venezuela 812<br>Breña | 431 4596 | 431 4596 |
| 7 Eduardo Salazar Lindo | Universidad Cayetano Heredia | Apartado Postal 4314<br>Lima 100 | 482 4291<br>482 0252 | 482 4291 |
| 8 Carlos Bustios | Director of the SENAMHI<br>Research Center | Jirón Cahuide 805 Of 411 CID<br>Jesus María | 472 4180 | 471 7287 |
| 9 Ing Luis Guerrero Osorio | National Coordinator — Action Network for Agrochemical Alternatives (RAAA) | Mariscal Miller 26220<br>Lince Lima | 440 4359<br>421 0826 | 440 4359 |
| 10 Carmen Mora Donaire | Subdirectorate of Environmental Oversight<br>Ministry of Industry (MITINCI) | Calle Uno Oeste<br>Corpac | 224 3347 | 224 3393 |
| 11 Albina Ruiz | Chief of the Department of Urban Development<br>ALTERNATIVA | Emeterio Pérez 348<br>Urbanización Ingeniería Lima 31 | 481 5801<br>481 1585 | 481 6826 |
| 12 Jorge Ruiz Botto | Independent Consultant, UNI | Av Central BK 29<br>Los Alamos de Monterrico Lima 33 | 481 1070 ext 262 | 482 1585 |
| 13 César del Carmen | PROMAR (PRONAP) | | 271 9638 | 271 2703 |
| 14 Hortensia Galloso<br>William Mori | Municipal Director of Health and Social Welfare<br>Municipality of Lima | Conde de la Superunda 446<br>Lima 1 - Cercado | 427 8777 | none |

| | | | | |
|---|---|---|---|---|
| 15 Ricardo de la Flor | INICAM | Micon Armendariz 193<br>Miraflores | 445 0367<br>447 9909 | 4473838 |
| 16 Eduardo Calvo | Graduate School of Chemistry<br>Universidad de San Marcos | Nicanor Arteaga 549<br>San Borja | 451 1479<br>436 5979 ca | 452 5635<br>452 8553 |
| 17 Eduardo Gómez-Cornejo B | Department of Biology, School of Science, UNALM | Av de la Universidad<br>La Molina | 435 2035 ext<br>271 | 436 3113 |
| 18 Raul Tolmos | CONAM | Ave Javier Prado Oeste 1121<br>San Isidro | 441 7333 | 441 7334 |

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## SECTION IV
## GENERAL CHARACTERISTICS OF METROPOLITAN LIMA

### A Geography

Lima, the capital city of Peru, is located on the shores of the Pacific Ocean at an average altitude of 153 meters above sea level, between average coordinates of 12°12'08" south latitude and 77°03'00" west longitude Its topography is fairly level and the city is surrounded by uncultivated hillsides of medium to high altitude, which increase in height as one moves inland toward the Andean mountain range Figure IV-1 shows a map of Peru in the context of South America A map of Metropolitan Lima is provided as Figure IV-2

Politically, the metropolitan area covers a total of 279,409 has , which as of 1995 consisted of 50,741 has of developed area and 22,000 has of agricultural lands, with the rest classified as uncultivated land It is estimated that, during the period between 1920 and 1984, 76% of the total agricultural area was lost to urban expansion

Lima's hydrogeology consists primarily of alluvial areas There are three watersheds Chillon to the north, Rimac in the center, and Lurin to the south, the total area of which, including the uncultivated *pampas* of San Bartolo and the *pampas* of Ventanilla, are shown in Table IV-1

**Table IV-1 Area of the Watersheds and Uncultivated Pampas of Metropolitan Lima**

| | |
|---|---|
| Pampas in the area of Ventanilla-Ancon | 3,684 has |
| Chillon River Valley | 18,000 has |
| Rimac River Valley | 37,330 has |
| Lurin River Valley | 6,900 has |
| Pampas in the area of San Bartolo | 8,415 has |
| Uncultivated hillsides | 206,080 has |
| Total | 279,409 has |

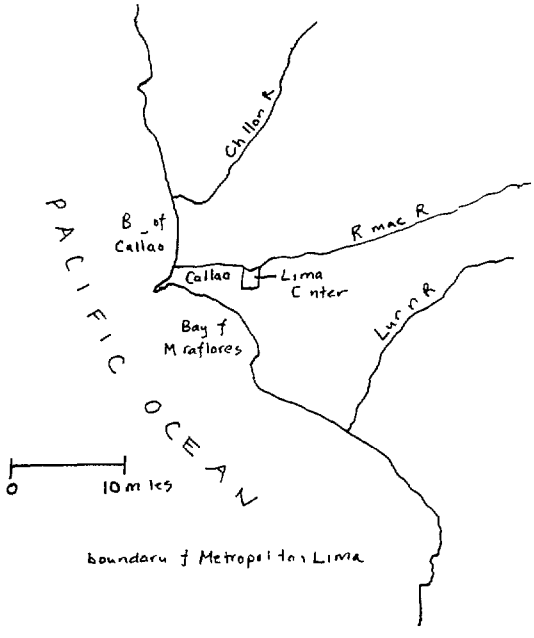
Source IMP, 1989

Water resources from the three watersheds and from the trans-Andean branch of Marcapomacocha (Mantaro River watershed) provide an average flow of 45 86 $m^3$/sec Underground water resources, which are tapped by wells, have usable reserves of 10 $m^3$/sec in the Chillon and Rimac aquifers and 1 8 $m^3$/sec in the Lurin aquifer

Marine coastal waters, which represent a valuable resource for fishing, recreation, business and defense purposes, extend 84 km from Ancon in the north to San Bartolo in the south The coastline consists of *payas*, deltas, cliffs, embayed peninsulas, large islands and aquatic media, which together make up a very dynamic and fragile ecosystem such as the wetlands of Villa in the district of Chorrillos

**Figure IV-1 Map of Peru**

**Figure IV-2 Map of Metropolitan Lima**



As for climate, the metropolitan area is extremely dry, characterized by subtropical thermal conditions Maximum and minimum temperatures are 28°C during the summer (December through March) and 12°C during the winter (April through November) Relative humidity ranges from 75 to 99% Winds range from between 5 and 12 m/sec , and blow predominantly northeast to southwest and east to west

## B Population and Housing

In 1995, the population of metropolitan Lima[1] totaled 6,706,348,[2] accounting for approximately 29% of the total population of the country Lima's growth rate is currently 2 44% per annum as compared to a national rate of 2 0% Table IV-2 reveals that population is now more than twelve times 1940 levels This growth is primarily due to the migrational inflow from the rural areas of the country, and represents one of the highest degrees of centralization in the entire world The growth rate should continue at about 2 0% through the year 2010, at which point it should decrease gradually through the year 2075 [3]

**Table IV-2 Growth of Metropolitan Lima And of the Country as a Whole (1000 inhabitants)**

| Year | Metropolitan Lima | | Peru as a Whole | |
|---|---|---|---|---|
| | Population | Rate of Growth | Population | Rate of Growth |
| 1940 | 520 | | 6,208 | |
| 1961 | 1,836 | 5 12 | 9,907 | 2 9 |
| 1972 | 3,295 | 5 44 | 13,538 | 2 8 |
| 1981 | 4,608 | 3 88 | 17,762 | 2 6 |
| 1993 | 6,346 | 2 44 | 22,048 | 2 0 |
| 1995 | 6,706 | | 23,465 | 1 8 |

The distribution of Lima's population is shown in Table IV-3 Population density in the urbanized areas ranges from 162 9 inhabitants/ha in the northern subregion to 83 3 inhabitants/ha in the eastern subregion, with an average of 131 7 inhabitants/ha for the entire metropolitan area

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1 The perimeter of metropolitan Lima includes a portion of the province of Lima plus the province of Callao

2 Rural and urban population as projected in the 1993 census

3 Quintanilla estimates population stabilization in the year 2075 using two scenarios of 12 5 and 16 5 million inhabitants



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**Table IV-3 Population, Area, and Density by Sub-Region**

| Sub-Region | Population | | | Area (Ha) | | Density (Inhab /Ha ) | |
|---|---|---|---|---|---|---|---|
| | Rural | Urban | Total | All Districts | Residential | All Districts | Urban Area |
| Callao I | 532 | 683,603 | 684,135 | 12,935 | 5,571 | 52 9 | 122 7 |
| South II | 11,291 | 1,389,666 | 1,400,957 | 88,400 | 11,776 | 15 8 | 118 0 |
| North III | 12,238 | 2,313,232 | 2,324,470 | 99,979 | 14,190 | 23 3 | 162 9 |
| East IV | 1,530 | 803,256 | 804,786 | 68,300 | 9,643 | 11 8 | 83 3 |
| City Center V | 0 | 1,492,000 | 1,492,000 | 9,795 | 9,561 | 152 3 | 154 1 |
| Total | 25,591 | 6,680,757 | 6,706,348 | 279,409 | 50,741 | 24 0 | 131 7 |

Source INEI, 1995 Adapted by Project Ecoriesgo

A breakdown of Lima's population by age group reveals a young population, with 52 6% under the age of 25 and 4 39% over the age of 65 Table IV-4 shows the breakdown by age group With such a young population, the city is likely to continue to grow for the foreseeable future, even without the impact of further in-migration

**Table IV-4 Breakdown of the Population of Metropolitan Lima by Age Group**

| Total Population | Age Groups | | | | | | |
|---|---|---|---|---|---|---|---|
| | 00 to 04 | 05 to 14 | 15 to 24 | 25 to 34 | 35 to 54 | 55 to 64 | 65 + |
| 6,706,348 | 610,277 | 1,488,809 | 1,435,158 | 1,106,547 | 1,374,801 | 395,674 | 295,079 |

With regard to housing, Lima has 1,069,069 housing units, of which 807,631 are individual dwellings, 105,831 are apartments, 45,032 are in the form of *quintas,*[4] 36,267 are neighborhood homes (*casas vecindad*), and 74,308 are other types of housing

Housing characteristics vary considerably According to the 1993 census, 26 2% of all homes (381,569 units) were not adequate, with 167,502 having inadequate physical characteristics and 154,751 having no drainage

[4] Several dwellings constructed on a single plot of land with shared income



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Over the last 20 years there has been tremendous growth through spontaneous urbanization of the peripheral areas of Lima The 1993 census recorded 1,662 peripheral settlements (called *pueblos jovenes,* or "young towns"), containing predominantly self-built homes and houses constructed in stages In these areas, sanitation services (piped water, sewers and trash collection) are generally limited or nonexistent

## C Economy

Several important aspects of Lima's current economic situation are

- The leading economic activities in the metropolitan area are the manufacturing industry, commerce, and services, which together generate more than 80 % of the GDP for the Department of Lima, in contrast to only 52 4% of the GDP at the national level Peru's economic activity, employment opportunities and capital are all heavily concentrated in Lima, a phenomenon that will continue to generate regional and urban-rural imbalances in the national economy

- The economically active population (EAP) consists of 2,945,101 individuals over age 14, of whom 74 3% are underemployed, 16 9% are adequately employed and 8 8% (259,160 persons) are unemployed Unemployment is higher among women than among men (11 8% of the female EAP and 7% of the male EAP)

- Fifty-five percent of the EAP are salaried while 44 5% are nonsalaried Average monthly income is 539 2 new soles, with a median of 344 new soles [5] It should be mentioned that approximately 2,167,500 individuals have monthly incomes of less than 599 new soles, which is extremely low in comparison with the cost of a basic family food basket of S/ 34 45 per day or S/ 1,048 50 per month [6]

- The highest salaries in Lima, based on type of employment, are found in the mining industry, where the monthly average is 1,578 new soles Mining is followed by personal services, construction and industry, at monthly levels of S/ 714 00, S/ 647 00 and S/ 627 00, respectively

- The economy of the metropolitan area is "tertiating," which involves a shifting of the work force from the primary sector (industry) to the tertiary sector (commerce and services)

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[5] Source Ministry of Labor and Social Welfare If we consider an exchange rate of US$1 = 2 57 new soles, average income is US$209

[6] CUANTO Peru en cifras 1995

- The informal economic sector is growing rapidly as a consequence of pressure on the job market from continuous migration from the countryside 48 4% of the EAP work in the formal sector, while 47% work in the informal sector and 4 5% are domestic employees [7]

## D Industry

Metropolitan Lima accounts for 65% to 70% of the country's industrial infrastructure In 1995, a total of 33,385 industrial businesses were registered in the metropolitan area, the categories and subregional locations of which are shown in Table IV-5 This table also shows the percentages of these establishments per CIIU in each of the subregions, with the Lima-City region accounting for the greatest number of industrial facilities

Generally speaking, although industrial activity is widely scattered across Lima, it is possible to identify six important industrial centers

- The Callao Subregion, along Av Argentina and Colonial
- The Northern Subregion, between Av Tupac Amaru and the Northern portion of the Pan-American Highway
- The Eastern Subregion, along the Central Highway in the district of Ate
- The Lima-City Subregion, along Av Argentina and Colonial
- The Southern Subregion, at the intersection of Av Pachacutec and the southern portion of the Pan-American Highway
- The Southern Subregion in the district of Villa El Salvador

[7] The term *trabajador del hogar* is used here to signify domestic employee

**Table IV-5 Industrial Infrastructure in Metropolitan Lima, by Sub-Regions**

| Sub-Region | Establishments by Work Force Size | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Small (< 5 employees) | | Medium (5-19 empl ) | | (Large (> 20 empl ) | | | |
| | Number | % | Number | % | Number | % | Number | % |
| Callao I | 1,369 | 4 8 | 259 | 6 8 | 118 | 12 3 | 1,746 | 5 2 |
| South II | 4,241 | 14 8 | 481 | 12 6 | 77 | 8 0 | 4,799 | 14 4 |
| North III | 9,443 | 33 0 | 806 | 21 1 | 143 | 14 9 | 10,392 | 31 1 |
| East IV | 2,950 | 10 3 | 487 | 12 8 | 190 | 19 8 | 3,627 | 10 9 |
| City Center V | 10,603 | 37 1 | 1,786 | 46 8 | 432 | 45 0 | 12,821 | 38 4 |
| Total | 28,606 | 100 0 | 3,819 | 100 0 | 960 | 100 0 | 33,385 | 100 0 |

Source Census, 1995

## E Land Use

Figure IV-3 shows land use in the metropolitan area Residential areas in 1988 accounted for 37,865 has , or 11% of the total metropolitan area and 70% of the urban occupied area Industrial areas take up approximately 3,049 has , while institutional, educational, health and industrial infrastructure together account for 13,086 has In addition, it is estimated that agricultural areas cover 17,900 has , urbanizable uncultivated areas cover 34,919 has , and nonurbanizable areas (hills and uncultivated knolls) cover 172,590 has

## F Physical and Geographic Characteristics of Lima

Several physical and geographic characteristics of Lima importantly affect the nature of environmental problems in the city

- Atmospheric thermal inversions The vertical distribution of temperatures over Lima varies widely as a result of the presence of isothermal zones caused by the continuous anticlinal movement of air masses or high pressure areas from the Pacific This causes low clouds (between 600 and 1,500 meters above the ground) In winter, clouds may drop to 400 meters, creating a significant decrease in air renewal

- Lack of rain Precipitation is only 7 - 10 mm per year There is essentially no rainfall to wash pollutants out of the air The air is purified only by means of wind and settling of particles Settled particles can easily be re-suspended by the wind Without precipitation, ground water is recharged only from river valleys and irrigated areas Pollution at the surface in these areas



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(e g , contaminants in river water, pathogens in waste water used for irrigation, agricultural chemicals) can contaminate ground water In other areas where there is no recharge, surface pollution (e g , spills, pollution from solid waste dumps) will not contaminate ground water With no rain, agricultural lands must be irrigated, using river water well water or waste water

- Humidity, dust and warm temperatures The high relative air humidity throughout the year and the dust that blows from uncultivated hills contribute to the high levels of dust in the air Warm temperatures further exacerbate respiratory stress

- Erosion The upper and middle reaches of the river valleys have been affected by erosion and loss of riverside forests Torrential rains and geodynamic disasters exacerbate water pollution

- Proximity to the ocean Lima benefits from the north-to-south winds generated by the high pressure areas in the Pacific that counteract the predominant winds from south to north Average wind speeds are moderate at 5 to 7 m/sec

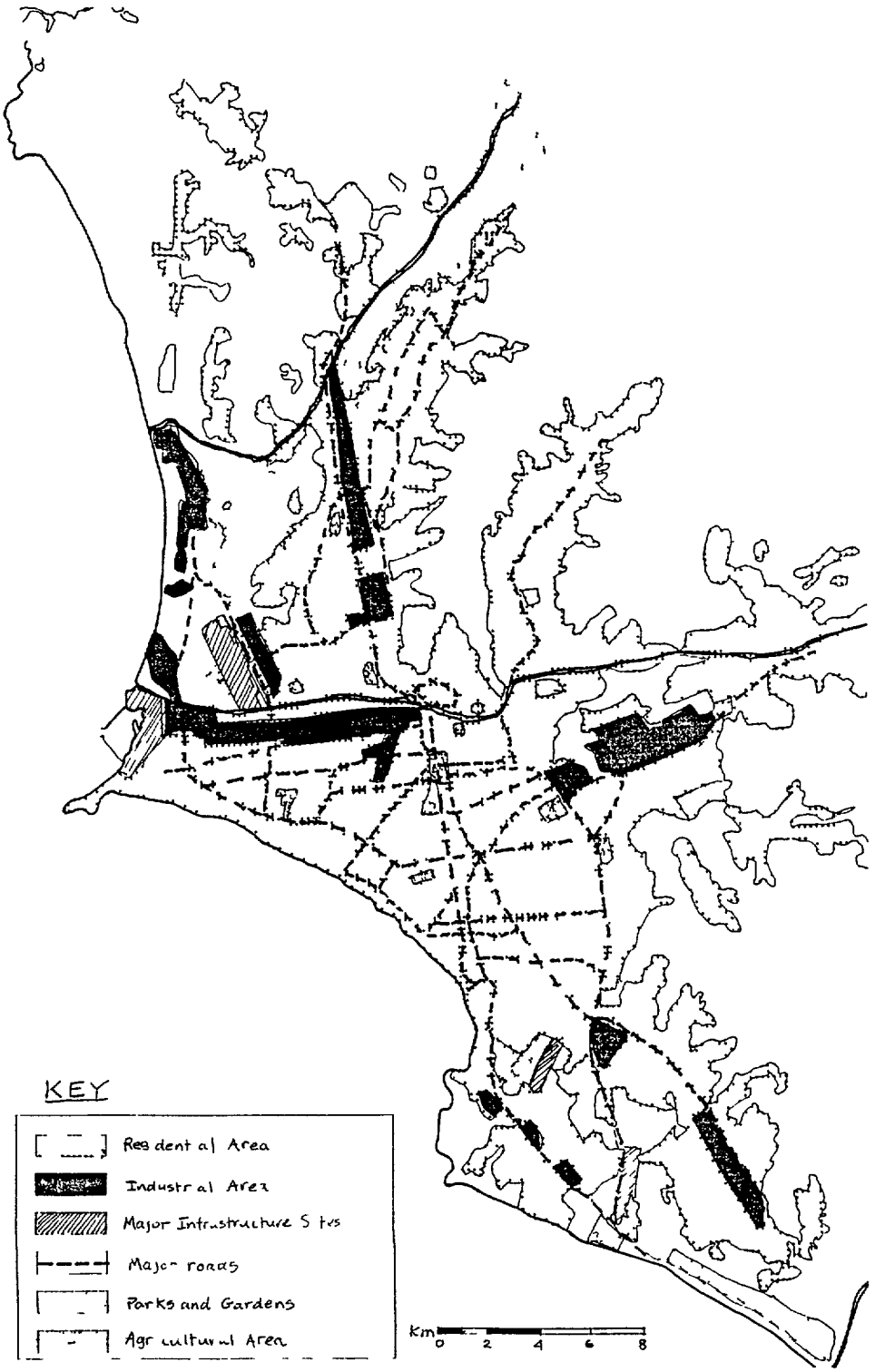
Physical-spatial characteristics with the potential to influence environmental problems in metropolitan Lima include

- A pattern of horizontal, low-density settlement Lima's sprawling nature consumes open space, green areas and agricultural zones, increases transportation costs and makes the provision of many sorts of infrastructure much more expensive Increased transportation needs bring with them pollution In addition to driving up urbanization and transportation costs, the extensive horizontal pattern produces additional pollution Average daily travel time per worker is between 2 and 2 5 hours Studies conducted by the World Bank have estimated that 150 million dollars annually is lost in the form of poorly utilized fuel, and 66 5 million dollars is lost in unavailable work days

- Monocentric and ramified growth The urbanization process has created imbalances in the locations of housing, employment, and commerce while much of the housing is in peripheral areas, employment, commerce, markets, etc are in the center The monocentric scheme creates serious pollution problems by overloading the downtown area and distribution points on the periphery, encouraging high concentrations of gases, chemicals, noise, etc in residential areas and school and hospital zones, stressing the waste management infrastructure, and creating cultural problems of an environmental nature, such as ecological vandalism, etc

- Lack of parks and landscaped areas Relative to accepted per capita standards, it is estimated that Lima now has a deficit of between 3,560 to 3,800 has of parks and landscaped areas A further problem lies in the lack of water to maintain such areas

**Figure IV-3 Land Use in Metropolitan Lima**



## SECTION V
## INSTITUTIONAL FRAMEWORK FOR ENVIRONMENTAL MANAGEMENT IN LIMA

There are many institutions in Lima either directly or indirectly involved in urban environmental management Their functions and responsibilities are often duplicative and uncoordinated There are institutions responsible for the following major functions policy design and planning, monitoring and oversight, legislation, delivery of basic services, financing, human resource development and public awareness However, in most cases these institutions do not limit their activities to a single strategic function but rather carry out a variety of functions simultaneously As a result, they often impede each other's effectiveness

Described below are the primary institutions with responsibilities related to environmental management in Lima It should be noted that the great majority of these institutions have participated in the consultation and review process for this study, through their participation in meetings of the Technical and Management Committees

### A Local Government Provincial Municipalities of Lima and Callao and District Municipalities

There are 50 District Municipalities and two Provincial Municipalities within the boundaries of Metropolitan Lima

The basic responsibilities of these local governments or municipalities include planning, implementation, and promotion of activities to maintain and improve the lives of their citizens These activities are aimed at satisfying the general public's needs for housing, health, education, recreation, transportation and communication

In addition, municipalities are authorized by law to plan and manage the development of their geographic jurisdictions This involves planning, regulating, monitoring, administering and in some cases delivering environmental sanitation, traffic and other public services

Lima, the capital of the country, and Callao, the capital of the Constitutional Province, are governed under a special regime, due to the scale and complexity of the task of urban management in Metropolitan Lima

### B National Council on the Environment (CONAM)

CONAM was created on December 22, 1994 by Law No 26410 to be the guiding entity for national environmental policy CONAM reports to the President of the Council of Ministers and has functional, economic, financial, administrative and technical autonomy Its responsibilities include formulating, coordinating, directing and evaluating national environmental policy

CONAM seeks to implement a national environmental management system which will coordinate activities of the various entities involved with environmental issues Accordingly, the scope of CONAM's activities is cross-cutting in nature, which enables it to support, rather than replace, existing operating structures Thus, CONAM was established as an entity to facilitate and coordinate the many initiatives that are undertaken by institutions involved in environmental management activities in Peru

## C Ministries and Sector Agencies

### C1 Ministry of the Presidency (MIPRE)

MIPRE is authorized to serve the needs of the public by developing basic infrastructure and social support programs It defines government policy in the areas of planning, development, monitoring, operation and maintenance of basic infrastructure, including water and sewerage service, wastewater treatment and garbage disposal

Through its decentralized public agencies, it provides services and supervises and evaluates the implementation of its policies Chief among these agencies are the National Superintendency of Sanitation Services (SUNASS) and the National Water and Sewerage Program (PRONAP)

#### C1a National Superintendency of Sanitation Services (SUNASS)

SUNASS was created in 1992 by Decree Law No 25965, with the objective of ensuring that users receive the highest quality water and sanitation service possible

At the national level, SUNASS regulates and oversees the provision of three services piped water, sanitary and storm drainage, and sewage In addition, it is authorized to propose to MIPRE policies and standards related to the provision of water and sanitation services, and to assess the performance of the agencies that provide such services, such as the Water and Sewerage Enterprise of Lima (SEDAPAL)

#### C1b National Water and Sewerage Program (PRONAP)

PRONAP is a special project of MIPRE which is authorized to carry out activities in the water and sanitation sector PRONAP's personnel management scheme is the same as the one governing private activity PRONAP implements three subprojects i) sectoral strengthening at the central level, ii) institutional and operational strengthening of the agencies providing water and sewerage services, and iii) preparation of final preinvestment and design studies for expansion plans In addition, the Wastewater Management Project for Metropolitan Lima (PROMAR) also functions within the framework of PRONAP

The purpose of the PROMAR Project is to address pollution of the coastal waters along a 40-kilometer stretch of beach between the mouths of the Chillon and Lurin rivers To this end, PROMAR directly promotes the appropriate disposal of domestic and industrial wastewater in Metropolitan Lima

### C2 Ministry of Health (MINSA)

#### C2a Directorate General for Environmental Health (DIGESA)

DIGESA is a line agency of the Ministry of Health, with both technical and normative functions It reports to the Vice-Minister It is authorized to formulate, regulate, supervise and disseminate standards for environmental protection and basic sanitation DIGESA also regulates, supervises, controls, evaluates and coordinates -- with regional and local governments and other components of the National Health System, as well as with other sectors -- issues involving environmental protection, basic sanitation, food hygiene, monitoring and occupational health

Through its Directorate of Basic Sanitation, DIGESA regulates and establishes quality criteria for drinking water and evaluates drinking water quality control activities Through its Directorate of Ecology and Environment, it regulates, monitors and applies appropriate sanctions aimed at preventing pollution caused by biological agents, chemicals and potentially hazardous forms of energy

#### C2b National Institute for the Protection of Health and the Environment (INAPMAS)

INAPMAS is authorized to formulate and propose MIPRE policies and standards relating to public health and the environment It is charged with actively promoting coordination and collaboration between the various entities of the health sector and other institutions with ties to MIPRE

### C3 Ministry of Industry, Tourism, Integration and International Trade Negotiations (MITINCI)

MITINCI sets policy in matters of industry, tourism, integration and international trade negotiations It is authorized to propose policies and standards for environmental and natural resource protection in sector plans, programs and projects

The National Directorate of Industry is a normative technical unit that reports to the Vice-Minister of Industry This agency includes three line directorates the Directorate of Chemical Commodities and Controlled Substances, the Directorate of Industry and Artisanry, and the Directorate of Normative Affairs Through the Underdirectorate for Environmental Supervision and Oversight, it seeks to integrate the environmental management activities of the three line directorates reporting to MITINCI's National Directorate of Industry

### C4 Ministry of Agriculture

This ministry is authorized to formulate, coordinate, evaluate, supervise and monitor national policy relating to renewable natural resource preservation and conservation The scope of the agricultural sector includes, among other things agricultural land, riverbeds, lakes and other sources of water for agricultural uses, agricultural infrastructure, and agricultural health and protection Operating

within the framework of the Ministry of Agriculture are the National Natural Resource Institute (INRENA) and the Autonomous Authority for the Chillon, Rimac and Lurin Watersheds

### C4a National Natural Resource Institute (INRENA)

This agency coordinates its activities with those of the public and private sectors with regard to the use and conservation of renewable natural resources It is authorized to establish water reserves for any purpose serving the public interest, to modify the preferential order of water use for agriculture, energy production, industrial development, mining, etc , and to reorganize use of any given watershed or valley in order to improve the use of water resources, when such reorganization affects two or more regions

### C4b Autonomous Authority for the Chillon, Rimac and Lurin Watersheds

This agency was created as the highest decision-making authority with regard to the use and conservation of water and soil resources in the watersheds associated with the three rivers passing through Metropolitan Lima the Chillon, Rimac and Lurin Rivers

### C5 Ministry of Transportation, Communication, Housing and Construction

This ministry formulates, evaluates, supervises and implements policies relating to the construction, improvement and conservation of transportation, communications, housing and construction infrastructure at the national level, including urban development and environmental protection Through its General Directorate for Urban Development, this ministry proposes national policy and plans to meet the needs of population centers, and proposes, issues and oversees appropriate regulations

The General Directorate for the Environment proposes, supervises and monitors environmental improvement and monitoring policies affecting the sector and, among other things, is responsible for the Urban Environmental Protection Project, which is responsible for the stabilization ponds at San Juan de Miraflores (Lima)

### C6 Peruvian Oceanographic Institute (IMARPE), attached to the Ministry of Fisheries

IMARPE is a decentralized public agency of the Ministry of Fisheries responsible for conducting scientific and technical research on the ocean, continental waters and hydrobiological resources for the purpose of ensuring the rational use of such resources It also provides advisory assistance in the areas of marine and freshwater environmental concerns, pollution analysis, and taxonomic classification of fish and other aquatic organisms

## D National Meteorology and Hydrology Service (SENAMHI)

SENAMHI is charged with gathering, investigating, recording, processing and systematizing meteorological and hydrologic information in Lima and Callao, with a mandate to evaluate and oversee atmospheric pollution Since 1990, SENAMHI has been implementing the Project to Determine and Monitor Atmospheric Pollution in Lima (VICON Project)

## E Service-providing entities

### E1 Water and Sewerage Enterprise of Lima (SEDAPAL)

SEDAPAL is a government-owned enterprise that provides water and sewerage services in Lima and Callao It was established under national law with technical, administrative, economic and financial autonomy It is not subject to hierarchical control by either of the two Provincial Municipalities, Lima or Callao

SEDAPAL plans, constructs and operates water and wastewater treatment plants, as well as water distribution and wastewater collection networks Supreme Resolution No 023-93-PCM (January 22, 1993) ratified the need to promote private investment in the field of sanitation, providing for the privatization of SEDAPAL through the implementation of partnership, service provision, lease, management, concession and other similar contracts The process of privatizing SEDAPAL is currently underway, however, no specific time frame has been established for its completion

### E2 Lima Municipal Waste Removal Enterprise (ESMLL)

ESMLL was created by Decree Law No 22918 in early 1980 as a legally established entity based on domestic public law It has administrative and economic autonomy ESMLL's purpose is to collect, convey, treat and adequately dispose of solid waste in the entire jurisdictional area of the Province of Lima Since its creation, ESMLL has limited its activities to the collection of solid waste within the central urban perimeter (Lima-Cercado) and to the final disposal of solid waste in the entire city of Lima Solid waste collection is the responsibility of each of the fifty districts At present, the service previously provided by ESMLL has been assigned to a private consortium, Vega-Upaca, under a concessionary contract

## F Nongovernmental development organizations (NGDOs)

There are currently some 350 nongovernmental development organizations (NGDOs) in Lima They work in a variety of areas, including policy, economics and poverty, social organization, food and nutrition, health, education and the environment

Described below are the NGDOs whose activities are relevant to this study

### F1 Peruvian Environmental Network

This is a network made up of NGDOs that implement programs calling for direct intervention in environmental issues

### F2 Habitat Commission

This is a work group consisting of approximately 12 NGDOs working to solve problems relating to sustainable urban development

### F3 Ecological Forum

This forum provides an opportunity for the study and proposal of environmental policies and consists primarily of networks made up of NGDOs, research centers and universities

### F4 Consortium of the Journal Medio Ambiente

This is the policy and editorial group of the journal *Medio Ambiente* It consists of a large number of NGDOs conducting work on environmental issues Centro de Investigacion, Educacion y Desarrollo (CIED), Pro-Naturaleza (FPCN), Sociedad Peruana de Derecho Ambiental (SPDA), Instituto de Desarrollo y Medio Ambiente (IDMA), Centro de Investigaciones y Proyectos Urbanos Regionales (CIPUR), Instituto Regional de Ecologia Andina (IRINEA), Red Nacional de Agricultura Ecologica (RAE), Asociacion Peruana para la Conservacion de la Naturaleza (APECO), Asociacion Amazonia (AA), Naturaleza, Ciencia y Tecnologia para el Servicio Social (NCTL), Asociacion para la Investigacion y Desarrollo Rural Integral (AIDER), Red de Accion en Alternativas a los Agroquimicos (RAAA), Centro Alternativa (ALTERNATIVA), and Oficina de Asesoria y Consultoria Ambiental (OACA)

The following table presents an outline of the principle areas of activity in urban environmental management in Lima, by entity

**Table V-1 Summary of the Primary Areas of Activity in Urban Environmental Management in Lima, by Entity**

| Entity | Primary Area of Action |
|---|---|
| Ministries and ministerial agencies | Sectoral |
| Local governments | Territorial |
| Service delivery entities | Private/entrepreneurial |
| NGDOs and associations | Applied research, activism and awareness |

## G Comments

As can be seen from the preceding description of the functions and responsibilities of each institution, units of the national government have environmental responsibilities that are both wide-ranging and spread across many entities The ministries and their corresponding agencies have broad authority with regard to environmental concerns (from policy formulation to the authority to oversee and, as required, apply sanctions) in order to promote compliance with their sectoral development objectives This sectoral approach frequently results in duplicated efforts It also often works in direct opposition to the functions and mandates of local governments to promote the integrated development of their own geographic territories

Thus, the creation of CONAM as an agency to promote the harmonization of environmental criteria and policies as well as to seek the coordination and strengthening of institutional capacity, is quite necessary

## SECTION VI
## WASTE WATER COLLECTION, TREATMENT, AND DISPOSAL

### A Overview of the Problem in Lima

Lima produces between 15 and 18 $m^3/s$ of waste water each day This represents about 85% of the total amount of water produced daily by SEDAPAL Waste water is generated by many sources in the city households, industry, energy producers, and irrigation

Waste water is collected by a sewer system consisting of primary, secondary and tertiary networks These networks carry it to three destinations the coast, the rivers and sewage treatment plants The scarcity of Lima's water resources and the high organic content of the waste water make it an important water source for irrigating parks, gardens and the farmlands that still exist in the peri-urban areas around the city The waste water used for irrigation purposes is either purified in the treatment plants or intercepted from the sewerage network through illegal connections

Final disposal of waste water is via eight outfalls The Surco outfall, with a recorded flow of 5 36 $m^3/s$, is the largest It discharges south of Lima at the beach known as "La Chira" in the Chorrillos district (PROMAR, 1995, SEDAPAL, 1995) The other outfalls, in descending order of volume, are Centenario (Callao district), Costanero (Magdalena district), Comas (Ventanilla district) and Bocanegra (Callao) outfalls Sewage Channel 6, as well as the small Condevilla and Zarumilla sewage channels, discharge into the Rimac river (Fig VI-1)

Approximately 800 l/s, which represents 5 3% of Lima's waste water production, undergoes treatment before it is used or discharged In the San Juan de Miraflores district south of the city, a small drainage area is served by the San Juan sewage channel, which carries waste water to the San Juan treatment plant About 280 l/s are treated using oxidation ponds, the effluent from which is used to irrigate nearby farmlands and nurseries The waste water from the Lurigancho-Chosica and Chaclacayo districts (drainage area No 8) is treated using aerated ponds at the Carapongo treatment plant There are other smaller-capacity treatment systems which primarily use the oxidation pond system (Tables VI-1 and VI-2)

**Figure VI-1 Principal Sewage Channels in Lima**

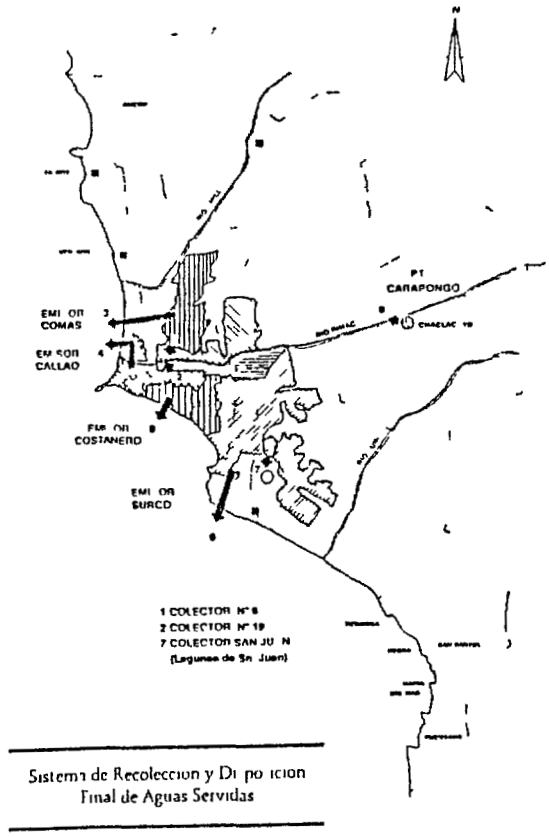





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**Table VI-1 Principal Drainage Areas in Lima**

| Drainage area | Area - hectares | Population | Discharge location | Est house hold flow $m^3/s$ | Industrial flow $m^3/s$ | Used for irrigation $m^3/s$ | Est daily flow $m^3/s$ | Recorded flow $m^3/s$ |
|---|---|---|---|---|---|---|---|---|
| Comas | 67,337 | 905,774 | Into the ocean, Oquendo beach | 2 10 | 0 28 | 1 78 | 1 60 | 2 03 |
| Centenario | 4,993 | 731,485 | Into the ocean, Acapulco beach | 1 69 | 1 45 | - | 3 14 | 3 01 |
| Sewage Ch 6 | 6,283 | 671,937 | Into the Rimac river, Jr Villa Rica (C 25 Av Peru) | 1 56 | 0 42 | 0 59 | 0 39 | 1 49 |
| Costanero | 4,499 | 547,416 | Into the ocean, Av Costanera Cdra 24 | 1 27 | 0 66 | - | 1 93 | 2 80 |
| Surco | 15,911 | 1,469,623 | Into the ocean, La Chira beach | 3 40 | 1 22 | - | 4 62 | 5 36 |
| San Juan | 1,844 | 179,768 | Into the San Juan treatment plant | 0 42 | 0 06 | - | 0 48 | 0 30 |
| Bocanegra | 493 | 66,049 | Into the ocean, Bocanegra Estate | 0 15 | 0 18 | - | 0 34 | 0 50 |
| Chosica | 887 | 45,913 | Into the Carapongo plant | nd | nd | nd | nd | nd |
| Total | 102,247 | 4,617,965 | | 10 59 | 4 27 | 2 37 | 12 5 | 15 49 |

Source SEDAPAL (1995) and PROMAR (1996)

Waste water treatment capacity has remained virtually unchanged over the past 15 years, and about 95 % of the waste water is now discharged untreated The percentage that is untreated is, in fact, even greater than 95% because many systems are inadequately operated and maintained The PROMAR project is currently studying a number of alternatives for treatment and final sanitary disposal of waste water The technical options being examined include (a) discharging all waste water through a single outfall on the north side of the city, which would intercept all currently existing sewage channels, (b) discharging through two suboceanic outfalls located on the north and south coasts, c) partial discharge into the ocean plus construction of recycling plants in different parts of the city This would make it possible to reuse water for agricultural purposes and also return it to the three rivers, thus stabilizing their erratic flow, d) discharge into the ocean and reuse of treated water in new agricultural areas to the north (Ancon) and south (San Bartolo) of the city

**Table VI-1 Principal Drainage Areas in Lima**

| Drainage area | Area (hectares) | Population | Discharge location | Est house hold flow $m^3/s$ | Industrial flow $m^3/s$ | Used for irrigation $m^3/s$ | Est daily flow $m^3/s$ | Recorded flow $m^3/s$ |
|---|---|---|---|---|---|---|---|---|
| Comas | 67,337 | 905,774 | Into the ocean, Oquendo beach | 2 10 | 0 28 | 1 78 | 1 60 | 2 03 |
| Centenario | 4,993 | 731,485 | Into the ocean, Acapulco beach | 1 69 | 1 45 | - | 3 14 | 3 01 |
| Sewage Ch 6 | 6,283 | 671,937 | Into the Rimac river, Jr Villa Rica (C 25 Av Peru) | 1 56 | 0 42 | 0 59 | 0 39 | 1 49 |
| Costanero | 4,499 | 547,416 | Into the ocean, Av Costanera Cdra 24 | 1 27 | 0 66 | - | 1 93 | 2 80 |
| Surco | 15,911 | 1,469,623 | Into the ocean, La Chira beach | 3 40 | 1 22 | - | 4 62 | 5 36 |
| San Juan | 1,844 | 179,768 | Into the San Juan treatment plant | 0 42 | 0 06 | - | 0 48 | 0 30 |
| Bocanegra | 493 | 66,049 | Into the ocean, Bocanegra Estate | 0 15 | 0 18 | - | 0 34 | 0 50 |
| Chosica | 887 | 45,913 | Into the Carapongo plant | nd | nd | nd | nd | nd |
| Total | 102,247 | 4,617,965 | | 10 59 | 4 27 | 2 37 | 12 5 | 15 49 |

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**Table VI-2 Waste Water Treatment Plants for Metropolitan Lima**

| Plant | Flow (l/s) | Treatment Technology | Location of Plant | Population Served | Management Entity |
|---|---|---|---|---|---|
| **IN OPERATION** | | | | | |
| **RUN BY SEDAPAL** | | | | | |
| 1 Carapongo plant | 210 | Aerated ponds | Ate - Vitarte | 142,317 | SEDAPAL |
| 2 Jose Galvez ponds | 60 | Oxidation ponds | V M Triunfo | | SEDAPAL |
| 3 Julio C Tello ponds | 30 | Oxidation ponds | Lurin | 6,456 | SEDAPAL |
| **RUN BY OTHER ENTITIES** | | | | | |
| 1 San Juan de Miraflores ponds | 280 | Oxidation ponds | S J Miraflores | 182,434 | mtcvc |
| 2 Ventanilla ponds | 100 | Oxidation ponds | Ventanilla | 28,584 | municipality |
| 3 Miraflores biofilter | 1 | Biofilter | Miraflores | | municipality |
| 4 UNI station | 8 | Irrig ditch & ponds | San Martin | | UNI |
| 5 Huascar oxidation ponds | 20 | Oxidation pond | Villa El Salvador | | SERPAR |
| **RUN BY PRIVATE ENTITIES** | | | | | |
| 1 Parque 26 ponds | 80 | Oxidation pond | Villa El Salv | | farmers |
| 2 Golf La Planicie station | 8 | Irrig ditch & ponds | La Molina | | private club |
| **TOTAL** | 797 | | | | |
| **TO BE RENOVATED** 1 Puente Piedra ponds | 80 | Oxidation pond | Puente Piedra | 16,796 | SEDAPAL |
| **UNDER CONSTRUCTION** 1 Piedras Gordas - Jerusalen | 30 | Oxidation pond | Ancon | | SEDAPAL |

Source SEDAPAL (1995) and PROMAR (1996)

Implementing the last two options would reap significant sanitary, environmental and socio-economic benefits They would reduce the environmental pollution of the rivers and coastal areas caused by improper disposal of waste water, increase the availability of farm land and green/landscaped areas and help to recharge the aquifer They could also create new opportunities for developing the agricultural sector on the outskirts of Lima If linked to projects to create green/landscaped areas and

ponds, these areas could be turned into valuable recreational space, which is essential in a city such as Lima (see section entitled "Loss of Farm Land and Green Areas")

### A1 Waste water quality

SEDAPAL performs systematic waste water quality monitoring in Lima This is mainly to evaluate treatment effectiveness A profile of Lima's waste water was developed in 1995 by Parsons Engineering, the results for which are reported in Table VI-3

The data give an idea of the extent of the pollution loads in coastal waters and the Rimac river Any conclusions should be tentative, however, as the data derive from very limited sampling The levels of streptococci and coliform bacteria are of the same order of magnitude in all sewage channels except the Centenario This channel has a value ten times higher than all the others for total coliform bacteria The BOD loads range from 149 mg/l to 243 mg/l, fairly typical for sewage largely from domestic sources All the outfalls, but especially the Comas and Centenario, have toxic metals (copper, chromium and arsenic) and nonmetals present in high concentrations

### A2 Sewer system coverage

Lima's sewer system does not serve the entire population The population that has no household drinking water connections is also without waste water collection and disposal service It is estimated that about 28% of the population--or about 1,780,000 residents--do not receive such services (Table VI-4) The districts with lack of coverage at substantially higher rates than the city's average include Puente Piedra (85 1%), Lurigancho (67 5%) and San Juan de Lurigancho (48 4%) in North Lima, Pachacamac (89 1%), Lurin (83 3%), Chorrillos (45 2%) and San Juan de Miraflores (42 1%) in South Lima, Ate Vitarte (52 6%) in East Lima, and the unincorporated area (69 4%)

The population without sanitation service uses pit latrines or septic tanks (16 5%), drainage ditches (1 0%), or they defecate outdoors (10 9%) Properly built and maintained septic tanks and latrines are a safe method of containment and anaerobic oxidation of feces The use of latrines in poor sanitary condition and the disposal of excrement in drainage ditches or outdoors pollutes water and soil with potentially pathogenic matter

## Table VI-3 Characteristics of Waste Water from the Principal Outfalls (June-July 1995)

| Pollutant | Units | Comas Outfall | Centen Outfall | Costan Outfall | No 6 Outfall | Surco Outfall |
|---|---|---|---|---|---|---|
| **Bacteriological** | | | | | | |
| Total coliform | MPN/100 ml | $2\ 09 \times 10^7$ | $4\ 28 \times 10^8$ | $2\ 48 \times 10^7$ | $5\ 75 \times 10^7$ | $6\ 76 \times 10^7$ |
| Fecal coliform | " | $1\ 40 \times 10^7$ | $1\ 92 \times 10^7$ | $1\ 40 \times 10^7$ | $2\ 98 \times 10^7$ | $2\ 89 \times 10^7$ |
| Fecal streptococcus | " | $1\ 12 \times 10^7$ | $5\ 54 \times 10^7$ | $8\ 06 \times 10^7$ | $1\ 82 \times 10^7$ | $6\ 15 \times 10^7$ |
| **Organic load** | | | | | | |
| BOD | mg/L | 215 | 243 | 149 | 341 | 160 |
| COD | " | 714 | 815 | 655 | 981 | 587 |
| Oil and grease | " | 47 | 51 | 44 | 77 | 47 |
| **Nutrients** | | | | | | |
| Total nitrogen | " | 45 0 | 50 2 | 38 4 | 54 2 | 46 8 |
| Ammonia nitrogen | " | 37 4 | 37 2 | 31 0 | 43 2 | 37 2 |
| Organic nitrogen | " | 9 | 17 | 4 | 12 | 6 |
| Nitrites | " | 0 15 | 0 016 | 0 19 | 0 016 | 0 013 |
| Nitrates | " | 7 4 | 0 3 | 1 46 | 0 38 | 0 30 |
| Total phosphorus | " | 8 | 9 1 | 7 2 | 10 6 | 8 1 |
| **Metals** | | | | | | |
| Arsenic (Ar) | mg/L | 0 154 | 0 096 | 0 018 | 0 044 | 0 012 |
| Cadmium (Cd) | " | 0 014 | 0 014 | 0 013 | 0 018 | 0 012 |
| Zinc (Zn) | " | 0 67 | 0 51 | 0 39 | 0 43 | 0 48 |
| Copper (Cu) | " | 0 45 | 0 12 | 0 05 | 0 13 | 0 13 |
| Total chromium (Cr) | " | 0 06 | 0 37 | 0 02 | 0 84 | 0 04 |
| Iron (Fe) | " | 1 40 | 2 47 | 1 44 | 2 11 | 1 56 |
| Manganese (Mn) | " | 0 066 | 0 066 | 0 032 | 0 058 | 0 035 |
| Mercury (Hg) | " | 0 0005 | 0 0008 | 0 0007 | 0 0003 | 0 0020 |
| Nickel (Ni) | " | 0 020 | 0 020 | 0 030 | 0 020 | 0 010 |
| Silver (Au) | " | 0 030 | 0 030 | 0 018 | 0 033 | 0 013 |
| Lead (Pb) | " | 0 17 | 0 22 | 0 22 | 0 19 | 0 25 |
| **Other inorganics** | | | | | | |
| Total alkalinity | mg/L | 261 | 257 | 220 | 286 | 269 |
| Total hardness | " | 444 | 322 | 309 | 370 | 346 |
| Bicarbonates | " | 261 | 257 | 220 | 286 | 269 |
| Chlorides | " | 127 | 126 | 81 | 199 | 142 |
| Fluorides | " | 0 16 | 0 16 | 0 15 | 0 15 | 0 16 |
| Sulfates | " | 321 | 233 | 221 | 254 | 241 |
| Total solids | " | 1183 | 1129 | 1046 | 1460 | 1182 |
| Suspended solids | " | 206 | 255 | 282 | 417 | 276 |
| Dissolved solids | " | 977 | 874 | 763 | 1043 | 906 |
| Volatile solids | " | 458 | 457 | 446 | 558 | 390 |
| Sedimentable solids | " | 4 3 | 4 6 | 4 0 | 8 1 | 2 7 |
| Hydrocarbons | µg/L | 2 7 | 2 5 | 1 0 | 3 6 | 1 3 |

Source PROMAR, 1996

## Table VI-4 Sewer Service Coverage by District in Metropolitan Lima, 1993

| District | Type of District* | Total Population | Public Connection (%) | Pit Latrine | Drainage Ditch | None (%) | Total w/o Coverage (%) |
|---|---|---|---|---|---|---|---|
| **NORTH LIMA** | - | 2 262 569 | 60 34 | 24 33 | 2 03 | 13 25 | 39 66 |
| Carabayllo | URB | 106 496 | 60 31 | 22 59 | 0 71 | 16 39 | 39 69 |
| Comas | PRO | 403 619 | 75 80 | 18 68 | 0 61 | 4 91 | 24 20 |
| Independencia | PRO | 183 537 | 82 48 | 9 07 | 0 19 | 8 25 | 17 52 |
| Los Olivos | PRO | 227,768 | 55 52 | 31 27 | 1 63 | 11 58 | 44 48 |
| Puente Piedra | URB | 99,877 | 14 86 | 56 07 | 6 86 | 22 21 | 85 14 |
| Rimac | CONS | 184,183 | 87 59 | 4 29 | 0 18 | 7 94 | 12 41 |
| S M Porras | PRO | 379,979 | 82 54 | 10 90 | 0 05 | 6 07 | 17 46 |
| Lurigancho | PRO | 98 833 | 32 50 | 35 85 | 7 02 | 24 63 | 67 50 |
| S J Lurigancho | URB | 578 277 | 51 47 | 30 22 | 1 01 | 17 30 | 48 53 |
| **CENTRAL LIMA** | - | 1,361,502 | 93 89 | 1 67 | 0 24 | 3 78 | 6 11 |
| Breña | CONS | 84 911 | 96 14 | 0 93 | 0 17 | 2 77 | 3 86 |
| Jesus Maria | RES | 62 629 | 69 14 | 0 40 | 0 00 | 0 50 | 30 86 |
| La Victoria | CONS | 224 575 | 91 37 | 5 50 | 0 39 | 25 06 | 8 63 |
| Surquillo | CONS | 87,683 | 95 79 | 0 94 | 0 25 | 3 02 | 4 21 |
| Lince | RES | 62 430 | 97 91 | 0 73 | 0 04 | 1 32 | 2 09 |
| Miraflores | RES | 87 191 | 98 51 | 0 57 | 0 03 | 0 85 | 1 49 |
| San Borja | RES | 72,656 | 96 79 | 3 39 | 0 72 | 1 15 | 3 21 |
| San Isidro | RES | 61 721 | 99 25 | 0 21 | 0 06 | 0 50 | 0 75 |
| Lima | CONS | 333,236 | 91 66 | 1 76 | 0 65 | 5 93 | 8 34 |
| Magdalena | CONS | 47 847 | 97 90 | 0 91 | 0 06 | 1 13 | 2 10 |
| Pueblo Libre | CONS | 73 292 | 97 52 | 1 05 | 0 19 | 1 24 | 2 48 |
| San Miguel | CONS | 114 717 | 92 22 | 4 07 | 0 57 | 3 24 | 7 78 |
| San Luis | CONS | 48 614 | 96 35 | 1 20 | 0 00 | 2 45 | 3 65 |
| **SOUTH LIMA** | - | 1 300 480 | 56 20 | 26 89 | 0 74 | 16 17 | 43 80 |
| Barranco | RES | 40,410 | 97 21 | 0 78 | 0 12 | 1 89 | 2 79 |
| Chorrillos | CONS | 208 563 | 54 75 | 35 08 | 0 60 | 9 57 | 45 25 |
| Santiago de Surco | RES | 197 117 | 89 80 | 6 41 | 0 45 | 3 34 | 10 20 |
| Lurin | URB | 34 117 | 16 72 | 58 53 | 2 21 | 22 54 | 83 28 |
| Pachacamac | NI | 19,849 | 10 88 | 41 44 | 1 29 | 46 39 | 89 12 |
| S J Miraflores | PRO | 283 019 | 57 90 | 25 02 | 0 50 | 16 58 | 42 10 |
| V M Triunfo | PRO | 262 919 | 60 91 | 25 91 | 0 34 | 12 84 | 39 09 |
| Villa Salvador | PRO | 254 486 | 61 39 | 21 97 | 0 38 | 16 19 | 38 61 |
| **EAST LIMA** | - | 612 551 | 67 38 | 16 52 | 1 77 | 14 33 | 32 62 |
| Ate Vitarte | PRO | 264 854 | 47 44 | 24 38 | 3 18 | 25 00 | 52 56 |
| El Agustino | PRO | 151 686 | 63 92 | 19 11 | 1 14 | 15 84 | 36 08 |
| La Molina | RES | 77 664 | 88 77 | 6 16 | 0 32 | 4 75 | 11 23 |
| Santa Anita | CONS | 118 347 | 69 37 | 16 44 | 2 45 | 11 73 | 30 63 |
| **CALLAO** | - | 534 553 | 93 18 | 2 96 | 1 07 | 3 61 | 6 82 |
| Bellavista | CONS | 70 851 | 97 73 | 0 85 | 2 37 | 1 39 | 2 27 |
| Callao | PRO | 361 989 | 73 50 | 12 00 | 1 06 | 13 43 | 26 50 |
| C de la Legua | PRO | 38,095 | 97 39 | 1 27 | 0 12 | 1 22 | 2 61 |
| La Perla | CONS | 58 845 | 97 96 | 0 70 | 1 82 | 1 32 | 2 04 |
| La Punta | RES | 4 773 | 99 30 | 0 00 | 0 00 | 0 69 | 0 70 |
| **UNINCORP AREA** | PRO | 771 202 | 30 59 | 37 62 | 2 02 | 29 77 | 69 41 |
| **METRO LIMA** | - | 6 272 295 | 71 61 | 16 53 | 0 95 | 10 89 | 28 39 |

**NI** Districts not included in Metropolitan Lima, with a high percentage of rural population unpopulated areas and very inadequate services **URB** Districts undergoing urban development and incorporation into Lima, with an originally rural population now living in settlements on the city's outskirts in unsuitable housing without services **PRO** Districts in the process of consolidation Most of the residents live in AAHH in consolidated independent houses **CONS** districts consolidated or in the process They occupy the old city and much of the population lives in conditions of overcrowding and urban blight **RES** residential districts with adequate housing and services

## B Health Risks from Waste Water

The population of Lima is exposed both directly and indirectly to the pollutants found in waste water The direct exposure routes are limited to specific subpopulations These include workers in the water and sewer industry and farmers who use untreated waste water for irrigation

For the remainder of the population, exposure is indirect and includes

- Ingestion of drinking water from wells or surface springs that are polluted by waste water,
- Ingestion of drinking water that has been contaminated by waste water infiltrating into drinking water supply pipes,
- Contact with surface and sea water during productive (industry, agriculture, fishing) and recreational activities,
- Ingestion of fish and seafood from polluted habitats, and
- Ingestion of crops watered with untreated waste water
- An additional route with less risk is respiration of contaminated aerosols and dermal exposure during productive and recreational activities

The magnitude of the risk from these sources is discussed in the sections on water pollution, food contamination and ocean pollution

The main health risks associated with waste water are the ones associated with the lack of sewerage coverage and the absence of appropriate systems for safe disposal and removal of feces An assessment of the health impact on Lima's population appears in the portion of the water pollution section entitled "Health Risks Associated with Inadequate Water Supply and Sanitation Services "

## SECTION VII
## SOLID WASTES

### A General Definition of the Problem

Any large concentration of people in an urban area will require significant amounts of material and energy to sustain daily activities The consumption and processing of material and energy in cities generate waste and emissions, particularly solid waste

The volume and nature of the solid waste produced varies from city to city, depending on the number of inhabitants, patterns of consumption, levels of wealth and degree of industrialization Per-capita solid waste generation can range from 0 2 kg/resident/day to 1 4 kg/resident/day in urban areas of less-industrialized countries to 3 kg/resident/day in industrialized countries

For a variety of reasons, cities in Latin America are finding it difficult to establish adequate collection and disposal services for municipal solid waste Limited administrative capacity, growing per-capita production of solid waste, lack of suitable equipment, lack of separate systems for managing different types of waste (household, industrial, hospital, etc ) and poor public awareness are among the principal contributing reasons The relationship between poor municipal solid waste management and public health is difficult to quantify Citizens will, however, demand proper collection of solid waste if they recognize the connection between solid waste and disease and because they desire an attractive and healthy living environment

The potential impacts of solid waste on health and on the environment more generally vary at each stage in the process of handling the waste For example, generation and storage of solid waste in the home can result in the proliferation of pathogenic microorganisms and vectors and unpleasant odors Improper storage or disposal of solid waste along public thoroughfares has a major impact on the city's appearance It also provides food and breeding grounds for the insects, rodents and dogs that can transmit infectious disease Transporting solid waste can scatter it throughout the city and can result in occupational accidents Uncontrolled disposal of solid waste pollutes the soil, surface and ground water and the air This directly compromises the health of solid waste handlers and residents near disposal sites The broader public may also be affected by improper disposal of solid waste if animals that are used for human consumption are fed with solid waste without regard to sanitary considerations Health effects may also occur from modern waste management methods The following table demonstrates this

**Table VII-1 Predicted Cadmium Exposure for Persons Living near a Municipal Solid Waste Incinerator**

| Exposure Route | Daily Ingestion (ng/day) | % |
|---|---|---|
| Fruits and vegetables | 3 58 | 72 6 |
| Milk and milk products | 0 10 | 2 1 |
| Meats | 0 42 | 8 7 |
| Eggs | 0 01 | 0 2 |
| Soil ingestion | 0 74 | 15 0 |
| Inhalation | 0 08 | 1 6 |
| **Total** | **4 93** | **100 0** |

Source Petts, Judith and Eduljee, Gev 1994

Cities produce various types of solid waste Depending on the activity that generates it, solid waste can be classified as household, industrial, commercial, hospital, etc , with different hazard levels for each

The demand for solid waste collection and disposal in Latin America and the Caribbean is growing as a direct function of urbanization Between 1975 and 1990, the urban population grew from 198 million to 323 million This urban development trend is expected to continue until at least the turn of the century By that time, it is anticipated that Latin America and the Caribbean will have 57 cities with over one million inhabitants, including two of the largest cities in the world, Mexico City and Sao Paulo (PAHO, 1991) Each city of over a million people will require collection truck fleets of 100-1,500 vehicles and 500-10,000 sweepers The requirements for managing the growing volume of urban solid waste efficiently and sustainably is one of the major challenges of the next century

## B Overview of the Solid Waste Problem in Lima

Over the last fifty years the city of Lima has experienced a twelve-fold increase in population It currently stands at 6 7 million Growth has also occurred in per-capita generation of solid waste and in the fraction of solid waste that does not easily degrade i e , plastic has replaced wood and non-returnable bottles have replaced reusable ones As the city has grown, its solid waste management problems have increased exponentially The dumps located on the outskirts of the city in the 1950s have now been displaced by urban sprawl Each day the city must dispose of its solid waste further away Rapid growth, however, encroaches on these areas The attitude and habits of many residents compound the problem

The number of municipalities responsible for providing solid waste collection and disposal service has also increased There are now 50 municipalities in Lima and Callao The autonomy of these institutions, with no clear prospect of coordination among them, makes it immensely difficult to develop or implement any master plan for public sanitation Collection and disposal capacities have not increased in proportion to population growth

### B1 Production of Household Solid Waste

Per-capita solid waste production in Lima is estimated to be between 0 2 and 0 8 kilograms per resident per day, with an average of 0 5 kilograms The lower-income districts generate waste at the low end of this range, while high-income areas generate much larger amounts

In Callao, the average per-capita production of household solid waste is very similar to the figures given for Lima (about 0 5 kg/res/day) However, a study conducted for three different socio-economic classes in Callao found little difference in the amount by weight of waste generated It ranged from 0 45 to 0 47 kg/res/day as shown in Table VII-2 The physical composition of waste apparently varied among the three socioeconomic classes studied, as higher income residents generated a greater volume of waste

**Table VII-2 Unit Production of Solid Waste in Callao**

| Description | Area | Waste production | | | | | |
|---|---|---|---|---|---|---|---|
| | | per capita/day | | per 100 $m^2$/day | | per 100 m*/day | |
| | | kg | liter | kg | liter | kg | liter |
| Urban high-income | S1 | 0 47 | 3 18 | | | | |
| Urban medium-income | S2 | 0 45 | 2 66 | | | | |
| Urban low-income | S3 | 0 46 | 2 24 | | | | |
| Commercial restaurant | S4 | | | 21 88 | 53 12 | | |
| Commercial store | S5 | | | 2 18 | 38 50 | | |
| Market | S6 | | | 8 02 | 20 08 | | |
| Office | S7 | | | 0 42 | 12 57 | | |
| Squatter settlement | S8 | | | | | 0 49 | 2 44 |

Source OACA, 1995
m* = linear meter

Total solid waste production in Callao is 314 8 tons per day La Punta and Callao have the lowest and highest household solid waste production, with 3 2 and 181 9 tons per day, respectively (see Table VII-3)

**Table VII-3 Total Solid Waste Production for Districts in Callao**

| District | Population | Production (tons/day) |
|---|---|---|
| Ventanilla | 101,056 | 46 5 |
| La Punta | 6,940 | 3 2 |
| Bellavista | 76,640 | 35 3 |
| Carmen de la Legua | 40,797 | 18 8 |
| Callao | 395,435 | 181 9 |
| La Perla | 63,267 | 29 1 |
| Total | 684,135 | 314 8 |

Source Based on OACA, 1995

Based on this estimate for Callao and the figure of 0 5 kg/capita/day for Lima, total production of household solid waste in Lima is estimated at 3,326 tons per day, with 3,011 and 3,015 tons/day for Lima and Callao, respectively

Table VII-4 shows the composition of household solid waste in Lima and Callao

**Table VII-4 Comparative and Average Composition of Household Solid Waste in Lima and Callao in 1990 and 1994, Respectively**

| Component | Percentage in Lima (1990) | Percentage in Callao (1994) | Average Percentage |
|---|---|---|---|
| Paper and cardboard | 10 30 | 17 58 | 13 94 |
| Plastic | 3 23 | 9 30 | 6 26 |
| Glass | 1 20 | 4 95 | 3 07 |
| Metal | 2 52 | 3 59 | 3 05 |
| Textile | 1 39 | 2 61 | 2 00 |
| Organic matter | 43 29 | 50 81 | 47 05 |
| Other | 38 07 | 11 16 | 24 62 |
| Total | 100 0 | 100 0 | 100 0 |
| Moisture (%) | 62 55 | 37 07 | 47 81 |
| Density (kg/m$^3$) | 294 24 | 176 70 | 235 47 |

Source Alternativa, et al , 1990, and OACA, 1995

Household solid waste in Callao has an average organic content of 50 8% This yields 160 tons per day of organic solid waste Using a similar calculation for the organic content of Lima's waste, it can be estimated that Lima produces about 1,300 tons per day of organic waste

### B2 Solid Waste Collection

In Lima and Callao, each of the 50 municipalities handles its own solid waste collection No definitive statistics are available on the fraction of solid waste that is collected in Lima and Callao, but a typical assumption is that 65% of the total produced in the city is collected If so, of the 3,326 tons per day generated, about 1,164 tons per day of household solid waste are apparently not collected The districts most affected by this short-coming are on the city's periphery

The type and age of collection vehicles vary depending on the purchasing power or financial resources of each district The predominant vehicles are compactor and *baranda* trucks with 1 5-7 tons of carrying capacity In some districts on the outskirts of the city, small human-powered collection units are used These have a capacity of 100-250 kilograms

Table VII-5 indicates that the total amount of solid waste collected in Lima and Callao came to approximately 3,834 tons per day in 1994 An indeterminate majority of this was household solid waste It should be noted that these official figures provided by the municipalities may be higher than the actual amounts due to overestimation of the volume of collection and therefore the extent of service

## Table VII-5 Trash Collected by Truck, Containers and Public Restrooms (April, 1984)

| Province & District | Trash Collected (tons/day) | Collection Trucks | Containers | Public Restrooms |
|---|---|---|---|---|
| **Lima and Callao** | **3833 8** | **403** | **172** | **131** |
| Lima (subtotal) | 3712 6 | 380 | 168 | 126 |
| North Lima | 655 3 | 64 | 25 | 5 3 |
| Ancon | 1 0 | 2 | - | 2 |
| Carabayllo | 50 0 | 5 | 5 | - |
| Comas | 280 0 | 18 | 15 | 32 |
| Independencia | 98 0 | 14 | 5 | 17 |
| Los Olivos | 70 0 | 15 | - | - |
| Puente Piedra | 48 0 | 4 | - | |
| San Martin de Porres | 108 8 | 5 | - | - |
| Santa Rosa | 1 5 | 1 | - | 2 |
| South Lima (subtotal) | 1009 0 | 76 | 42 | 21 |
| Chorrillos | 256 0 | 11 | 6 | |
| Lurin | 1 6 | 2 | - | 3 |
| Pachacamac | 10 0 | 2 | - | 1 |
| Pucusana | 1 0 | 3 | - | 3 |
| Punta Hermosa | 6 0 | 1 | - | 8 |
| Punta Negra | 0 5 | 2 | - | 2 |
| San Bartolo | 1 0 | 1 | - | - |
| San Juan de Miraflores | 140 0 | 14 | 4 | 2 |
| Santa Maria del Mar | 3 0 | 1 | - | 2 |
| Santiago de Surco | 180 0 | 27 | - | |
| Villa El Salvador | 80 0 | 6 | 32 | |
| Villa Maria del Triunfo | 350 0 | 6 | - | - |
| Central Lima (subtotal) | 1083 7 | 171 | 81 | 47 |
| Barranco | 35 0 | 5 | - | 0 |
| Breña | 50 0 | 4 | - | 5 |
| Jesus Maria | 40 0 | 10 | - | 3 |
| La Victoria | 113 0 | 21 | - | - |
| Lince | 72 0 | 11 | - | - |
| Lima | 290 0 | 30 | 52 | 18 |
| Magdalena del Mar | 20 0 | 8 | - | 2 |
| Pueblo Libre | 80 0 | 5 | - | |
| Miraflores | 115 0 | 11 | 18 | 7 |
| Rimac | 81 0 | 14 | - | |
| San Borja | 1 8 | 13 | - | |
| San Isidro | 75 0 | 11 | 8 | |
| San Miguel | 10 9 | 13 | - | - |
| Surquillo | 100 0 | 15 | 5 | 4 |

| | | | | |
|---|---|---|---|---|
| East Lima (subtotal) | 964 6 | 69 | 20 | 5 |
| Ate | 65 4 | 12 | 20 | - |
| Cieneguilla | 0 5 | 1 | - | |
| Chaclacayo | 15 0 | 2 | - | |
| El Agustino | 280 0 | 5 | - | |
| La Molina | 380 0 | 13 | - | - |
| Lurigancho (Chosica) | 60 0 | 6 | - | 2 |
| San Juan de Lurigancho | 170 0 | 17 | - | - |
| San Luis | 2 5 | 6 | - | 2 |
| Santa Anita | 1 2 | A | - | 1 |
| Callao (subtotal) | 121 3 | 23 | 4 | 5 |
| Bellavista | 10 0 | 7 | - | |
| Callao | 5 0 | 4 | - | - |
| Carmen de la Legua | 25 0 | 3 | - | - |
| La Perla | 30 0 | 3 | - | 1 |
| La Punta | 2 0 | 2 | - | 1 |
| Ventanilla | 49 3 | 4 | 4 | 3 |

Source INEI 1994

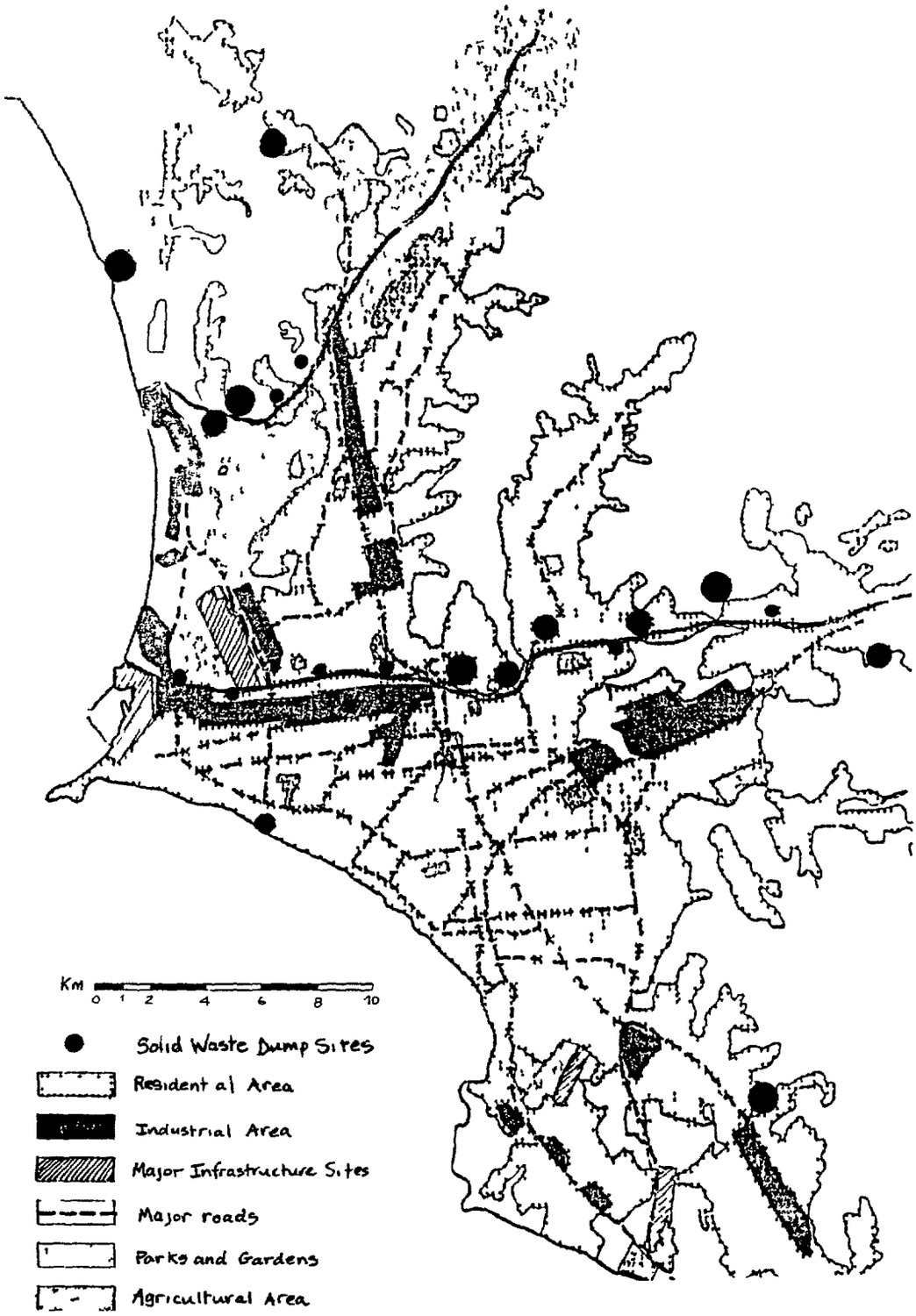
The collection frequency varies from daily in districts with high socio-economic levels to every two weeks or monthly in outlying urban areas There is practically no differentiation of collection by type of waste The large majority of household, hospital, industrial, commercial and other waste is collected and moved together in the same trucks

### B3 Final disposal

There are two principal sanitary landfills in Lima Zapallal to the north, which receives about 812 tons per day, and Portillo Grande to the south, with 300 tons per day La Cucaracha in Callao is estimated to receive 160 tons per day, but currently it is not operating properly and is not counted as a sanitary landfill Therefore, at present only 1,112 tons per day are disposed at the city's sanitary landfills The remaining 2,214 tons per day of household waste is disposed of inadequately -- either not collected, or collected but dumped somewhere other than in a sanitary landfill Figure VII-1 shows the locations of Lima's solid waste dumps

Use of the sanitary landfills has increased slightly since 1994 In that year, it was reported that a total of 1,050 tons per day reached the sanitary landfills (see Table VII-6) The remaining 2,060 tons/day were (and continue to be) thrown into the ocean and rivers, burned, recycled, used as pig feed, or left in the streets and other public areas

**Figure VII-1 Solid Waste Dumps in Metropolitan Lima**



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## Table VII-6 Origins of Solid Waste Received at Sanitary Landfills in Lima in 1994

| Province & District Of Origin | Tons | |
|---|---|---|
| | Annual | Daily |
| **Total** | **383,248** | **1050** |
| Lima (District) | 112,265 | 307 6 |
| Ancon | 10 | 0 |
| Ate-Vitarte | 13 550 | 37 1 |
| Barranco | 4090 | 11 2 |
| Breña | 0 | 0 |
| Carabayllo | 705 | 1 9 |
| Chaclacayo | 0 | 0 |
| Chorrillos | 26,931 | 73 8 |
| Cieneguilla | 0 | 0 |
| Comas | 23,825 | 65 3 |
| El Agustino | 5 | 0 |
| Independencia | 7439 | 20 4 |
| Jesus Maria | 5971 | 16 4 |
| La Molina | 4182 | 11 5 |
| La Victoria | 27309 | 74 8 |
| Lince | 0 | 0 |
| Los Olivos | 1860 | 5 1 |
| Lurigancho (Chosica) | 0 | 0 |
| Lurin | 843 | 2 3 |
| Magdalena del Mar | 0 | 0 |
| Miraflores | 17 749 | 48 6 |
| Pachacamac | 1345 | 3 7 |
| Pucusana | 0 | 0 |
| Pueblo Libre | 0 | 0 |
| Puente Piedra | 7406 | 20 3 |
| Punta Hermosa | 0 | 0 |
| Punta Negra | 0 | 0 |
| Rimac | 6228 | 17 1 |
| San Bartolo | 0 | 0 |
| San Borja | 5 | 0 |
| San Isidro | 21 274 | 58 3 |
| San Juan de Lurigancho | 108 | 0 3 |
| San Juan de Miraflores | 6174 | 16 9 |
| San Luis | 32 | 0 1 |
| San Martin de Porres | 18 102 | 49 6 |
| San Miguel | 269 | 0 7 |
| Santa Anita | 0 | 0 |
| Santa Maria del Mar | 0 | 0 |

| | | |
|---|---|---|
| Santa Rosa | 6 | 0 |
| Santiago de Surco | 55 779 | 152 8 |
| Surquillo | 1940 | 5 3 |
| Villa El Salvador | 977 | 2 7 |
| Villa Maria del Triunfo | 16 869 | 46 2 |
| Other | 76 186 | 208 7 |
| Businesses | 2005 | 5 5 |
| Trunk lines | 28 292 | 77 5 |
| Markets | 42 956 | 117 7 |
| Hospitals | 2933 | 8 |

Source INEI 1994

The informal sector uses some of the uncollected solid waste and some of that which does not reach the sanitary landfills, even after it has been collected by municipal trucks Perhaps 5,000 persons are engaged in activities connected with the informal use of solid waste They are directly at risk from accidents and illnesses associated with its improper handling

Wounds and falls or blows are the principal accidents involving informal-sector waste handlers They constitute 57% and 18%, respectively, of the accidents Among the chief illnesses suffered by street recyclers are kidney problems (49%) and stomach ailments (14%) (IPES, 1995)

Many of the improper practices in handling and disposal of household solid waste in Lima contribute to environmental pollution in the city and increase the residents' risk of contracting an infectious or other disease The principal causes are

- Open-air burning of solid waste, which pollutes the air with particles, toxic substances and infectious agents,
- Accumulation of solid waste in public areas where it is available for direct contact and to support disease vectors,
- Informal recycling of commercially useful solid waste, involving extensive contact by handlers with the waste materials,
- Use of untreated solid waste for feeding pigs that are then eaten by people, and
- Dumping solid waste in surface waters and the ocean, which can contaminate water supplies used for drinking or recreation

## C Health Impacts

The portion of Lima's population that does not receive solid waste collection (perhaps 35%) is very likely to be at a greater risk of contracting an infectious disease than those who do The incidence of infectious diseases can increase as a result of pollution of water or food, by direct contact, or through vectors In areas without collection service, the burning of solid waste and its storage in the home or along public thoroughfares have been observed to be common practice and a public nuisance

Although the emissions and exposures from burning solid waste in Lima have not been established, incomplete combustion of the waste releases into the immediate atmosphere significant amounts of a number of by-products noxious to humans These include particles, CO, $SO_2$, PCBs and dioxins These are reflected in the figures given in the chapter on air pollution

The disposal of household solid waste along public thoroughfares is life-sustaining and attractive to vectors such as rats, flies and cockroaches They spread disease largely by contaminating food and water This situation is especially aggravated during the summer because decomposition of the organic component of household solid waste (47%) is particularly conducive to the breeding of flies and other vectors In addition, dumping wastes in public areas increases the risk of disease through direct contact with the skin, eyes and mucous membranes of persons handling it deliberately or accidentally

The population of Lima is also at risk of contracting an illness such as cysticercosis via pork from pigs fed with unsanitary organic solid waste The incidence of occupational accidents and illnesses suffered by solid waste handlers is not precisely known It is estimated, however, that at least 5,000 informal waste handlers are at high risk

Solid waste pollution of the sources of water used for human consumption is difficult to quantify Direct river pollution is thought to be more significant than that from ground water polluted by leachates This is due to the near absence of precipitation in Lima and the depth of water-bearing rock strata In many cases, the ocean serves as a disposal place for solid waste This mainly affects bathers and the consumers of marine products

On balance, we expect the contribution of improperly managed household solid waste to infectious disease rates to be less than that for several other environmental factors such as the lack of water or sewers Most of the infectious diseases that are environmentally related are transmitted via the fecal-oral route Vectors are relatively minor contributors to this route Most involve person to person contact or where one person touches an object in the home which then contaminates food or water

## D Discussion

The inadequate handling and treatment of solid waste in Lima is mainly thought to affect four population groups (I) persons who have no solid waste collection service, (ii) informal handlers of solid waste, (iii) consumers of pork from pigs fed with untreated organic waste, and (iv) the general population, through vectors and air and water pollution

In the first case, 2 35 million people (35% of Lima's population), are thought to be affected by inadequate collection coverage In the second group, 5,000 people are presumed to be at high risk of contracting disease It has not been possible to determine the number of persons at risk of contracting ailments such as cysticercosis from consuming contaminated pork

There is adequate information on the per-capita production and physical composition of household solid waste in Lima The number and location of the people at greatest risk of acquiring an infectious disease from contaminated solid waste however, is not precisely known Nor is there information on the extent to which solid waste contributes to pollution of the ocean, water and food We cannot generate any quantitative estimate of the impact of improper handling of waste on morbidity and mortality among the population of Lima

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## SECTION VIII
## WATER POLLUTION

### A Water and Health

Historical evidence of links between water pollution and health dates back to the Fourth Century before Christ, when Hippocrates discovered a link between the febrile illnesses assailing the population and the stagnant waters found in marshes and swamps It is a well-known fact that the construction of sanitary facilities in Nineteenth Century France and England was accompanied by a plunge in mortality rates It was not until 1855 that Dr John Snow in London was finally able to establish a direct correlation between water and cholera We now have an abundance of research data establishing the relationships between water and health

Both the quantity and quality of water have effects on human health Water is the reservoir for a number of biological and chemical contaminants and the habitat for organisms and vectors transmitting pathogenic organisms Water scarcity can interfere with good personal and household hygiene practices, causing "water-washed" diseases such as typhus

There are direct and indirect pathways of exposure to contaminated water Direct pathways include the ingestion of polluted drinking water (in which case the pollution may be present originally in the water source, or it may be introduced subsequently during water treatment, distribution or storage), and contact with polluted water in the pursuit of productive, household and recreational activities Indirect pathways include the consumption of crops irrigated with waste water, the ingestion of foods prepared with polluted water, and the consumption of fish and shell fish contaminated by pathogens or with bioaccumulated contaminants present in their natural habitat The inhalation of contaminated aerosol products is a less common direct pathway of exposure but is known to cause diseases such as Legionellosis

Water is thus an important link in the "epidemiological chain " It plays a major role in the transmission of infectious diseases as well as modern-day disorders associated with exposure to organic and inorganic chemical agents

There is a mass of evidence attesting to the direct correlation between water and health and we note that 21 of the 37 leading diseases in developing nations are associated with inadequacies in water supply services This situation is no different in Lima, Peru

### B Lima's Water Resources

From its source in the Andes mountains at 4,830 meters above sea level, to its mouth in the district of Callao, the Rimac river flows for a distance of 132 kilometers It flows through a narrow valley within which the area's leading productive activities occur These range from ore mining and processing in the upper, Andean reaches to crop farming along the river's narrow alluvial plain In its

last 50-kilometer stretch before emptying into the Pacific, the Rimac flows through a densely populated area that also includes most of the city's industry

The Rimac is dependent on precipitation levels in the central highlands, and as such it shows large fluctuations in its annual flows (Table VIII-1) The river serves as Lima's main source of water The city has meager water resources and is categorized as a "desert" city In addition to the Rimac, water needs are also satisfied by tapping groundwater resources and by the surface waters of two other smaller rivers, the Chillon and the Lurin The water is used for many activities human consumption, domestic uses, power production, farming, mining, industrial manufacturing and business, residential and social activities

Together, the three river basins have been classified as a critical environmental area (ONERN, 1985) This is as a result of high levels of pollution and damage to their ecosystems and the urban environment

**Table VIII-1 Annual Flow in Lima Area Rivers**

| Water source | Total flow in 1992 (million $m^3$) | Total flow in 1993 (million $m^3$) |
|---|---|---|
| Rimac River | 480 15 | 826 19 |
| Chillon River | 81 32 | 236 67 |
| Lurin River | 46 00 | 205 28 |

Source CUANTO, 1996

Lima's groundwater resources come from a wide variety of alluvial and colluvial deposits They are composed mainly of sand and gravel, with small clay strata, found mainly in coastal valleys According to geophysical surveys, the largest such strata is up to 400 meters thick In general, these sedimentary deposits are highly permeable, forming a large water-bearing stratum or aquifer which is recharged mainly from the Rimac and Chillon river valleys, both of which have their source in the central Andes This water-bearing stratum is also recharged through the irrigation system associated with these same rivers, as well as by a number of man-made bodies of water such as recreational lakes in the La Molina District and waste water treatment ponds However, as irrigation and these surface water bodies recharge ground water, they can also operate as pollutant sources (Geake et al , 1986)

In general, the water table is low (20 to 80 meters below the surface) and its level is falling at the rate of 2 to 4 meters annually Water shortages throughout the Lima area have created a growing dependency on groundwater resources, and ground water is now being depleted faster than it is replenished This causes the rate at which the water table drops to increase 1995 estimates place the number of wells in the city of Lima at over 1,000, of which approximately 360 are managed directly by

SEDAPAL (Servicios de Agua Potable de Lima) These are used for drinking water as well as for irrigation and industrial manufacturing

### B1 Surface Water Quality

Despite their role as the city's primary water sources, all three rivers serve as receiving waters for liquid and solid waste generated by activities in and around the urban area

Existing records show a total of 175 waste water discharges into the Rimac from mining, industrial and household activities (CEPIS, 1991) Most releases of pollutants in the upper reaches of the Rimac are from mining operations Tailings, acidified water and drainage water load the water with solid wastes, as well as metals, nonmetallic elements and other toxic substances The main sources of pollution in the middle and lower reaches of the river are farming, industrial and urban activities (residential waste water) The Chillon and Lurin rivers have much smaller pollutant loads Although there are no industrial-scale mining operations in either of these river basins, farming and urban sprawl, particularly in the lower reaches of the rivers, degrade their water quality

Household activities also contribute to surface water pollution in Lima Many of the most unstable and vulnerable lands along the banks of the rivers house poor communities with highly inadequate public services For example, according to residents of 11 settlements located along the banks and mouths of Lima's three rivers (interviewed as part of the PROMAR project), service coverage for water supply, sanitation and street cleaning is below the average for the capital area as a whole Many community residents use the rivers to dump trash and human excreta

A nationwide study of sewage discharge into National Drinking Water Program rivers (PRONAP, 1995) identified 10 urban communities discharging sewage directly into the Rimac at a rate of approximately 100,000 cubic meters/day Another 2 urban communities discharged sewage directly into the Chillon and Lurin rivers (Table VIII-2)

**Table VIII-2 Direct Discharges of Sewage into Lima Area Rivers**

| River Basin | Population Connected to the Sewerage System | Volume Discharged ($m^3$/day) |
|---|---|---|
| Rimac | 374,977 | 93,744 |
| Chillon | 17,896 | 4,474 |
| Lurin | 2,099 | 525 |

Source PRONAP, sector study
Data compiled by the ECORIESGO project

There are no monitoring programs at the present time for the Chillon and Lurin rivers SEDAPAL and several mining companies located in the upper reaches of the Rimac, however, have

been performing regular water quality sampling to help achieve targets set under environmental management and upgrading programs (PAMA)

The dominant metals in the Rimac include iron, zinc, lead, cadmium and copper, as well as manganese, arsenic and chromium The concentrations of some metals (iron, lead, copper and chromium) are higher from May to August, when the river is at its lowest level Otherwise, concentrations of metals fluctuate throughout the year without any clear pattern, depending on receiving water flows, the rate of mining activity, and any accidental releases of tailings and acidic drainage water

Table VIII-3 shows the levels of metals in the Rimac at three different locations at upstream mining outfalls, in the main river in the vicinity of the mining operations, and at the intake works for the La Atarjea water treatment plant at kilometer 15 within Metropolitan Lima The persistently high concentration of metals at all three points is an indication that the desired dilution effects are not being achieved over the length of the river downstream of the mines, or that pollutant sources other than mining operations are releasing additional metal compounds into the river

**Table VIII-3 Concentrations of Metals at Different Points along the Rimac River, 1995**

| Parameter (mg/l) | Range of Concentrations at Mine Outfalls* | Range of Concentrations in the Mining Area | Range of Concentrations at La Atarjea Intake |
|---|---|---|---|
| Arsenic** | 0 03-0 87 | 0 02-0 15 | 0 05-0 102 |
| Cadmium | 0 01-0 03 | 0 03-0 04 | 0-0 223 |
| Copper | 0 02-0 26 | 0 05-0 44 | 0 02-0 223 |
| Iron | 0 64-7 98 | 0 98-2 8 | 0 39-13 9 |
| Manganese | 0 04-0 56 | 0 1-0 88 | 0 04-1 465 |
| Lead | 0 04-0 59 | 0 11-0 79 | 0 028-0 806 |
| Zinc | 0 16-6 37 | 0 45-6 06 | 0 15-3 69 |
| Mercury | 0 01 | n a | n a |
| Hexavalent chromium | <0 01 | n a | 0 01-0 008 |

* According to data reported by the Ministry of Energy and Mines The specific location from which the samples were drawn is unknown, ** Nonmetallic element, n a = not available
Sources SEDAPAL, Ministry of Energy and Mines Data compiled by the ECORIESGO Project

La Atarjea is Lima's only water treatment plant, and more than 60 % of the city's drinking water supply is drawn from the Rimac at the La Atarjea intake Data furnished by SEDAPAL and presented in Table VIII-4 below indicates that the Rimac at this point is severely polluted with high concentrations of solids, heavy metals and bacteria Average metal and bacteria levels in the river water exceed maximum allowable concentrations under the provisions of the General Water Act (Decree-Law 17752-69 and Executive Order 007-83 SA) for Class II (residential water supplies subject to a combination of treatment processes), Class III (water used for the irrigation of crops to be consumed in their raw state)

and Class IV water (recreational uses) The volume of organic matter present in the river is equivalent to that of weak or "low-load" residential waste water There are no available data on hydrocarbons or other organic compounds potentially from industrial sources (such as phenol, toluene, benzene, etc )



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## Table VIII-4 Water Quality, Rimac River at La Atarjea Intake Works, 1995

| Parameter | Unit | Maximum | Minimum | Average | Standards Water Act (Class II) | Standards Water Act (Class III) | Standards Water Act (Class IV) |
|---|---|---|---|---|---|---|---|
| Physical pollutants | | | | | | | |
| pH | pH unit | 8 560 | 7 790 | 8 14 | 5-9 | 5 9 | 5 9 |
| Conductivity | mhos/cm | 659 000 | 398 000 | 524 000 | - | | |
| Color | Pt/Co unit | 2 00 | 1 00 | 1 33 | 10 | 20 | 30 |
| Temperature | C | 23 00 | 17 00 | 18 70 | -- | | |
| Total solids | mg/l | 1512 00 | 414 00 | 553 00 | -- | - | |
| Dissolved solids | mg/l | 504 00 | 342 00 | 444 000 | | -- | - |
| Suspended solids | mg/l | 1170 00 | 12 00 | 110 00 | | -- | |
| Inorganic chemicals | | | | | | | |
| Total alkalinity | mg/l CaCO3 | 133 000 | 79 000 | 111 000 | - | | |
| Total hardness | mg/l CaCO3 | 315 000 | 191 000 | 271 000 | -- | | |
| Calcium hardness | mg/l CaCO3 | 281 000 | 183 000 | 240 000 | - | | |
| Chlorides | mg/l C11 | 24 800 | 15 600 | 19 700 | -- | - | - |
| Sulfates | mg/l SO4 2 | 225 000 | 123 000 | 174 000 | | - | -- |
| Nitrates | | 5 412 | 2 380 | 3 920 | 10 | 100 | 1000 |
| Nitrites | " | 0 97 | <0 001 | 0 158 | | | |
| Ammonia | ' | 0 210 | 0 007 | 0 093 | - | | |
| Dissolved oxygen | " | 9 4 | 6 8 | 7 8 | 3 | 3 | 3 |
| COD | | 65 660 | 2 570 | 15 661 | -- | -- | |
| Phosphates | " | 0 378 | 0 014 | 0 152 | -- | -- | |
| Silica | " | 18 940 | 12 470 | 16 136 | -- | | -- |
| Organic chemicals | | | | | | | |
| Total carbon | mg/l | 31 550 | 20 660 | 27 120 | -- | - | -- |
| Organic carbon | | 7 130 | 1 250 | 2 65 | | -- | -- |
| Inorganic carbon | | 28 290 | 18 370 | 24 47 | | - | |
| Trihalomethanes | µg/l | 3 180 | 0 000 | 0 88 | | - | |
| Chloroform | µg/l | 2 910 | 0 000 | 0 460 | | -- | -- |
| Dichlorobromo methane | µg/l | 1 180 | 0 000 | 0 110 | | | |
| Dibromochloro methane | µg/l | 0 170 | 0 000 | 0 04 | - | | |
| Bromoform | µg/l | 1 100 | 0 000 | 0 280 | - | | |
| Metals | | | | | | | |
| Iron Fe 3+ | mg/l | 13 910 | 0 396 | 2 284 | 0 03 | 0 001 | -- |
| Manganese Mn 2+ | " | 1 465 | 0 04 | 0 2 | 0 01 | 0 05 | -- |
| Lead Pb 2+ | " | 0 806 | 0 028 | 0 162 | 0 05 | 0 1 | |
| Cadmium Cd 2+ | ' | 0 223 | 0 000 | 0 013 | 0 01 | 0 05 | |
| Chromium Cr 6+ | | 0 008 | 0 001 | <0 020 | 0 05 | 1 | 5 |
| Zinc Zn 2+ | | 3 690 | 0 152 | 0 595 | 5 | 25 | -- |
| Copper Cu 2+ | | 0 223 | 0 02 | 0 062 | 1 | 0 5 | 3 |
| Aluminum Al 3+ | | 3 647 | 0 178 | 0 795 | | -- | 1 |
| Sodium Na 1+ | ' | 24 85 | 8 630 | 17 098 | | | - |
| Potassium K 1+ | | 6 112 | 2 125 | 2 903 | | | |
| Nonmetals | | | | | | | |
| Arsenic As 3+ | mg/l | 0 102 | 0 005 | 0 029 | 0 1 | 0 2 | 1 |
| Boron B 1+ | ' | 0 077 | 0 002 | 0 019 | - | | |
| Cyanide CN 1+ | " | 0 005 | <0 001 | <0 005 | 0 2 | 0 005 | 0 005 |
| Fluoride F 1+ | " | 0 470 | 0 190 | 0 261 | 1 5 | 1 5 | 2 0 |
| Biological agents | | | | | | | |
| BOD5 | mg/l | 8 99 | 2 71 | - | 5 | 15 | 10 |
| Fecal coliform organisms | MPN/100ml | 280,000 | 8 000 | - | 4 000 | 1 000 | 1 000 |

Measurements of water quality in the Chillon and Lurin rivers were made as part of the "National Survey of Current Water Usage" conducted by the National Bureau of Water Resources (INRENA) in 1982 The Chillon river flows 126 kilometers from its source in the Andes, 4,600 meters above sea level to its mouth in the "Northern Cone" of Lima, where it empties into the Pacific Ocean Its pollution load is attributable primarily to agricultural and household activities Table VIII-5 shows the average concentrations of various substances at two sampling stations These are Llipata, at 1,200 meters above sea level, which is a site representative of the middle reaches of the river basin (Point 1), and Hacienda Chichicorral, 300 meters above sea level (Point 2), a site representative of the lower river basin In general, the river has low levels of organic matter and metals, with a slightly larger downstream load of organic matter There are no significant differences in levels of physical and chemical pollutants or metal concentrations at the two sampling stations Levels of manganese, lead and cadmium exceed maximum allowable levels for Class II (residential water supply) and Class III (irrigation) water

**Table VIII-5 Water Quality in the Chillon River, 1982**

| Parameter | Unit | Average Concentration | |
|---|---|---|---|
| | | Point 1* | Point 2* |
| **Physical pollutants** | | | |
| Electrical conductivity | micromhos/cm | 1062 5 | 1153 33 |
| Temperature | C | 19 75 | 21 33 |
| Rate of flow | $m^3$/second | 2 4 | 1 82 |
| Color | | 0 0 | 75 |
| Turbidity | units | 0 0 | 19 33 |
| pH | units | 8 1 | 8 1 |
| Suspended solids | ppm | 206 0 | 10 |
| Total dissolved solids | ppm | 557 5 | 758 |
| **Chemical Pollutants** | | | |
| BOD | ppm $O^2$ | 1 7 | 1 8 |
| Total hardness | ppm $CaCO_3$ | 349 98 | 593 |
| Calcium hardness | ppm $CaCO_3$ | 347 5 | 427 17 |
| Dissolved O2 | ppm | 6 35 | 6 03 |
| O2 Saturation | % sat | 74 83 | 69 17 |
| $NO_2$ | ppm | 0 000 | 0 053 |
| $NH_4$ | ppm | 0 06 | 5 025 |
| $PO_4^{3}$ | ppm | 0 84 | 1 05 |
| **Metals** | | | |
| Mn | ppm | 0 165 | 0 13 |
| Fe | ppm | 0 0025 | 0 003 |
| Co | ppm | 0 01 | 0 00 |
| Ni | ppm | 0 01 | 0 03 |
| Cu | ppm | 0 02 | 0 02 |
| Ag | ppm | 0 013 | 0 0025 |
| Zn | ppm | 0 05 | 0 095 |
| Cd | ppm | 0 017 | 0 099 |
| Al | ppm | 0 02 | 0 00 |
| Pb | ppm | 0 10 | 0 10 |
| As | ppm | 0 008 | 0 018 |
| F | ppm | 0 52 | 0 65 |
| Hexavalent Cr | ppm | 0 025 | 0 024 |
| Cn | ppm | <0 001 | <0 001 |

* Point 1 Llipata, Point 2 Hacienda Chichicorral
Source INRENA Data compiled by the ECORIESGO Project

The 1982 survey also provided water quality data for the Lurin River, covering the same parameters (Table VIII-6)



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**Table VIII-6 Water Quality in the Lurin River**

| Parameter | Unit | Average Concentration | |
|---|---|---|---|
| | | Point 1* | Point 2* |
| **Physical pollutants** | | | |
| Electrical conductivity | micromhos/cm | 312 5 | 1195 |
| Temperature | C | 17 25 | 21 75 |
| Rate of flow | $m^3$/second | 0 28 | 0 54 |
| Color | APHA | 3 75 | 6 25 |
| Turbidity | units | 1 75 | 2 |
| pH | -- | 8 08 | 8 25 |
| Suspended solids | ppm | 22 | 4 |
| Total solids | ppm | 226 24 | 810 13 |
| **Chemical pollutants** | | | |
| BOD | ppm O2 | 5 63 | 21 83 |
| Total hardness | ppm $CaCO_3$ | 141 75 | 361 23 |
| Calcium hardness | ppm $CaCO_3$ | 80 88 | 303 25 |
| Dissolved O2 | ppm | 5 03 | 5 13 |
| O2 Saturation | % sat | 75 8 | 92 28 |
| $CO_2$ | ppm | 5 75 | 15 75 |
| $NO_2$ | ppm | 4 5 | 3 00 |
| $NH_4$ | ppm | 0 91 | 0 62 |
| $PO_4^{3}$ | ppm | 0 53 | 0 45 |
| **Metals** | | | |
| Mn | ppm | 0 08 | 0 015 |
| Fe | ppm | 0 025 | 0 022 |
| Co | ppm | 0 005 | 0 025 |
| Ni | ppm | 0 00 | 0 015 |
| Cu | ppm | 0 02 | 0 017 |
| Ag | ppm | 0 003 | 0 1 |
| Zn | ppm | 0 05 | 0 07 |
| Cd | ppm | 0 017 | 0 02 |
| Al | ppm | 0 01 | 0 00 |
| Pb | ppm | 0 18 | 0 015 |
| As | ppm | 0 011 | 0 01 |
| F | ppm | 0 23 | 0 24 |
| Hexavalent Cr | ppm | 0 02 | 0 02 |
| Cn | ppm | 0 022 | 0 005 |

* Point 1 Middle reaches, Point 2 Lower reaches There is no indication of any specific sampling sites
Source INRENA Data compiled by the ECORIESGO Project

A 1993 OACA survey of pollution sources and concentrations in the Lurin River showed that water quality was degraded in the lower reaches of the river basin and that the physical and chemical quality of the river water was best during high-water phases (Table VIII-7)

**Table VIII-7 Pollution in the Lower Reaches of the Lurin River, 1993**

| Parameter | Maximum Measured Concentration (OACA, 1993) |
|---|---|
| pH | 8 2 |
| Electrical conductivity | 0 5 mmhos/cm |
| Turbidity | 84 units |
| Total hardness | 152 mg/l |
| Biochemical oxygen demand (BOD) | 8 0 mg/l |
| Nitrates | 4 5 mg/l |
| Phosphates | 0 0 mg/l |
| Lead | 0 03 mg/l |
| Cadmium | <0 02 mg/l |
| Zinc | 0 04 mg/l |
| Fecal coliform organisms | 990 MPN/100 ml |

In 1982, INRENA (the National Bureau of Water Resources) measured levels of the pesticides DDT, Lindane, Heptachlor, Methoxychlor and Malathion in the rivers, detecting trace amounts of DDT and Lindane in all three rivers They also found trace amounts of Malathion in the Rimac (Table VIII-8) There was no indication of the specific sampling points used in this study

**Table VIII-8 Pesticide Levels in Lima Area Rivers**

| Pesticide | Concentration in µg/l | | | |
|---|---|---|---|---|
| | Rimac River | | Chillon River | Lurin River |
| | 8/82 | 12/82 | | |
| DDT | ND | ND | 0 254 | 0 119 |
| Lindane | 0 0002 | 0 01333 | 0 055 | 0 007 |
| Heptachlor | ND | ND | 0 003 | -- |
| Methoxychlor | ND | ND | -- | -- |
| Malathion | 0 0222 | ND | -- | -- |

ND = none detected, (--) = not measured
Source ONERN

## B2 Groundwater Quality

In Lima, there are large variations in water quality between wells In low-lying areas of districts such as Callao and the Villa de Chorrillos, where the water table is high, ground water is commonly polluted by septic tanks and infiltration from the city sewerage system (PROMAR, 1996) In some areas near the sea where there have been substantial ground-water withdrawals, salt water has intruded into

the underground water-bearing stratum, causing salinization of well water In other areas, ground water is generally of good quality though frequently subject to local contamination from surface sources

In 1995, there were roughly 1,000 wells in the city of Lima, of which approximately 360 were managed by Lima's water company, SEDAPAL (see the section on drinking water) SEDAPAL regularly monitors all wells under its jurisdiction It measures 17 physical and chemical parameters, including pH, turbidity, conductivity, alkalinity, total, calcium and manganese hardness and levels of manganese, calcium, sulfates, chlorides, nitrates, sodium, potassium and dissolved solids We have no information on the quality of water supplied by the non-SEDAPAL wells in the city No thorough attempt has been made to evaluate the quality of area groundwater resources, nor are the non-SEDAPAL wells monitored on a regular basis by their managing agencies (most of which are private firms and municipal government agencies) In addition, we have no access to data on the water quality measurements made by private firms using well water in their production processes

The main sources of area groundwater pollution are industrial/residential waste water and excreta filtration and the percolation of polluted irrigation water Since there is virtually no rainfall in the Lima area and the water table is quite deep, it is generally accepted that polluted leachate from sanitary landfills or garbage dumps poses little threat to water sources In some cases, inadequate well construction and operating procedures (well casings with no sanitary engineering devices, pumps and pipes in poor condition) can allow pollutants to seep into well water

The portions of aquifers exposed to the greatest risk of pollution generally lie near sites where there is a sizeable static head (such as areas lying under ponds, ditches, sewerage lines or storage tanks for various types of liquids) or where the water table is close to the surface This occurs in certain parts of the Chillon and Rimac river valleys and at the international airport (Geake, 1985)

The parameters or pollutants that are typically most important in determining the suitability of ground water for use include

- For aesthetic concerns total dissolved solids, hardness, salinity (chlorides), iron and manganese,
- For acute health considerations contamination by fecal matter, and
- For chronic toxicity nitrates, hydrocarbons, metals, pesticides

With the exception of nitrates, most of the parameters measured by SEDAPAL are indicators of the natural quality of ground water rather than of pollution related to human activities *per se* Data from its 1995 monitoring program show that 5% of the well water samples analyzed by SEDAPAL were contaminated by fecal coliforms ("unsatisfactory" samples) (Table VIII-9) and 15 8% contained excessively high levels of salts (electrical conductivity of over 2000 mhos/cm) or nitrates ($NO_3$ > 50 mg/l) (Table VIII-10) With the water supply for 38 1% of the population of Lima furnished by groundwater resources and a total output of 254,286,000 cubic meters of well water for the year 1995,



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we can estimate that more than 272,000 residents of the Lima metropolitan area are exposed to nitrates at levels exceeding the maximum allowable concentration under Peruvian water quality standards [1]

**Table VIII-9 Bacteriological Quality of Well Water in the Lima Metropolitan Area, by District, 1995**

| District | Bacteriological Analysis | | |
|---|---|---|---|
| | Satisfactory | Unsatisfactory | Total |
| Northern District | 440 | 29 | 469 |
| Central District | 164 | 17 | 181 |
| Southern District | 68 | 0 | 68 |
| Eastern District | 491 | 16 | 507 |
| Western District | 254 | 14 | 268 |
| Callao | 175 | 8 | 183 |
| Lima Metro Area | 1592 (95%) | 84 (5%) | 1676 (100%) |

Source SEDAPAL, 1995 Statistical Yearbook

[1] According to ITINTEC standard 241-003, the maximum allowable concentration of both N and $NO_3$ is 45 mg/l However, SEDAPAL uses a value of 50 mg/l for both N and $NO_3$ to measure water quality in Lima area wells The WHO-recommended guideline for drinking water and the U S and European Union water quality standard for nitrate-N is 10 mg/l



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**Table VIII-10 Physical/chemical Quality of Well Water in the Lima Metropolitan Area, by District, 1995**

| District | Physical/Chemical Quality Conductivity <2000 mhos/cm and $NO_3$ <50 mg/l* | | |
|---|---|---|---|
| | Satisfactory | Unsatisfactory | Total |
| Northern District | 82 | 16 | 98 |
| Central District | 24 | 7 | 31 |
| Southern District | 5 | 1 | 6 |
| Eastern District | 90 | 16 | 106 |
| Western District | 44 | 6 | 50 |
| Callao | 22 | 4 | 26 |
| Lima Metro Area | 267 (84%) | 50 (16%) | 317 (100%) |

* Water samples with conductivity values at or under 2000 mhos/cm and $NO_3$ concentrations of less than or equal to 50 mg/l are considered satisfactory
Source SEDAPAL, 1995 Statistical Yearbook

Findings from well water monitoring during the first eight months of 1996 showed that 60 wells (16 7%) throughout the Lima metropolitan area had nitrate levels exceeding the standard of 45 mg/l (Table VIII-11) The average nitrate concentration for this group of wells was 73 mg/l, with individual values ranging from a low of 50 mg/l (which already exceeds the standard) to a high of 111 5 mg/l For the year 1996, the average concentration of nitrates in all SEDAPAL wells in the Lima area is estimated to be 23 mg/l, which, while well below the maximum allowable level, nevertheless exceeds expected natural levels

According to our calculations, the average production of groundwater with nitrate concentrations exceeding the water quality standard over the period from January to August 1996 was 3,684 cubic meters per month Based on this, an estimated 579,000 residents are consuming water with nitrate concentrations over 45 mg/l on a daily basis

The nitrates in Lima's groundwater come from a variety of different sources Leaks from sewer lines, percolation of irrigation water carrying nitrogenous wastes and perhaps nitrate fertilizers, and natural recharge of the water table with polluted surface water from the Rimac and Chillon rivers are all possible sources The list of possible indirect sources includes industrial discharges from fertilizer and textile plants and agroprocessing plant effluent These generally have high levels of organic nitrogenous wastes which are quickly oxidized to nitrites and nitrates under the right conditions Because Lima has no rain, leaching of nitrogenous compounds that deposit out of the atmosphere is not considered a significant pollutant source

Given the steady shrinkage in farmland within the metropolitan area, the leading source of nitrates in area groundwater resources is most likely to be waste water infiltration In cases where the pollutant source is irrigation water, nitrates will be accompanied by chemical residues from agricultural products (e g , pesticides) and possibly by pathogens of animal origin Where the source is residential sewage water, nitrates will be accompanied by pathogens of human origin

We have no recent data on levels of metals, hydrocarbons, pesticides or other organic compounds in Lima area wells Monitoring operations dating back to 1985 detected in some wells high levels of the hydrocarbons benzene, toluene and xylene (likely from leaks of liquid fuels or industrial chemicals) along with relatively high concentrations of metals (Geake, 1985, Nakamatsu, 1985) SEDAPAL has assured us that all these wells have been shut down and are undergoing repairs

**Table VIII-11 Contamination of Lima Area Wells by Nitrates (SEDAPAL, 1996)***

| District | # Wells with $NO_3$ > 45 mg/l | Output of Those Wells (1000 $m^3$/mo) | Avg Nitrate Conc ($NO_3$ > 45 mg/l) | Pop Exposed to $NO_3$ > 45 mg/l (# Individuals) |
|---|---|---|---|---|
| NORTHERN DISTRICT | 24 | 1319 | 60 65 | 207,403 |
| Carabayllo | 0 | 0 | 0 | 0 |
| Comas | 6 | 334 96 | 58 5 | 52 667 |
| Independencia | 0 | 0 | 0 | 0 |
| Los Olivos | 8 | 181 86 | 76 75 | 28 594 |
| Puente Piedra | 4 | 424 07 | 50 | 66 678 |
| Rimac | 0 | 0 | 0 | 0 |
| S M Porras | 6 | 378 19 | 57 33 | 59 464 |
| CENTRAL DISTRICT | 16 | 690 68 | 52 44 | 108 597 |
| Breña | 1 | 26 78 | 52 | 4 211 |
| Jesus Maria | -- | 0 | 0 | 0 |
| La Victoria | -- | 0 | 0 | 0 |
| Lima | 4 | 217 26 | 50 75 | 34 160 |
| Magdalena | 1 | 15 07 | 53 | 2,369 |
| Pueblo Libre | 1 | 20 58 | 53 | 3 236 |
| San Miguel | 9 | 410 99 | 53 44 | 64 621 |
| SOUTHERN DISTRICT | - | 0 | 0 | 0 |
| Lurin | -- | 0 | 0 | 0 |
| Pachacamac | - | 0 | 0 | 0 |
| S J Miraflores | - | 0 | 0 | 0 |
| V M Triunfo | -- | 0 | 0 | 0 |
| Villa Salvador | -- | 0 | 0 | 0 |
| EASTERN DISTRICT | 10 | 796 68 | 81 28 | 125 264 |
| Ate Vitarte | -- | 0 | 0 | 0 |
| El Agustino | -- | 0 | 0 | 0 |
| La Molina | 2 | 198 65 | 111 5 | 31 234 |
| Lurigancho | 3 | 188 68 | 61 3 | 29 667 |
| S J Lurigancho | 5 | 409 35 | 71 | 64 363 |
| San Luis | -- | 0 | 0 | 0 |
| Santa Anita | -- | 0 | 0 | 0 |
| WESTERN DISTRICT | 3 | 207 20 | 94 33 | 32,579 |
| Barranco | -- | 0 | 0 | 0 |
| Chorrillos | 3 | 207 20 | 94 33 | 32 579 |
| Lince | -- | 0 | 0 | 0 |
| Miraflores | - | 0 | 0 | 0 |
| San Borja | -- | 0 | 0 | 0 |
| San Isidro | - | 0 | 0 | 0 |
| Santiago de Surco | - | 0 | 0 | 0 |
| Surquillo | - | 0 | 0 | 0 |
| CALLAO | 7 | 670 09 | 76 25 | 105 360 |
| Bella Vista | -- | 0 | 0 | 0 |
| Callao | 6 | 670 09 | 80 25 | 105 360 |
| Carmen de la Legua | 1 | 0 | 72 | 0 |
| La Perla | -- | 0 | 0 | 0 |
| La Punta | - | 0 | 0 | 0 |
| NONSERVICED AREA | 0 | 0 | 0 | 0 |
| LIMA METRO AREA | 60 | 3683 72 | 72 99 | 579 203 |

* Includes only those wells under the jurisdiction of SEDAPAL

## C Water Supply in Lima

There are wide disparities in the level of water service in Lima Most residents of high-income districts such as San Isidro, Miraflores, La Molina, San Borja and Surco[2] occupy dwellings connected to piped water, the sewer system and power grids They also have access to adequate and in some cases, first-rate health care services In these districts, the average resident has treated water piped directly into the home, has a water supply of over 350 liters of water a day, consumes roughly the same quantity on a day-to-day basis and pays a water charge of 1 85 soles/$m^3$ [3] Thus, in these areas the risk of contracting a waterborne disease is relatively low

However, the situation is quite different in low-income districts of the city such as Los Olivos, San Juan de Miraflores and Villa El Salvador,[4] where health and sanitation facilities for large segments of the population are highly inadequate Residents of many "shanty town" settlements obtain their water from public standpipes or tank trucks The water is collected, carried to the home and stored in tanks, barrels or other inadequate containers by women and children Residents here consume a daily average of 20 to 70 liters per person at a monthly household cost of anywhere from 3 50 to 40 soles [5] In many cases, the water quality is suspect and the water must be boiled for periods of from 2 to 10 minutes to ensure its safety This adds to the cost of its use Over a period of one calendar year, a child under five years of age from a typical household in these districts may experience anywhere from three to nine episodes of diarrhea
associated with inadequacies in water supply and sanitation services (PROCAME, 1994)

These descriptions of typical conditions in high and low-income communities highlight existing disparities and inequities in city water services They also serve as a reminder of how access to water service affects usage and consumption patterns Although both these situations may represent extremes, they nevertheless provide a useful insight into the realities of water supply service in the city of Lima and the links between water, hygiene practices and human health

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[2] There tends to be a large concentration of high or very high income groups (7 8% of the total population) within these districts (PROMAR, 1995)

[3] SEDAPAL water and sewerage charges for 1995 (SEDAPAL Statistical Yearbook, 1995)

[4] The districts of Carabayllo, Carmen de la Legua, Cieneguilla, Comas, Independencia, Lurigancho, Lurin Pachacamac, Puente Piedra, San Juan de Lurigancho, San Martin de Porres and Villa Maria del Triunfo also have large concentrations of low-income residents (59 2% of all households) The districts of Ancón, Barranco, Bellavista, Jesus Maria, La Perla, La Punta, Lince, Magdalena, Pueblo Libre, Pucusana, Punta Hermosa, Punta Negra, San Bartolo, San Miguel, Santa Maria and Surquillo are classified as middle-income districts (33% of the population) (PROMAR, 1995)

[5] Surveys conducted in January of 1996 in the district of Pachacamac by the Environmental Advisory and Consulting Bureau (OACA)

### C1 Sources and Production

Lima gets nearly all of its drinking water from two sources (Figure VIII-1)

- The Rimac river with the city's sole water treatment plant (La Atarjea), which accounts for 61% of the city's water supply, and
- Ground water, which is tapped through 360 wells that produce 38% of the water consumed by the city

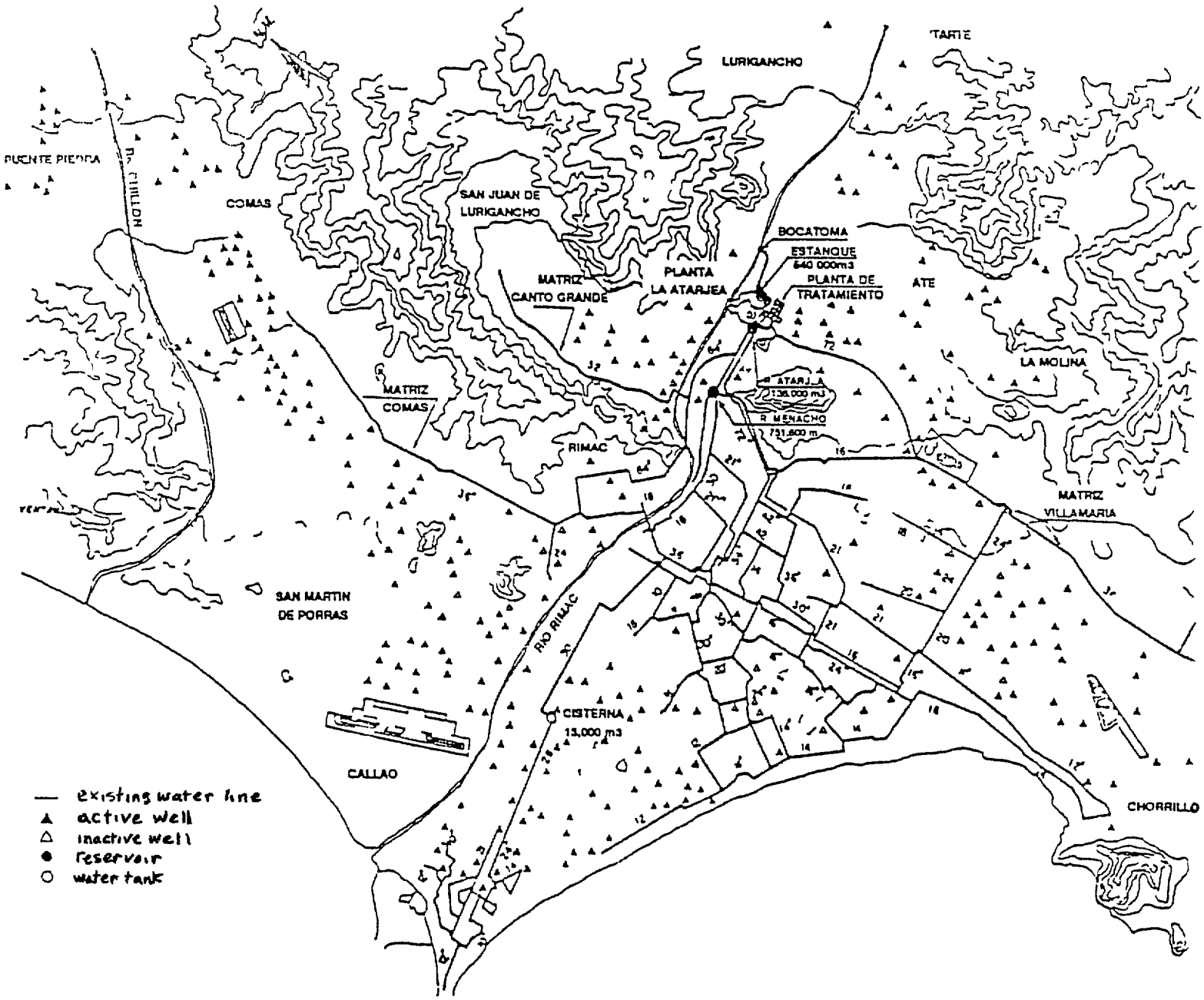
The additional amount of water produced by infiltration galleries (0 4%) is negligible

This data refers to the 75% of the population with direct house connections to the SEDAPAL water supply system There is no data available on the sources of water for the remaining 25% of the population without conventional water services It is assumed that these residents rely mainly on groundwater for their water

The city's water company, SEDAPAL is responsible for all technical and commercial aspects of the operation of the area-wide supply system This includes treatment and distribution of water

Water is withdrawn from the Rimac for the La Atarjea treatment plant at kilometer 15, where it is subject to a series of treatment processes These processes include the addition of polymers (to improve coagulation efficiency), sand filtration and prechlorination to reduce the microbiological load This is followed by the addition of aluminum sulfate and ferric chloride, which operate as coagulants, whereupon the water is filtered through a battery of rapid filters Finally, it is chlorinated with chlorine gas and pumped to storage reservoirs or pumping stations for distribution to area customers

**Figure VIII-1 Location of Sources of Drinking Water for the Lima Metropolitan Area**



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The La Atarjea water treatment plant has two treatment units and a production capacity of 20 $m^3/s$ Its average output of treated water ranges from 10 to 16 $m^3/s$ Water production peaks during the summer season (from January to April) However, the water shortage is greatest during the summer months due to increased water usage

In contrast, groundwater from all 360 wells under SEDAPAL's jurisdiction is distributed without treatment except disinfection It is assumed that water from most of the city's remaining wells, including those operated by private individuals, water marketing firms, manufacturing firms and local jurisdictions within the Lima metropolitan area, is not properly chlorinated

According to SEDAPAL, its production figure for 1995 was 666 8 million cubic meters of water This corresponds to a monthly average of 21 14 $m^3/s$ (Table VIII-12) Historical data shows a proportional increase in water production levels in line with Lima's population growth This increased production is sustained mainly by tapping increasingly large volumes of river water and constructing a growing numbers of wells (Table VIII-13) In contrast, the share of water supplied by filtration galleries has steadily declined An overreliance on wells is causing the water table to drop (see the section on groundwater) In 1995, for example, groundwater production was increased by more than 8% over the previous year This was to compensate for the drop in river levels that resulted from a drought in the central highlands

**Table VIII-12 Drinking Water Production by SEDAPAL in the Lima Area, 1995**

| Water Production | Thousand $m^3$/year | $m^3/s$ | % |
|---|---|---|---|
| Total production | 666,827 | 21 14 | 100 |
| Rimac river | 409,378 | 12 98 | 61 4 |
| Wells | 254,286 | 8 06 | 38 1 |
| Filtration galleries | 3,163 | 0 1 | 0 47 |

Source SEDAPAL, 1995 Statistical Yearbook



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**Table VIII-13 Historical SEDAPAL Water Production Data, by Type of Water Source ($m^3/s$)**

| Type of Water Source | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1955 | 1968 | 1971 | 1976 | 1983 | 1994 | 1995 |
| Plants (Rimac river) | 2 61 | 6 43 | 7 90 | 9 12 | 11 88 | 11 81 | 12 98 |
| Filtration galleries | 0 46 | 0 41 | 0 43 | 0 39 | 0 26 | 0 12 | 0 10 |
| Wells | 0 50 | 1 20 | 1 78 | 5 30 | 6 30 | 7 47 | 8 06 |
| TOTAL production | 3 56 | 8 04 | 10 10 | 14 81 | 18 45 | 19 40 | 21 14 |

1955 - Commissioning of La Atarjea I (5 $m^3/s$), 1968 - Production capacity expanded by 2 5 $m^3/s$
1971 - Callao district comes under the jurisdiction of SEDAPAL, 1976 - Plant production capacity is expanded to 10 $m^3/s$
1983 - Construction of a second plant at La Atarjea (5 $m^3/s$), 1994 - Plant 2 expanded to 10 $m^3/s$
Source SEDAPAL, 1995 Statistical Yearbook

### C2 Distribution System

Water produced by SEDAPAL is conveyed through a network of water lines consisting of large-diameter pipes (16-72" or 450mm to 2 meters) The secondary network, with smaller-diameter pipes, distributes water to individual dwelling units on a street-by-street basis The system is divided into six districts for management purposes The Northern, Central and Callao districts are served by the Northern Distribution Office, while the Southern, Eastern and Western districts are served by the Southern Distribution Office

The main problems with Lima's water distribution system include low water volume and low pressure, the dilapidated condition of its pipelines (25% of its water lines are more than 32 years old), cross connections between the water supply and sewage systems and illicit connections These problems are responsible for large water losses Water losses are estimated at somewhere between 30 and 50% of the total volume produced They are also a contributing factor to intermittent water service and water rationing and cause clean water to become contaminated in the distribution system

### C3 Supply and Demand

Studies of water supply and demand employ two basic indicators a service coverage indicator and a per capita water supply indicator Coverage is an indicator of access to a direct house connection, while supply denotes the availability of water to each inhabitant Access and availability affect water consumption and, as such, affect health

The water produced by La Atarjea is earmarked primarily for customers in the city center and surrounding areas Other districts rely on groundwater or a mixture of both sources Data compiled by



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SEDAPAL puts total water production for 1995 at an average of 21 14 $m^3/s$, corresponding to 362 52 l/d per customer served

In contrast, our study shows that each resident has a household water supply[6] of between 106 and 148 liters per day Based on a minimum daily requirement of 250 liters of water per person, this produces a shortfall of between 40% and 57% and explains the rationing in many parts of the city The average service period is 21 3 hours a day (SEDAPAL, 1994) although, service is strictly rationed in many areas The actual availability of running water ranges from four hours a month to twelve hours a day (OACA, 1996) Though production outstrips needs, the volume of water available to area customers falls short of the minimum daily requirement

**Water Demand, 1995**

| | |
|---|---|
| Total population | 6,759,244 inhabitants |
| Average supply | 250 l/per capita/day |
| Demand | 19 56 $m^3/s$ |

Source SEDAPAL Data compiled by the ECORIESGO Project

**Water Supply, 1995**

| | |
|---|---|
| Total production | 21 14 $m^3/s$ |
| Average availability | 362 52 l/customer served/day |
| | 270 29 l/total pop/day |
| Consumption | Household = 78 5% |
| | Other[a] = 21 5% |
| Total real supply [b] | 10 57-14 79 $m^3/s$ |
| Real household supply | 8 29-11 61 $m^3/s$ |
| Real household availability | 106-148 l/capita/day |

a = Commercial, industrial, government and social consumption, calculated based on billing volumes
b = Production net of losses (minus 30 to 50%)
Source SEDAPAL Data compiled by the ECORISEGO Project

According to SEDAPAL, its service coverage rate (direct connections) for 1995 was 74 56% of the capital area population, corresponding to over 4 5 million inhabitants Only 61% of the population with direct service connections actually has running water in their homes The remainder are served by shared connections (multidwelling spigots) A quarter of the Lima area population, or 1,720,000

6 Calculations of demand were based on recent statistical data compiled by SEDAPAL on the area population and on the average availability of water Calculations of real supply take into account transmission losses estimated at from 30 to 50% of total water production and nonresidential water use in quantities equivalent to 21 5% of the aggregate production figure

inhabitants, do not have direct house connections and obtain their water from public standpipes, wells or trucks or by temporarily tapping into connections to nearby dwellings (Figure VIII-2)

**Table VIII-14 Water Service Coverage Levels in Lima, 1995**

| Indicator | Number of Persons | Percentage (%) |
|---|---|---|
| Population served | 5,039,000 persons | 74 6 % |
| Unserved population | 1,720,000 persons | 25 4% |

Source SEDAPAL, 1995 Statistical Yearbook

We calculated water service coverage rates at the district and health subdistrict levels in search of useful information for an assessment of corresponding health risks Our calculations are based on household coverage rates per dwelling and average household occupancy rates broken down by district As such they are not totally consistent with the coverage data furnished by SEDAPAL

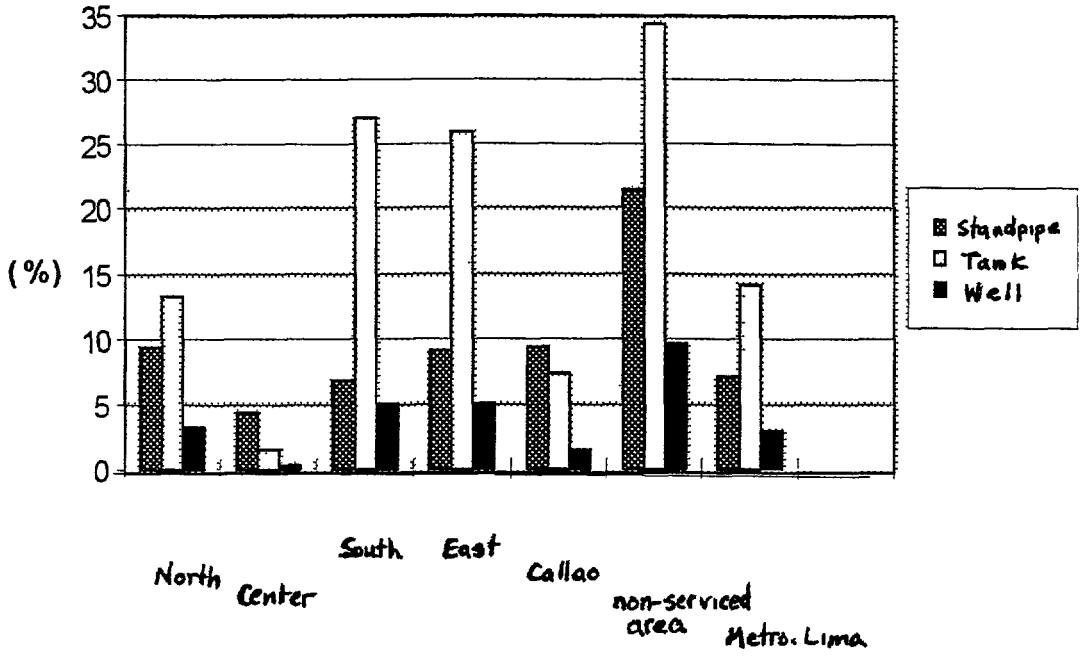
Service coverage levels vary from one part of the city to another (Table VIII-15) In general, consolidated districts in the historical central city and high-income residential districts have better service coverage than areas on the urban fringe These house low-income communities still in the process of being developed or transformed into consolidated districts

Districts with the poorest service coverage include Pachacamac (with 87% of its population still without service), Puente Piedra (72%), Lurin (70%) and districts lying outside the SEDAPAL service area (65%) [7] These districts are not an integrated part of the capital area In all cases they are developing areas with large rural populations or with a large percentage of their population living in shanty-town settlements The highest service coverage levels (> 90%) are found throughout Old Lima and Callao, as well as in Barranco, Surco and La Molina

The areas of the capital with the largest populations without direct service connections are Lima North, Lima South, Lima East, Central Lima and Callao, in that order (Table VIII-14, Figure VIII-2) The population served directly by tank trucks includes 431,700 residents of Lima North, 273,000 residents of Lima South, 128,000 residents of Lima East, 38,000 residents of Callao and 27,700 residents of Central Lima

[7] The Ventanilla district and settlement areas in the Puente Piedra district lay outside the SEDAPAL service area back in 1993

**Figure VIII-2 Sources of Water for Population Without Direct Connections**



## Table VIII-15 Water Supply in Lima, by District and Health Subdistrict, 1993

| District | Type of District | Total Population | Public Connection (%) | Stand-pipe (%) | Tank Truck (%) | Well (%) | Total without Service (%) |
|---|---|---|---|---|---|---|---|
| LIMA NORTH | | 2 262 569 | 64 53 | 10 80 | 18 59 | 6 08 | 35 47 |
| Carabayllo | URB | 106 496 | 65 75 | 7 09 | 21 38 | 5 77 | 34 25 |
| Comas | PRO | 403 619 | 80 13 | 4 39 | 12 95 | 2 53 | 19 87 |
| Independencia | PRO | 183 537 | 84 67 | 8 23 | 6 80 | 0 29 | 15 33 |
| Los Olivos | PRO | 227,768 | 56 01 | 16 07 | 27 30 | 0 61 | 43 99 |
| Puente Piedra | URB | 99 877 | 28 01 | 25 32 | 21 68 | 24 98 | 71 99 |
| Rimac | CONSOL | 184,183 | 88 43 | 5 29 | 5 80 | 0 48 | 11 57 |
| S M Porras | PRO | 379,979 | 83 19 | 8 80 | 6 50 | 1 51 | 16 81 |
| Lurigancho | PRO | 98 833 | 38 46 | 14 82 | 32 80 | 13 92 | 61 54 |
| S J Lurigancho | URB | 578 277 | 56 14 | 7 17 | 32 09 | 4 61 | 43 86 |
| CENTRAL LIMA | | 1 361 502 | 96 37 | 2 44 | 1 02 | 0 24 | 3 63 |
| Breña | CONSOL | 84,911 | 96 40 | 2 34 | 0 85 | 0 41 | 3 60 |
| Jesus Maria | RES | 62 629 | 98 76 | 0 73 | 0 36 | 0 15 | 1 24 |
| La Victoria | CONSOL | 224 575 | 91 55 | 6 17 | 1 77 | 0 50 | 8 45 |
| Surquillo | CONSOL | 87 683 | 96 01 | 2 71 | 1 08 | 0 19 | 3 99 |
| Lince | RES | 62 430 | 97 98 | 1 14 | 0 69 | 0 19 | 2 02 |
| Miraflores | RES | 87 191 | 98 54 | 0 87 | 0 47 | 0 12 | 1 46 |
| San Borja | RES | 72 656 | 97 22 | 2 75 | 0 92 | 0 03 | 2 78 |
| San Isidro | RES | 61 721 | 99 27 | 0 23 | 0 35 | 0 15 | 0 73 |
| Lima | CONSOL | 333 236 | 92 05 | 5 33 | 2 25 | 0 37 | 7 95 |
| Magdalena | CONSOL | 47,847 | 97 94 | 1 32 | 0 53 | 0 21 | 2 06 |
| Pueblo Libre | CONSOL | 73 292 | 97 75 | 1 65 | 0 43 | 0 17 | 2 25 |
| San Miguel | CONSOL | 114 717 | 92 61 | 5 07 | 1 93 | 0 39 | 7 39 |
| San Luis | CONSOL | 48 614 | 96 73 | 1 45 | 1 58 | 0 25 | 3 27 |
| LIMA SOUTH | | 1 300 480 | 61 45 | 5 36 | 25 32 | 7 88 | 38 55 |
| Barranco | RES | 40 410 | 97 31 | 1 62 | 0 99 | 0 09 | 2 69 |
| Chorrillos | CONSOL | 208 563 | 68 83 | 5 71 | 19 95 | 5 52 | 31 17 |
| Santiago de Surco | RES | 197 117 | 91 14 | 4 83 | 2 92 | 1 11 | 8 86 |
| Lurin | URB | 34 117 | 29 44 | 7 85 | 35 90 | 26 81 | 70 56 |
| Pachacamac | NONURB | 19 849 | 12 74 | 2 03 | 66 78 | 18 45 | 87 26 |
| S J Miraflores | PRO | 283 019 | 60 36 | 11 15 | 25 54 | 2 95 | 39 64 |
| V M Triunfo | PRO | 262 919 | 65 82 | 5 43 | 23 82 | 4 94 | 34 18 |
| Villa Salvador | PRO | 254 486 | 65 92 | 4 26 | 26 66 | 3 16 | 34 08 |
| LIMA EAST | | 612 551 | 69 82 | 9 28 | 17 26 | 3 65 | 30 18 |
| Ate Vitarte | PRO | 264 854 | 52 97 | 12 58 | 28 15 | 6 31 | 47 03 |
| El Agustino | PRO | 151,686 | 65 03 | 17 15 | 16 13 | 1 69 | 34 97 |
| La Molina | RES | 77 664 | 90 55 | 3 40 | 4 64 | 1 42 | 9 45 |
| Santa Anita | CONSOL | 118 347 | 70 73 | 3 98 | 20 11 | 5 19 | 29 27 |
| CALLAO | | 534 553 | 93 49 | 3 16 | 2 60 | 0 75 | 6 51 |
| BellaVista | CONSOL | 70,851 | 97 80 | 1 09 | 0 60 | 0 51 | 2 20 |
| Callao | PRO | 361 989 | 74 46 | 13 20 | 10 36 | 1 99 | 25 54 |
| Carmen de la Legua | PRO | 38,095 | 97 73 | 0 37 | 1 10 | 0 80 | 2 27 |
| La Perla | CONSOL | 58 845 | 98 15 | 0 89 | 0 59 | 0 37 | 1 85 |
| La Punta | RES | 4 773 | 99 30 | 0 26 | 0 35 | 0 09 | 0 70 |
| NONSERVICED AREA | PRO | 171 202 | 34 60 | 21 44 | 34 35 | 9 61 | 65 40 |
| LIMA METRO AREA | | 6 074 814 | 75 70 | 7 18 | 14 14 | 2 99 | 24 30 |

**NONURB** Districts lying outside the Lima metropolitan area with a large rural population large empty tracts of land and highly inadequate services
**URB** Developing districts in the process of being assimilated into the Lima metropolitan area, with what was originally a rural population living in poor urban-type settlements in makeshift dwellings, with inadequate services
**PRO** Districts in the process of being transformed into consolidated districts with the majority of their population living in settlements in upgraded single-family homes
**CONSOL** Consolidated districts or districts in the process of being transformed into consolidated districts lying in the old section of the city with a large part of their population living in slum areas
**RES** Residential areas with decent housing and adequate services

Gaps in service coverage extend beyond the residential sector, affecting businesses, government and community facilities For example, according to a 1993 INEI survey of school facilities, over 33% of all pre-primary school facilities for children under 5 or 6 years of age (who run a higher risk of contracting waterborne diseases) had absolutely no water supply or sanitation Moreover, where such facilities did exist, they were severely dilapidated

Cuts in service, low water pressure and gaps in service coverage force residents to store water both inside and outside the home This increases the likelihood of contamination The pumping of water from the distribution system into elevated storage tanks creates negative pressure in the distribution lines, resulting in the infiltration of waste water or groundwater Storage tanks constructed by residents of poor communities often lack the necessary features to ensure the water is stored under sanitary conditions (a top or lid to protect the water from dust, insects and animals, pipes and a tap through which the water can be withdrawn in a sanitary manner, a built-in cleaning mechanism, etc ) In many cases, the storage of water in inadequate containers inside the home can also be dangerous and heighten the risk of contamination

### C4 Consumption and Cost

Existing disparities in service coverage levels and available water supplies are matched by corresponding large variations in per capita daily water consumption Water consumption figures range from a high of 224 liters per person per day (JICA, 1990) down to a low of 20 liters per person per day (OACA, 1993) A 1989 survey of water consumption in Callao found that approximately 170 thousand people consumed less than 50 liters of water a day, of whom roughly 70 thousand consumed less than 26 liters a day In other words, 25% of the population was using extremely meager amounts of water (Del Agua, 1989) It is widely accepted that each person should have access to 250 liters of water a day to satisfy various needs An amount below this figure will jeopardize household cleanliness and good personal hygiene practices, thereby heightening the risk of contracting a water-related disease

There are also disparities in water costs The cost per unit of volume for a resident without a house connection is significantly higher than for a customer with a direct service connection As of

1995, water charges in Lima ranged from 0 64 soles/m$^3$ for a dwelling with a direct service connection to 9 0 soles/m$^3$ for residents purchasing water from tank trucks [8]

All area residents, including both those with and those without water service, run a risk of contracting a water-related disease Erratic or intermittent water service, gaps in service coverage, inadequate water consumption and contaminated water supplies are all exposing the population of Lima to water-related health risks

## D Drinking Water Quality

SEDAPAL monitors water quality on a daily basis, at the source, in its treatment and distribution systems (in waterlines, reservoirs, pumping lines, storage tanks), at individual house connections and at public standpipes It monitors for physical, chemical, biological and bacteriological pollutants The Environmental Health Service (DIGESA) and local health units (UTES) attached to the Ministry of Health also routinely monitor water quality, measuring chlorine concentrations and indicators of bacterial contamination

### D1 Quality of Area Water Sources

Rimac river water at the intake works for the La Atarjea treatment plant is highly polluted It contains high levels of organic matter, organic and inorganic chemicals and microorganisms Table VIII-4 presents data furnished in 1995 from SEDAPAL monitoring operations along the river and at the sampling station located at La Atarjea According to this data, levels of iron, manganese, lead, cadmium, BOD5 and coliform bacteria in the river water exceeded the maximum allowable concentrations prescribed by the General Water Act (Decree-Law 17752-69 and Executive Order 007-83 SA) for water used as a source of residential water supplies subject to a combination of treatment processes (Class II water)

There are wide variations in groundwater quality from one well to another The most important water quality criteria for groundwater resources from the public health standpoint (for which we have access to data) are the levels of coliform organisms and nitrates

A more in-depth discussion of the quality of groundwater resources and Rimac river water can be found in sections of the report dealing specifically with each of these water sources

### D2 Water Quality in the Distribution System

The treatment processes at the La Atarjea plant produce water that meets the legally prescribed standards for drinking water quality (Table VIII-16) The treatment significantly reduces pollution

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[8] Surveys conducted by the OACA in January of 1996

## Table VIII-16 Quality of Treated Water from SEDAPAL's La Atarjea Plant, 1995

| Parameter | Unit | Max Conc | Min Conc | Avg Conc | ITINTEC Std 214-003 |
|---|---|---|---|---|---|
| **Physical pollutants** | | | | | |
| pH | pH units | 7 940 | 7 300 | 7 56 | 6 5-8 5 |
| Conductivity | mmhos/cm | 678 000 | 387 000 | 521 000 | n s |
| Color | Pt/Co units | 1 00 | 1 00 | 1 00 | 1 00 |
| Temperature | C | 23 00 | 19 00 | 20 00 | n s |
| Total solids | mg/l | 544 00 | 342 00 | 450 00 | n s |
| Dissolved solids | mg/l | 522 00 | 331 00 | 433 00 | 1000 00 |
| Suspended solids | mg/l | 60 00 | 4 00 | 16 90 | n s |
| **Inorganic chemicals** | | | | | |
| Total alkalinity | mg/l ($CaCO_3$) | 126 000 | 84 000 | 101 000 | n s |
| Total hardness | mg/l ($CaCO_3$) | 302 000 | 196 000 | 265 000 | n s |
| Calcium hardness | mg/l ($CaCO_3$) | 266 000 | 178 000 | 233 000 | n s |
| Chlorides | mg/l (C11-) | 29 900 | 15 400 | 23 630 | 600 000 |
| Sulfates | mg/l ($SO_4$-2) | 219 000 | 123 000 | 174 000 | 400 000 |
| Nitrates | " | 5 000 | 2 470 | 3 614 | 45 000 |
| Nitrites | " | 0 037 | <0 001 | 0 005 | n s |
| Ammonia | " | 0 066 | 0 001 | 0 008 | n s |
| Dissolved oxygen | " | 9 1 | 6 4 | 7 592 | n s |
| COD | " | 46 900 | 0 190 | 7 850 | n s |
| Phosphates | " | 0 233 | <0 001 | 0 032 | n s |
| Silica | " | 16 950 | 6 000 | 14 005 | n s |
| **Organic chemicals** | | | | | |
| Total carbon | mg/l | 27 67 | 20 43 | 24 93 | n s |
| Organic carbon | " | 2 740 | 0 100 | 1 42 | n s |
| Inorganic carbon | " | 26 68 | 18 69 | 23 49 | n s |
| Trihalomethanes | µg/l | 71 65 | 7 15 | 24 14 | 100 000 |
| Chloroform | " | 27 58 | 2 82 | 9 24 | 30 000 |
| Dichlorobromomethane | " | 28 00 | 2 98 | 9 41 | n s |
| Dibromochloromethane | " | 21 15 | 0 970 | 4 95 | n s |
| Bromoform | " | 3 190 | 0 000 | 0 55 | n s |
| **Metals** | | | | | |
| Iron Fe 3+ | mg/l | 0 126 | 0 005 | 0 043 | 0 300 |
| Manganese Mn 2+ | " | 0 025 | 0 002 | 0 008 | 0 100 |
| Lead Pb 2+ | " | 0 039 | <0 005 | 0 001 | 0 050 |
| Cadmium Cd 2+ | " | 0 004 | <0 0005 | 0 002 | 0 005 |
| Chromium Cr 6+ | ' | 0 002 | <0 005 | <0 020 | 0 050 |
| Zinc Zn 2+ | ' | 0 247 | 0 040 | 0 12 | 5 000 |
| Copper Cu 2+ | " | 0 023 | 0 002 | 0 011 | 1 000 |
| Aluminum Al 3+ | ' | 0 274 | 0 024 | 0 067 | 0 200 |
| Sodium Na 1+ | | 23 640 | 7 840 | 15 721 | n s |
| Potassium K 1+ | | 5 850 | 1 890 | 2 816 | n s |
| **Nonmetals** | | | | | |
| Arsenic As 3+ | mg/l | 0 031 | 0 001 | 0 008 | 0 050 |
| Boron B 1+ | " | 0 070 | 0 002 | 0 017 | n s |
| Cyanide CN 1+ | " | <0 005 | <0 005 | <0 005 | 0 100 |
| Fluoride F 1+ | " | 0 445 | 0 170 | 0 237 | 1 500 |

levels, efficiently removing suspended solids, nitrites, ammonia, phosphates and chemical oxygen demand, reducing metal concentrations and eliminating bacteria Statistical data compiled by SEDAPAL attest to the plant's efficient removal of metals as well as nonmetallic substances by factors of 10 to 100

SEPADAL does not measure levels of organic compounds, such as the hydrocarbons, benzene, toluene or xylene According to existing data, concentrations of pesticides in water produced by the treatment plant are either nonexistent or undetectable (SEDAPAL, personal communication)

All of this drinking water data reflects the quality of finished water as it is produced by the treatment plant We obtained no data on the levels of potential pollutants further on in the distribution system or at the customer's tap Absent data from the distribution system, it is generally assumed that the concentrations of pollutants there are comparable to those in water discharged by the treatment plant As discussed in the section on health risks associated with water quality, however, the concentrations of three sorts of contaminants may increase in the distribution system

- Lead and copper may leach into drinking water from distribution and plumbing pipes and fittings,

- Trihalomethane concentrations may increase due to reactions between residual chlorine and organic matter in the distribution system, and

- Any contaminants (pathogens are of particular concern) may enter the distribution system through cross-connections with sewers or cracks in pipes in areas where pressure is inadequate

Sufficient chlorine is added to water produced by the treatment plant and wells to give the residual chlorine content necessary for disinfection throughout the distribution system Customer tap water should have a minimum chlorine content of from 0 4 to 0 6 mg/l to ensure its bacteriological quality The residual chlorine level should not exceed 1 0 mg/l, above which it would give the water a bad taste and could raise concentrations of trihalomethanes (formed by the reaction between chlorine and organic matter)

Data from 1995 monitoring in the distribution system showed that 0 4% of the water samples deriving from La Atarjea had a residual chlorine content below recommended levels, while 4 1% of the samples deriving from wells showed insufficient chlorine (Table VIII-17) The greater frequency of inadequate chlorine residual in samples from wells could be attributable to inconsistencies in the amount of disinfectant added to wells The responsibility for them is shared by the large number of SEDAPAL technicians It could also be attributable to relatively larger quantities of organic matter in ground water that will continue to react with the chlorine in the distribution system until it reduces the residual chlorine content to zero A third cause may be greater infiltration of sewage water in areas relying on well water

According to 1995 SEDAPAL monitoring program data, the total percentage of water samples with an unsatisfactory chlorine content was 2 1% for the Lima metropolitan area as a whole At the other end of the scale, chlorine concentrations in 23 3% of the samples analyzed showed chlorine levels of over 1 0 mg/l (SEDAPAL, 1995) (Table VIII-18)

**Table VIII-17 Chlorination Efficiency, Lima Metropolitan Area Water Distribution System, 1995**

| District | Chlorination | | |
|---|---|---|---|
| | Satisfactory | Unsatisfactory | Total |
| Northern District | 2,766 | 98 | 2,864 |
| Central District | 1,773 | 20 | 1,793 |
| Southern District | 997 | 12 | 1,009 |
| Eastern District | 2,023 | 65 | 2,088 |
| Western District | 2,102 | 18 | 2,120 |
| Callao | 1,221 | 15 | 1,236 |
| Surface water | 6,159 (99 6%) | 25 (0 4%) | 6,184 (100%) |
| Groundwater | 4,723 (95 9%) | 203 (4 1%) | 4,926 (100%) |
| Total for Lima metropolitan area | 10,882 (97 9%) | 228 (2 1%) | 11,110 (100%) |

Source SEDAPAL, 1995 Statistical Yearbook

**Table VIII-18 Chlorination Efficiency in the Distribution System, 1995**

| Chlorine Concentrations | Number of Samples |
|---|---|
| 0 0-0 4 mg/l | 228 (2 05%) |
| 0 5-0 7 mg/l | 1622 (14 60%) |
| 0 8-1 0 mg/l | 6667 (60 00%) |
| > 1 0 mg/l | 2593 (23 33%) |
| TOTAL | 11,110 (100%) |

Source SEDAPAL, 1995 Statistical Yearbook

Chlorine added in the treatment process (prechlorination and final chlorination) combines with organic materials in the water to raise the concentrations of trihalomethanes (chloroform, bromoform, dibromochloromethane and dichlorobromomethane) in drinking water Finished water as discharged by the treatment plant showed an average trihalomethane level of 24 1 µg/l, ranging from 71 6 µg/l to



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7 2 µg/l There is no data available on the levels of these compounds in the distribution system, but they can be expected to rise as the chlorine continues to react with organic matter present in the water supply

Surveys conducted by the Ministry of Health suggest that residents without direct service connections are more exposed to microbiological pollutants in their water supplies than those with direct connections According to 1996 data on 37 water pumps supplying 303 tank trucks in the metropolitan area's Northern, Southern and Eastern "Cones," nearly 31% of all water samples showed evidence of fecal coliform (Table VIII-19) A 1995 health surveillance program targeting 139 tank trucks in Lima East found only 55% supplying water fit for human consumption In addition, a 1993 inspection program for household water storage facilities in Lima South found 43% of water samples contaminated by fecal matter (>1 MPN/100 ml)

**Table VIII-19 Water Quality at Pumps, Lima Metropolitan Area, 1996 (Ministry of Health)**

| Location | # of Pumps | # of Trucks | Percentage (%) Operated by | | | | Samples containing fecal coliforms (unfit samples) |
|---|---|---|---|---|---|---|---|
| | | | SEDAPAL | Local Govts | Private | N A | |
| Southern Cone | 23 | 83 | 4 35 | 17 39 | 65 22 | 13 04 | 22% |
| Northern Cone | 10 | 173 | 20 | 40 | 40 | - | 20% |
| Eastern Cone | 4 | 47 | 25 | 25 | 25 | 25 | 50% |

Source DIGESA

The fluoride content of public water supplies is also a public health issue It is thought by some that public water supplies should have fluoride levels of approximately 0 9 mg/l in order to prevent tooth decay There is, however, some debate in developed countries over the mass application of medical interventions through the water supply Concentrations exceeding 1 6 mg/l have been associated with fluorosis, while fluoride levels above 4 mg/l may cause skeletal deformities and pain in the joints

Measurements of fluoride levels in Lima area water supplies found an average concentration of 0 18 mg/l in all Lima and Callao The highest concentrations were in groundwater and in the city's northern districts (concentrations as high as 0 36 mg/l) (Villena, 1987) SEDAPAL data on fluoride levels in water discharged by the treatment plant show average, maximum and minimum concentrations of 0 237 mg/l, 0 445 mg/l and 0 17 mg/l, respectively These findings suggest the need for a fluoridation program for water, salt or food supplies to increase the daily intake of this element

## E Conclusions

The quantity and quality of drinking water in the Lima area is adversely affected by the following problems

- Increasing demand caused by steady population growth (currently estimated at 2 4% a year), corresponding to 450 new residents a day,

- Large fluctuations in the level of the Rimac, the city's main water source It can fall to half its high water level during the low water phase This makes it necessary to increase ground-water pumping or to cut the public water supply through rationed water services,

- The steady drop in the level of the ground-water table as a result of the increased pumping and reduced recharge (exacerbated by the lack of precipitation and the steady loss of farmland and greenbelt areas),

- The multiple uses of water resources, causing water shortages and pollution Agricultural activities, industries, mining operations, power plants and public water supplies are all dependent on the same water source,

- The increasingly dilapidated state of the distribution system infrastructure, and

- Inequities in service coverage and service delivery

Under these circumstances, the entire population runs a risk of contracting a waterborne disease Erratic or intermittent water service, gaps in service coverage, inadequate water consumption and contaminated water supplies are all exposing the Lima area population to water-related health risks

### E1 Health Risks Caused by Water Pollution

The Lima area population is exposed to health risks through a variety of water-related pathways

- the consumption of drinking water drawn from the Rimac river and treated by SEDAPAL,

- the consumption of drinking water from wells managed by SEDAPAL,

- the consumption of ground water from wells outside the jurisdiction of SEDAPAL,

- the use of untreated surface water from the three rivers flowing through Lima, including human ingestion,

- the consumption of foods irrigated, washed or prepared with contaminated water or of fish and shellfish from polluted waters,

- contact with polluted river or seawater through bathing or recreational activities, and

- limited access to water for those population without direct house connections or with erratic water service



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The following sections examine the risks associated with each of these pathways in an attempt to identify the number of persons exposed via each pathway, the magnitude of the risks facing affected individuals, and the overall risk posed to the Lima population

**E2 Risks Associated with Drinking Water Quality**

The health risks caused by the pollution of Lima's water supplies were assessed by analyzing data on water quality Water quality data were collected reflecting surface and ground water sources, treated water and the formal (water lines), informal (tank trucks) and private (storage tanks) water distribution systems There was virtually no quantitative data available portraying water quality in the distribution systems, so we describe qualitatively how risks are likely to be affected by conditions in the water distribution systems

SEDAPAL data (1995) on water production and water quality showed the Rimac as the source of 61 4% of the city-wide water supply, with area wells furnishing 38 1% and filtration galleries accounting for 0 5% Service coverage rates supplied by SEDAPAL showed 74 6% of the population connected to the water supply system

Where sufficient data is available on contaminant concentrations in drinking water, quantitative risk analysis proceeded in several steps We calculated the daily dose of each drinking water contaminant ingested by a typical Lima resident by multiplying the amount of water ingested each day (assumed as 2 2 liters/day/capita) by the concentration of each contaminant in the drinking water We then expressed this volumetric dose per day on a per unit of body weight basis by dividing by an average adult body weight of 62 kg Finally, we consulted a health effects data base (the USEPA Integrated Risk Information System -- IRIS) to determine what health impacts might be expected from long-term exposure to the contaminant at this dose level

To evaluate the likelihood that a contaminant in drinking water might cause a non-cancer health effect, we calculated a hazard index comparing the estimated dose through drinking water with the reference dose for oral exposure to that substance given in IRIS [9] The reference dose (RfD) is the estimated level of daily human exposure to a given substance which, over the course of a lifetime, is considered to pose no health risks The RfD is established in a conservative manner -- it includes a margin of safety and is intended to be protective of particularly sensitive individuals It is thus likely that lifetime exposure to a pollutant at or below the reference dose is safe, while exposure at above the RfD is not necessarily unsafe

[9] Hazard index = actual dose/reference dose

Health risks posed by carcinogenic substances were assessed using the dose-response relationship established by the USEPA for each specific carcinogen and the estimated daily dose of that carcinogen

Our health risk calculations are summarized in Tables VIII-20 through VIII-25 for all substances for which both monitoring data and dose-response relationships from the USEPA are available We computed both lifetime risks to a typical individual in Lima and aggregate risks to the total population of the Lima area over a one-year period This was based on a total population figure of 6,706,000 inhabitants for the year 1995 (INEI, 1995)

Risks associated with microbiological contamination of drinking water supplies were assessed based on an examination of the literature on factors affecting the incidence of waterborne diseases in the Lima metropolitan area

### E3 Health Risks From Surface Water Pollution

Given its multiple uses, polluted surface water in the Lima area poses a public health risk These bodies of water are not only used as sources of drinking water, but are used in industrial manufacturing processes, in the irrigation of food crops and the pursuit of recreational activities All three area rivers empty into the Lima-Callao bay and contribute to its continuing degradation

There is virtually no consumption of raw water drawn directly from rivers, therefore the leading direct pathway of exposure is contact by riverside dwellers who use river water to wash their clothing and eating utensils Despite high levels of pollution, the Rimac, Chillon and Lurin rivers are used for recreational activities by nearby residents and by some tourists The problems associated with this pathway of exposure are mainly microbiological Although there are no figures on the size of the population at risk, it is assumed to be a small segment of the population

There are numerous indirect pathways of exposure to polluted surface water

The Rimac is the main source of drinking water for the capital area Its waters are subject to a complex series of treatment processes, but the treatment leaves low levels of pollutants in the water which are then ingested by the local population Of the 4 5 million residents with direct drinking water connections, in 1995 61% (over 2 7 million) were supplied with treated Rimac river water This percentage will vary according to seasonal fluctuations in the level of the river The leading non-microbiological pollutants are heavy metals and trihalomethanes

Considering its important role in recharging ground water, river water represents a potentially significant source of ground-water pollution This is particularly so in areas where the water table is high The leading pollutants in this case tend to be nitrates, metals and pesticides On the whole, though, surface water is probably a lesser source of ground-water pollution in the Lima area Ground-water pollution results mainly from infiltration of irrigation and waste water (see the section on health risks caused by groundwater pollution)

Water from area rivers is intercepted and diverted to agricultural areas at various points The irrigation of croplands with polluted surface water poses health risks, both to farm workers and their families, and to consumers of products irrigated with waste water (see the section on the contamination of food supplies) In turn, the irrigation water can percolate into the water table, polluting groundwater

Among these indirect pathways for exposure to polluted surface water, we can begin to quantify risks only for drinking treated water withdrawn from the Rimac Risks from this pathway do not appear to be substantial

**Risks posed by chemicals present in drinking water drawn from the Rimac river**

Despite effective treatment by SEDAPAL, the drinking water consumed by Lima area residents contains low levels of organic and inorganic compounds, salts, metals and nonmetals Concentrations of all such substances are in keeping with tolerance limits established under Peruvian legislation (ITINTEC standard 214-004) While these concentrations may be low, Lima residents are nevertheless ingesting a certain minimal level of these compounds on a daily basis and health risks may result

The following paragraphs examine the risks associated with each specific type of pollutant

**Risks posed by metals**

Data are available on the concentrations of iron, manganese, lead, cadmium, chromium, zinc, copper and aluminum in the treated water from La Atarjea as it is fed into the distribution system With the exception of aluminum, the maximum and average concentrations of all these elements are in keeping with the water quality criteria established in ITINTEC standard 214-002 and therefore are considered safe From time to time, maximum aluminum concentrations may exceed the legally established 0 2 mg/l standard, but this will not pose a health risk

Although data on the chemical quality of customer tap water is lacking, we can assume that concentrations of most metals are acceptable Some metals such as lead and copper can leach out of distribution and plumbing pipes and fixtures, resulting in higher concentrations at the tap than existed immediately subsequent to the water treatment plant Concentrations of some elements can be affected by the household handling of drinking water For example, the practice of boiling drinking water, which is recommended to eliminate the risk of contamination by bacteria, precipitates certain salts and metals and induces volatilization of certain organic compounds, thus removing them

There is no quantitative data available with which to calculate increases or reductions in chemical concentrations during the distribution process Our assessment necessarily assumes that the quality of water at the tap is comparable to that of the water discharged by the treatment plant Table VIII-20 presents data on daily doses and risks for all the aforementioned metals No noncancerous health effects are expected, as for each metal the daily dose is well below the corresponding reference

dose No carcinogenic effects are expected because there is no evidence that any of these metals are carcinogenic through ingestion

**Risks posed by nonmetallic substances**

Of the nonmetals present in Lima water supplies, only arsenic is a carcinogen, however, given its low concentrations, the calculated risk is very low (20 8 additional cases of cancer per year among the entire population of Lima) The concentrations and daily doses for all other substances are well below corresponding reference doses These substances are not expected to have any noncancerous effects on human health (Table VIII-21)

**Risks posed by organic substances (disinfection byproducts)**

Both the source water for the La Atarjea treatment plant and the treated water contain some trihalomethanes SEDAPAL routinely measures total trihalomethanes and the constituent compounds chloroform, dichlorobromomethane, dibromochloromethane and bromoform The average concentration of each of these compounds following water treatment is below the legally prescribed tolerance limit Chlorine added in the disinfection process however, continues to react throughout the distribution system with any organic matter present in the water The concentrations of trihalomethanes to which customers are actually exposed at the tap are probably slightly higher than those represented by monitoring data obtained at the treatment plant

In the absence of data on trihalomethane concentrations in water lines or tap water, our risk assessments assume that the concentrations described by SEDAPAL represent actual human exposure levels

A comparison of reference and actual doses shows that Lima area residents are exposed to low concentrations of the trihalomethanes, with a daily intake much lower than the reference dose and thus no noncancerous effects expected Three of the trihalomethanes have been found to be carcinogenic in animal experiments and may pose aggregate cancer risks totaling less than 2 cases per year among the entire population (See Table VIII-22)

**Risks posed by nitrates and nitrites**

Calculations based on the levels of nitrates and nitrites in drinking water from the Rimac river suggest that the presence of these substances poses no risk (Table VIII-23)

**E4 Health Risks Caused by Groundwater Pollution**

Ground water is becoming an increasingly important source of drinking water in the Lima area The leading pathway of exposure is ingestion A second, probably less important pathway for health risks is the use of polluted well water for irrigation of food crops



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The health risks associated with the direct ingestion of groundwater are due primarily to pathogens Nitrates pose additional risks but at a much lower level This section of the report takes a closer look at the risks posed by the presence of nitrates and other related pollutants The health effects of microbiological water pollution are discussed at length in the section on health risks associated with drinking water quality Likewise, public health problems associated with the consumption of crops irrigated with polluted irrigation water are examined in the section dealing with the contamination of food supplies

Calculations of health risks caused by nitrates in groundwater are based on average nitrate levels found in wells in 1995, as published by SEDAPAL in its Statistical Yearbook We also used data on well water production and nitrate levels for the first eight months of 1996 In light of the heightened concerns for infants under six months old, we developed separate risk assessments for two segments of the Lima area population for adults, based on an average body weight of 62 kg and a daily water consumption figure of 2 2 liters, and for infants (children from 0 to 6 months of age) weighing up to 4 kg and consuming an average of one liter of water a day in their formula

We calculated the size of the two populations at risk from nitrates as follows

- Adults We assumed that 38 1% of Lima area residents with direct SEDAPAL service connections are supplied with drinking water from area wells, resulting in 1,905,096 residents exposed to nitrates in well water

- Infants The infants at risk are those that are bottle-fed with formula made from well water We estimate their number as follows Among the 1 9 million residents served by SEDAPAL well water, about 1 % are likely to be infants between zero and six months of age [10] Among these infants, we assume that 30 - 50 % are likely to be bottle-fed with formula This puts the size of the total at-risk child population at somewhere between 5,700 and 9,600 infants

Table VIII-24 shows the results of risk calculations for these populations potentially exposed to nitrates in well water At the average concentrations observed across all SEDAPAL wells, adults appear to be exposed at levels less than the Reference Dose, while bottle-fed infants are exposed at levels nearly 5 times higher than the Reference Dose Adults and infants in areas where wells show higher nitrate concentrations (using either 1995 or 1996 SEDAPAL data for the more contaminated wells) are exposed at levels consistently exceeding the Reference Dose

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[10] 12 6 % of the population of Lima and Callao is between zero and 5 years of age A breakdown of the Peruvian child population under five years old into different age groups puts 16% under one year of age We are assuming that 50% of this group is under the age of six months Thus infants from zero to six months of age might constitute 126 x 16 x 5 = about 1 % of the total population

Although these figures might appear to suggest widespread risks from nitrates in well water, further investigation into the health effect that the Reference Dose is established to protect against suggests that risks are minimal

Nitrates may cause a rare disease affecting bottle-fed infants known as methemoglobinemia or "well water cyanosis " The role played by nitrates in this disease depends on their reduction to nitrite by intestinal microflora Nitrites then oxidize the ferrous ion in hemoglobin to the ferric state, making it incapable of carrying oxygen through the blood stream Body tissues then become oxygen-starved The condition is reversible, but if it goes too far, brain injury or death can result Infants under six months of age are susceptible to this disorder as a result of, among other factors, their low stomach acidity Diarrhea, which is associated with an increase in gastric pH and the increased nitrate reduction by natural intestinal flora, predisposes infants to methemoglobinemia Thus, the risk of cyanosis is heightened by the presence of microbiological pollution associated with high concentrations of nitrates Because this rare condition is only associated with highly contaminated water it is thought that the microbiota are in fact the limiting factor

The practice of boiling water for formula may have two effects on the likelihood of cyanosis First, boiling concentrates nitrates in the remaining water In one case of cyanosis in the UK approximately 50 years ago, the water used in preparing formula had been boiled repeatedly for long periods of time Nitrate concentrations were not surprisingly much higher than in water taken directly from the water source (Packham, 1992) On the other hand, boiling water will, of course, normally remove the bacteria in the water that might cause diarrhea, thus reducing the risk

USEPA and WHO water quality standards for nitrates and their corresponding reference doses were established to protect the most sensitive group -- infants The prescribed 10 mg/l standard (determined as nitrogen) for drinking water is intended to protect infants, with a margin of safety for them For adults, the effective result is a very substantial margin of safety Adults can likely be exposed to nitrate concentrations far exceeding the water quality standard without any ill effects ensuing According to the USEPA, virtually all cases of methemoglobinemia are associated with exposure to nitrate levels above 20 mg/l Reported cases of this disease at concentrations of between 11 and 20 mg/l are generally associated with exposure to water containing a combination of nitrates and microbiological pollutants or to excessively high levels of nitrates from other sources

Even with exposures to nitrates at far above the 10 mg/l standard, occurrence of methemoglobinemia is rare There has never been a single reported case of methemoglobinemia among the infant population of Lima

Monitoring data on SEDAPAL's wells shows an average nitrate concentration of slightly less than 30 mg/l We estimate that 5,700 to 9,700 bottle-fed infants are exposed to nitrates at this average level Among them are perhaps 900 to 1,500 infants who are exposed to nitrate concentrations well above recommended levels (> 50 mg/l) Because methemoglobinemia is so very rare, no dose-response relationship has been established, even for high exposures such as among this group There is very little likelihood of actually contracting methemoglobinemia We expect that the number of infants

contracting this disease will represents only a small fraction of the at-risk population Any potential risk is greater among children in low and very low-income households (representing 50-60% of the population), who are exposed to water with a combination of high nitrate concentrations and bacterial pollutants

In the absence of data on water quality in wells managed by individuals, private enterprises or local jurisdictions, our calculations for these sources are based exclusively on water quality data furnished by SEDAPAL Assuming that the source of the water consumed by most Lima area residents without direct service connections (who represent 25 4% of the metropolitan area population) is ground water, and extrapolating the water quality data for SEDAPAL-managed wells, this would increase the size of the at-risk population by an additional 5,000 to 8,600 infants

The presence of nitrates in well water is indicates that pollution from human activity on the land surface has reached underground aquifers Other pollutants from this activity are likely to accompany the nitrates Where the pollution source is agriculture, we can expect to find pathogens of animal origin and pesticides in the ground water along with the nitrates Where the pollution source is residential sewage water, the nitrates will be accompanied by pathogens of human origin High levels of nitrates in well water suggests that high levels of these other pollutants may be present also

SEDAPAL, however, systematically monitors and chlorinates its wells to protect against pathogens In 1995, only 5 % of SEDAPAL's routine samples of well water failed to meet bacteriological water quality standards In our opinion, microbiological pollutants in drinking water supplied by SEDAPAL from ground water do not present a major health risk

We have no information on the quality of water from the other 640 wells in the Lima area These are managed by various agencies, firms and individuals Nor do we have any information on the uses for these wells or the conditions under which they are operated and maintained Given the expected poor operation of many of these wells and the absence of effective water quality control and surveillance programs, it is assumed that a much higher percentage of these wells is contaminated by fecal matter than SEDAPAL-operated wells The number of affected wells is thought to be considerable It should be noted, though, that there is a greater likelihood of microbial contamination of drinking water during its distribution or its handling in the home The risk factors associated with these pathways of exposure are much greater (see the section on health risks caused by inadequate water service coverage and intermittent service)

In light of all these factors, we estimate that with the exception of private wells, the health risks associated with ground-water pollution are comparatively moderate

**Risks posed by chorine**

The introduction of chlorine into drinking water supplies arguably has been the most important public health measure ever carried out This chemical in water has saved untold millions of lives over the last 150 years Chlorine is the major disinfection agent used in Lima's public water supply

In general, the desirable concentration of chlorine in customer tap water is 0 5-0 7 mg/l SEDAPAL must add more chlorine than this at the treatment locations (La Atarjea and wells) in order to maintain a satisfactory minimum chlorine residual at all points in the distribution system The result is higher than desirable residual chlorine concentrations at points in the distribution system near the treatment locations SEDAPAL's measurements throughout the distribution system show 23% of the water samples drawn from area water lines contain chlorine concentrations above 1 mg/l

In light of some public concern over high concentrations of chlorine in the water system, we decided to study the noncancerous risks associated with the presence of this substance We assumed that the same proportion of customer tap water had "high" chlorine levels (exceeding 1 mg/l) as was found in SEDAPAL's sampling in the distribution system This assumption will overestimate the problem Chlorine is used up in the distribution system and large segments of the population boil, filter or store their water, which also removes this chemical from water

The findings from our study indicate that there is no risk to the general population (Table VIII-25) While the high residual chlorine content of Lima area water supplies may alter the water's organoleptic characteristics, it also operates as a sorely needed and very effective barrier against bacterial contamination Health-based concerns over the presence of chlorine in drinking water supplies should be directed at

- The formation of potentially toxic and carcinogenic compounds such as trihalomethanes or chloramines We have found the risks from trihalomethanes in Lima's drinking water to be low

- Adverse health effects from the chlorine itself, which will not begin to occur until residual chlorine concentrations above about 4 0 mg/l Such levels do not appear to be reached in Lima

Concerns about the safety of chlorine levels in Lima thus appear to be unfounded The population should not be encouraged to worry about the undeniably beneficial use of this very effective disinfecting agent

## Table VIII-20 Calculation of Health Risks From Metals in Drinking Water

| Pollutant | Concentration (mg/l) | Daily Consumption (l) | Daily Intake (mg/day) | Dose (mg/kg/day) | Ref Dose (mg/kg/day) | Hazard Index (HI) |
|---|---|---|---|---|---|---|
| Aluminum* | 0 06 | 2 2 | 0 132 | 2 1E-03 | NA | NA |
| Cadmium | 0 002 | 2 2 | 0 0044 | 7 1E 05 | 5E 04 | 0 142 |
| Copper | 0 011 | 2 2 | 0 0242 | 3 9E 04 | 3 7E 02 | 1 1E 02 |
| Hexavalent chromium | <0 002 | 2 2 | 0 0044 | 7 1E-05 | 5E-03 | 0 0142 |
| Iron* | 0 043 | 2 2 | 0 0946 | 1 5E-03 | NA | NA |
| Manganese** | 0 008 | 2 2 | 0 0176 | 2 8E-04 | 0 42** | 6 7E 04 |
| Lead | 0 001 | 2 2 | 0 0022 | 3 6E 05 | 1 4E 03 | 2 6E-02 |
| Zinc | 0 12 | 2 2 | 0 264 | 4 3E-03 | 3E 01 | 0 0143 |

* Aluminum and iron are not of concern from a public health standpoint High concentrations may affect the water's organoleptic characteristics
** According to the IRIS, the RfD for manganese is 1 4E-01 in food products The adjustment factor for drinking water is 3 0

## Table VIII-21 Calculation of Health Risks From Nonmetals in Drinking Water

| Pollutant | Concentration (mg/l) | Daily Consumption (l) | Daily Intake (mg) | Dose (mg/kg/day) | Ref Dose (mg/kg/day) | Hazard Index (HI) | Cancer Potency (mg/kg/day $^{1}$) | Individual Risk | Risk to Population (cases/year) |
|---|---|---|---|---|---|---|---|---|---|
| Arsenic | 0 008 | 2 2 | 0 0176 | 2 8E-04 | 3E-04 | 0 933 | 1 5 | 4 2E-04 | 20 8 |
| Boron | 0 017 | 2 2 | 0 0374 | 6 0E 04 | NA | NA | - | | |
| Cyanide | <0 0005 | 2 2 | 0 0011 | 1 77E 05 | 2E-02 | 8 9E-04 | - | | |
| Fluoride | 0 237<br>0 170 (Villena) | 2 2 | 0 521 | 8 4E 03 | 6E 02 | 0 140 | - | | |

## Table VIII-22 Calculation of Health Risks From Trihalomethanes in Drinking Water

| Pollutant | Concentration (mg/l) | Daily Consumption (l) | Daily Intake (mg) | Dose (mg/kg/day) | Ref Dose (mg/kg/day) | Hazard Index (HI) | Cancer Potency (mg/kg/day $^{1}$) | Individual Risk | Risk to Population (cases/year) |
|---|---|---|---|---|---|---|---|---|---|
| Total Trihalomethanes | 24 14 | 2 2 | 53 11 | 0 857 | NA | - | NA | - | - |
| Chloroform (Trichloromethane) | 9 24 | 2 2 | 20 33 | 0 328 | 10 | 3 28E 02 | 6 1E 03 | 2E-05 | 1 |
| Dichlorobromomethane | 9 41 | 2 2 | 20 70 | 0 334 | NA | - | NA | - | - |
| Dibromochloromethane | 4 95 | 2 2 | 10 89 | 0 176 | 20 | 8 8E-03 | 8 4E-02 | 1 5E-05 | 0 74 |
| Bromoform (Tribromomethane) | 0 55 | 2 2 | 1 21 | 0 0195 | 20 | 9 75E 4 | 7 9E 03 | 2E-07 | 0 01 |

## Table VIII-23 Calculation of Health Risks From Nitrates and Nitrites in Drinking Water

| Pollutant | Concentration (mg/l) | Population at Risk | Daily Consumption (l/day) | Intake (mg/day) | Dose (mg/kg/day) | Ref Dose (mg/kg/day) | Hazard Index (HI) |
|---|---|---|---|---|---|---|---|
| Nitrates in surface water | 3 614 (average) | 3,070,155 (61 4%) | 2 2 (adult) | 7 95 | 0 128 | 1 6 | 0 08 |
| | | 9,300-15,498 | 1 (child) | 3 614 aver | 0 90 | 1 6 | 0 56 |
| Nitrites in surface water | 0 005 | 3,070,155 (61 4%) | 2 2 (adult) | 0 011 | 1 77E-04 | 1E-01 | 1 77E-03 |
| | | 9,300-15,498 | 1 0 (child) | 0 005 | 1 25E-02 | 1E-01 | 1 25E-02 |

## Table VIII-24 Health Risks Associated with Ground-Water Pollution by Nitrates, SEDAPAL Data

| Pollutant | Concentration (mg/l) | Population at Risk | Daily Consumption (l/day) | Intake (mg/day) | Dose (mg/kg/day) | Ref Dose (mg/kg/day) | Hazard Index (HI) |
|---|---|---|---|---|---|---|---|
| Nitrates in well water | 29 98 (average for Lima area wells) | 1 905 096 (38 1%)* | 2 2 (adult) | 65 96 | 1 06 | 1 6 | 0 66 |
| | | 5 770-9 617 infants | 1 0 (child) | 29 98 | 7 5 | 1 6 | 4 68 |
| | > 50 00** (average for polluted wells, 1995) | 301,005 inhabitants (15 8%) | 2 2 (adult) | 110 | 1 77 | 1 6 | 1 11 |
| | | 912-1,520 infants | (1 (child) | 50 | 12 5 | 1 6 | 7 81 |
| | 72 99 (average for wells > 50 mg/l 1996) | 579 200 inhabitants | 2 2 (adult) | 160 58 | 2 59 | 1 6 | 1 62 |
| | | 1 754-2,924 infants | 1 0 (child) | 72 99 | 18 25 | 1 6 | 11 4 |

* 74 6 % of the population is assumed served by SEDAPAL, with 38 1% of that group being supplied with ground water

** In the absence of data furnished by SEDAPAL on the average concentration of NO3 in wells with levels of this substance exceeding 50 mg/l for the year 1995, our calculations were based on an average level of 50 mg/l

## Table VIII-25 Calculation of Health Risks Caused by Polluted Drinking Water (Chlorine)

| Pollutant | Concentration (mg/l) | Population at Risk | Daily Consumption (l/day) | Intake (mg/day) | Dose (mg/kg/day) | Ref Dose (mg/kg/day) | Hazard Index (HI) |
|---|---|---|---|---|---|---|---|
| Chlorine in water lines | 0 8-1 0 mg/l | 60% | 2 2 liters | 1 98 | 3 2E-02 | 1E-01 | 0 32 |
| | > 1 0 mg/l | 23 3% | 2 2 liters | > 2 2 | 0 0355 | 1E-01 | 0 355 |

## E5 Health Risks Associated with Inadequate Water Supply and Sanitation Services

Inadequate or unreliable water supply and sanitation services have a major impact on public health They can strongly affect the degree to which personal and household hygiene is maintained They cause fecal matter to be left in and around dwellings, fostering microbiological contamination of food and water and creating an ideal habitat for the breeding of mosquitos, flies and other vectors They facilitate the spread of diseases commonly transmitted through the fecal to oral route These diseases include gastroenteritis, cholera, typhoid fever, viral hepatitis and many more They also affect transmission of diseases associated with poor hygiene, such as trachoma and scabies All these disorders are referred to as water-related, water-washed or waterborne diseases

Analysis of risks caused by microbiological agents employs different methods from those used in evaluating risks posed by chemical pollution For chemical pollutants, we typically estimate risks by combining information on the concentration of the pollutant to which people are exposed with a dose-response function for that pollutant This approach is not practical for microbial agents, however First, given the wide fluctuations in levels of microbiological pollution over time and across samples, it is prohibitively costly to sample sufficiently often to accurately characterize the dose of microbial agents to which an individual is exposed Secondly, in most cases, generally applicable predictive dose-response formulas linking likelihood of illness to exposure have not been developed Lastly, the incidence of common waterborne diseases may also be linked to other environmental or social factors which must be taken into account in the study process According to certain studies, contaminated foods are responsible for 70% of all cases of waterborne diseases reported in developing countries

Available quantities of water, access to excreta disposal systems, the practice of good hygiene at the individual and community levels, household cleanliness, the contamination of food supplies and polluted recreational facilities are all examples of other environmental factors directly affecting the transmission of microbiological disease Other non-environmental, social factors are also extremely important, though, such as the quality of medical care, the level of immunity or susceptibility in the population (reflecting the general health status of the community, including nutrition, vaccinations, etc ), and the quality of housing Typhoid and gastroenteritis, for example, are both water-related diseases which can also be transmitted through other pathways or routes of exposure, such as poor hygiene or the consumption of contaminated foods The ultimate incidence of any such diseases is a function of a vast number of interrelating environmental and social variables

A 1990 study of the transmission factors for diarrheal diseases in a community on the outskirts of Lima found a close correlation between the incidence of diarrheal diseases and water storage methods, the nature of the facilities used for defecation, and the ingestion of soil or fecal matter by children (Yeager et al , 1991) A survey conducted in a Lima area shanty town in 1990 found sanitary conditions to be highly inadequate as measured by the daily quantity of soap and water used by community residents It concluded that the availability of water, rather than the community's awareness of the importance of good hygiene, was most important in creating these conditions Other studies found correlations between hand washing and the incidence of diarrheal diseases (Huttly et al , 1994) and

between *Helicobacter pylori*, an endemic bacteria in the Lima area (whose route of transmission has yet to be identified), the water source and the type of water storage system (Klein et al , 1991)

In 1995 the Ministry of Health reported a total of 282,014 cases of what were essentially waterborne diseases in the Lima metropolitan area A breakdown of the reported data by health subdistrict shows incidence rates for the year 1995 ranging from 31 7 per 1000 population in Central Lima to 76 1 per 1000 population in Lima East The reported incidence of waterborne diseases for the Lima metropolitan area as a whole was 42 1 per 1000 population (Ministry of Health, 1995) The Lima-East and Lima-South subdistricts, representing the areas with the lowest water supply and sanitation service coverage levels, had the highest incidence rates The following table summarizes the morbidity statistics, which are broken down by health subdistrict

**Table VIII-26 Reported Incidence of Waterborne Diseases in the Lima Metropolitan Area, by Health Subdistrict, 1995**

| Health Subdistrict | Subdistrict Population | Total Cases of Disease | Incidence (per 1000 pop ) |
|---|---|---|---|
| Lima South | 1,400,957 | 76,778 | 54 8 |
| Lima North | 2,324,470 | 65,653 | 27 8 |
| Lima East | 804,786 | 61,258 | 76 1 |
| Central Lima | 1,492,000 | 47,331 | 31 7 |
| Callao | 684,135 | 31,994 | 46 8 |
| Lima + Callao | 6,706,348 | 282,014 | 42 1 |

Source Local health unit for each subdistrict Data compiled by the ECORIESGO project

The actual incidence of these diseases is much higher than the reported statistics An incidence rate of 42 1 per 1,000 people per year implies that one person in 25 in Lima becomes sick with a waterborne illness each year This is far short of what residents of Lima would say is their typical experience Most people would say that they suffer at least one (and probably more) episode of what is probably a diarrheal food or water-related illness per year Under-reporting of these diseases is common because large numbers of cases go untreated or are treated in ways that do not result in being counted in the official statistics, which cover essentially only public clinics and hospitals (e g , the reported statistics would not count individuals treated through private clinics or physicians or those treated at home with drugs purchased through a pharmacy, etc ) A 1991-1992 survey in Metropolitan Lima by INEI of treatment for children less than five years old with diarrhea found that only 38 % were taken to or seen by a formal health care provider (hospital, clinic, dispensary, pharmacy, physician) Another INEI survey of the Department of Lima in 1995 found that only 39 % of young children with diarrhea received attention at Ministry of Health facilities

Other sources that do not rely on reporting from formal, public health facilities provide a better indication of the actual incidence of water-related or diarrheal diseases These include studies that directly observe and record family health over some period of time, or statistical surveys of individuals asking about their health status during a recent sample period Such sources have found that

- Children under 1 year of age were found to average 9 8 diarrheal episodes per year in Huascar, a poor peri-urban area on the outskirts of Lima (Black, et al , 1989) The frequency did not differ significantly by month of age

- Children under 3 years of age were found to average 8 0 diarrheal episodes per year in Canto Grande, another poor peri-urban community in Lima (Yeager, et al , 1991) The frequency changed by year from 8 7 for infants under 1, 10 2 for 1-year olds, and 6 3 for 2-year olds

- A survey covering metropolitan Lima found that 10 9 % of children under 5 years of age had had diarrhea within the previous two weeks (INEI, 1991-1992)

- Another survey of the Department of Lima found that the following percentages of children had suffered water and food-related illnesses (diarrhea, cholera, colitis, gastroenteritis, gastritis, hepatitis) within the previous 15 days age 0-4, 6 7 %, age 5-9, 1 7 %, age 10-14, 2 1 % (INEI, 1995)

Any of these illness rates, if extrapolated to Lima's entire population, would result in total incidence rates far in excess of the reported figures For example, the 1991 INEI survey found 10 9 % of young children in Metropolitan Lima to have had diarrhea in the previous two weeks prior to the survey Assuming that the individuals sampled and the time period are generally representative, we can estimate an annual rate for diarrhea among this age group by multiplying this number by 26 (the number of two-week periods in one year) This gives an estimate that, on average, a young child in Lima has 2 8 episodes of diarrhea per year This is more than 65 times higher than the officially reported rate for the population as a whole

Although comparisons across countries have limited relevance here, it is interesting to note that other countries show similar patterns of under-reporting of these sorts of illnesses The U S EPA estimates that only 4-25 % of the cases of waterborne disease in the U S are reported The U S Centers for Disease Control estimates that perhaps only 4 % of the cases of food-borne disease in the U S are reported A study in Bangkok, Thailand estimated that 10-20 % of sanitation-related diseases were reported (USAID, 1990)

For this study, we have adopted the figure from the World Health Organization, which estimated in Lima that the reported rate of diarrheal disease represented only 1-2% of the total number of cases

For risk calculations, we have applied an under-reporting rate of 98% With this, we estimate that the actual incidence rate for diarrheal diseases in Metropolitan Lima is approximately 2,100 per year

per 1,000 inhabitants in contrast to the reported rate of 42 1 per 1,000 This figure is equivalent to the average Lima citizen having 2 1 cases of diarrhea per year, for a total number of cases of more than 14 million per year

Other diseases associated with shortages of water include scabies and trachoma 5,200 cases of these diseases were reported in the Central Lima subdistrict in 1995 Data for the other subdistricts are unavailable The incidence rate for Central Lima is 3 5 per 1000 population which, extrapolated to the population of the remainder of the Lima metropolitan area, gives a total of approximately 23,500 cases The incidence rate for Central Lima, with its high service coverage levels, is likely to be lower than in other subdistricts Rates for the capital area as a whole could be even higher We have no basis for estimating the degree to which incidence of these diseases is under-reported but, as for diarrheal diseases, we expect that under-reporting is common

The Ministry of Health reports an average of 549 deaths a year attributable to water-related disease for the period from 1988 through 1992 It is unlikely that deaths would be significantly under-reported

In total then, there are probably more than 14 million cases of water-related illnesses in Lima each year The great majority of these cases are mild and transient, but the totals include some cases of serious disease and more than 500 deaths per year

It is not possible to say how many of these cases are due to each of the various environmental problems we discuss in this section contaminated surface water, contaminated ground water, inadequate water service, or inadequate sewerage In fact, nearly all of these diseases have multiple routes of transmission and multiple causes In addition to the water-related causes listed, most of these diseases are also commonly transmitted by other environmental means food contamination, vectors fostered by uncollected solid waste, indoor air pollution, etc And, a vast number of non-environmental factors are critical in causing high rates of these diseases poverty, crowded and inadequate housing, poor nutrition, low immunity, poor medical care, lack of vaccinations, poor home hygiene, limited knowledge of good sanitary practices, etc All of these factors -- water-related, non-water-related, and more broadly social -- interact jointly and simultaneously to yield the high rate of these diseases in Lima

A particular case of cholera, for example, might result when an individual drinks water that is contaminated with the pathogen Initially, then, this case might seem attributable to contaminated water However, the pathogen may be in the water supply because the water supply pipe was old and leaky and not under positive pressure, allowing the pathogens in the external environment through which the pipe passed to leak into the pipe In this sense, the case might be attributable to an inadequate water supply, where low and erratic pressure allows inflow and infiltration Furthermore, though, the pathogen may be in the environment around the water supply pipe because human fecal material from cholera-infected individuals has pooled there because of the lack of sewers that would otherwise carry it away Now the cause seems perhaps to be lack of sewers But other causes may be at work here also The case of cholera might have been avoided had the individual been healthier and better nourished, with greater

resistance and more able to tolerate the dose of pathogens that he received Or the case could have been avoided had the individual been wealthy enough to afford the fuel needed to boil the drinking water The conclusion is that multiple factors interact to cause most cases of such diseases, and as a result it is very difficult to estimate quantitatively what proportion of the cases of disease are due to any single cause

It is possible, though, to make some qualitative statements about the importance of different factors By reviewing the characteristics of each disease (e g , typical pathways, ability of the responsible agent to survive outside the host, minimum infective dose), it is possible to judge the likely relative contributions of the various environmental and non-environmental factors to transmission and persistence of the disease Alternatively, by reviewing the literature on reductions in disease incidence after a variety of health-related interventions, one can judge the relative effectiveness of measures addressing the different problems that we have been considering Below we summarize two major studies providing examples of each approach

1 Feachem et al (1981) studied many infectious and parasitic diseases and assigned them to groups having similar modes of transmission He then ranked each of several alternative control approaches (e g , improve water quality, improve domestic cleanliness, better food hygiene) according to its effectiveness in interrupting the primary mode of transmission for each disease group Feachem's chart summarizing his conclusions is presented as Table VIII-27 In general, he found that water availability and excreta disposal (toilets and sewers) are consistently more important than water quality and excreta treatment

2 Esrey at al (1985) reviewed 67 studies from 28 countries that analyzed the impact of several sorts of interventions on incidence of diarrhea Esrey found the following median reductions in diarrheal morbidity from different types of control interventions

| | |
|---|---|
| Improvements in water quality | 16 % |
| Improvements in water availability | 25 % |
| Improvements in water quality and availability | 37 % |
| Improvements in excreta disposal | 22 % |

In further work, Esrey et al (1991) found that non-environmental hygiene interventions (e g , health awareness education, hand washing campaigns) reduced morbidity by a median 35 % They also found that all interventions were likely to reduce mortality by a greater percentage than morbidity

## Table VIII-27 Importance of Alternate Control Measures for Environmentally Related Microbiological Diseases

| Diseases and Agents | Water Quality | Water Availability | Excreta Disposal | Excreta Treatment | Personal/domestic Cleanliness | Drainage/sullage Disposal | Food Hygiene |
|---|---|---|---|---|---|---|---|
| Diarrheal diseases and enteric fevers | | | | | | | |
| Viral agents (e g , enteroviruses rotavirus) | 2 | 3 | 2 | 1 | 3 | 0 | 2 |
| Bacterial agents (e g , Shigella, Salmonella) | 3 | 3 | 2 | 1 | 3 | 0 | 3 |
| Protazoal agents (e g Giardia lambia) | 1 | 3 | 2 | 1 | 3 | 0 | 2 |
| Poliomyelitis & Hepatitis A | 1 | 3 | 2 | 1 | 3 | 0 | 1 |
| Worms w/ no intermediate host | | | | | | | |
| Ascaris | 0 | 1 | 3 | 2 | 1 | 1 | 2 |
| Trichuris | 0 | 1 | 3 | 2 | 1 | 1 | 2 |
| Ancylostoma, Necator (Hookworm) | 0 | 1 | 3 | 2 | 1 | 0 | 1 |
| Beef & pork tapeworms | 0 | 0 | 3 | 3 | 0 | 0 | 3 |
| Worms w/ intermediate aquatic stages | | | | | | | |
| Schistosoma | 1 | 1 | 3 | 2 | 1 | 0 | 0 |
| Skin, eye, & louse borne infections | 0 | 3 | 0 | 0 | 3 | 0 | 0 |
| Infections spread by water related vectors | | | | | | | |
| Malaria | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Dengue | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Bancroftian filariasis | 0 | 0 | 3 | 0 | 0 | 3 | 0 |
| Encephalitis | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Rabies a) | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Tetanus a) | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Leptospirosis | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Typhus | 0 | 1 | 0 | 0 | 1 | 0 | 0 |

a) Related somewhat to solid waste disposal

KEY 3 of great importance in controlling disease
2 of moderate importance
1 of minor importance
0 of no importance

Source adapted from Feachem 1981

The conclusions of these and other studies are generally similar Non-environmental causes are as or more important than environmental causes for infectious diseases Among environmental factors, having a reliable, sufficient supply of water in the home is very important in preventing infectious diseases, as are toilets and sewers that convey fecal material away from the immediate home environment The quality of the water supplied is less important than having a reliable supply in the first place Treating human excreta properly (e g , in sewage treatment plants) is much less important than getting it away from large concentrations of people

To develop some rough estimates of the risk reductions that might result in Lima from improvements in water supply and sewers, we applied the numerical results developed by Esrey Our calculations here should be viewed as highly uncertain, as Esrey's findings represent the average effectiveness of a wide variety of interventions in a wide variety of settings The actual effectiveness of a specific program to upgrade water or sewer service in Lima might prove to be substantially different from these averages

We estimated the reduction in disease incidence in Lima that would result from 1) Extending piped water service to the entire population of Lima, and 2) Extending sewer service to the entire population of Lima The assumptions that we use in developing these estimates include

- 71 6% of the Lima metropolitan area population is currently served with both piped water and sewers, 2 9% has water service only, and 25 5% has neither piped water nor sewer service

- Providing piped water to a community lacking it will reduce the morbidity rate for diarrheal diseases by 25% Providing sewers will reduce the disease rate by 22%, and providing both water and sewers will give a 47 % reduction These represent the average effectiveness of water and sewer project elsewhere throughout the world, as compiled by Esrey at al (1985)

- Diarrheal diseases constitute the great majority of cases of disease that can be influenced by provision of water and sewer services Although the incidence of other sorts of diseases can clearly be affected by the availability of water supplies and by fecal sanitation (e g , scabies, helminth-related infections), the number of cases of these other diseases is far less than the number of cases of diarrheal disease The estimated incidence of diarrheal diseases in Lima is now 2,100 per 1,000 people per year, averaging across all the communities in metropolitan Lima with their current pattern of full, partial or no water and sewer service

In the following calculations, we estimate the reduction in disease incidence that would result from extending water and sewer service to 100% of Lima's population In essence, we estimate 1) The number of people now in each of three groups (full service, water only, no service), and 2) The per person reduction in disease incidence that will result from upgrading the second and third groups to full service The total reduction in disease incidence is then (1) x (2), summed across the second and third groups



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**Reduction in Disease Incidence From Universal Water and Sewer Service -- Calculations**

1 F is the disease incidence (in cases per year per 1,000 population) in a community with full service
W is the incidence in a community with piped water only, but not sewers
N is the incidence in a community with neither water nor sewers
Lima's overall incidence is 2,100

2 71 6 % of metropolitan Lima's population is fully served and has incidence F
2 9 % of metropolitan Lima's population has water only and has incidence W
25 5 % of metropolitan Lima's population has neither water nor sewers and has incidence N

3 $0\ 716 \times F + 0\ 029 \times W + 0\ 255 \times N = 2{,}100$

The incidence rate in each of the three types of communities in Lima, when weighted by the fraction of the total population in each of the community types, equals the overall incidence rate in Lima

4 $F = (1 - 47) \times N$ and $W = (1 - 25) \times N$

Using Esrey's averages a) Incidence in a community with no service will be reduced by 47 % if full water and sewer service are provided, and b) Incidence in a community with no service will be reduced by 25 % if water service alone is provided

5 Substituting the relationships in (4) into equation (3), we get

$0\ 716 \times (0\ 53 \times N) + 0\ 029 \times (0\ 75 \times N) + 0\ 255 \times N = 2{,}100$

6 Solving (5) and then substituting the value of N into the equations in (4), we get

Incidence rate per 1,000 population per year

| | |
|---|---|
| For a community with no service (N) | 3,200 |
| For a community with water only (W) | 2,400 |
| For a community with full service (F) | 1,696 |

7 Thus, providing water and sewers for a community with no service will reduce incidence by 1,504 per 1,000 people (3,200 - 1,696) and providing sewers for a community with water only will reduce incidence by 704 (2,400 - 1,696)

8 Multiplying by the number of people in Lima in each type of community , we get

| | |
|---|---|
| Providing water and sewers for those with no service now | Avoids 2,571,000 cases/yr |
| Providing sewers for those with only water service now | Avoids 134,000 cases/yr |



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The resulting estimate is that extending water and sewer service to the entire current population of metropolitan Lima would avoid approximately the following number of cases of disease each year

- 134,000 cases by providing sewers for the small fraction of the population that now has water service only,

- 2,571,000 cases by providing water and sewers for the much larger fraction of the population that now has neither water nor sewer service Of these cases, perhaps about 53 %, or 1,368,000, might be prevented because of water service, while 1,203,000 might be avoided because of sewers [11]

These figures might perhaps be considered to be conservative estimates, since SEDAPAL's official coverage statistics are really overestimates Many poor urban districts have water mains and house connections in place, but no actual service The estimated reductions in disease incidence would increase if we postulated not just extending service to those currently not served, but also providing ample, reliable service to those who are now served inadequately

The number of cases of disease that could be avoided with improved water and sewer infrastructure is quite large in comparison to the magnitude of the environmental health risks at stake for other environmental problems investigated in this project Providing universal water and sewer service would have major public health benefits

[11] According to Esrey's figures, water service alone reduces disease incidence by an average of 25 %, while sewers alone reduce it by an average of 22% We thus assume that 25/47 of the reduction stemming from provision of both water and sewers is attributable to the water service, while the remainder is attributable to sewers



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## SECTION IX
## CONTAMINATION OF FOOD SUPPLIES

### A Definition of the Problem

This section of the report examines health risks caused by the chemical and biological contamination of food products from environmental sources It does not deal with non-environmental sources of contamination such as natural toxins in food (e g , aflatoxin in peanuts), chemical additives (preservatives, colorants, etc ) or substances produced by or added during the course of the preparation of foods (carcinogenic products from partial combustion when foods are grilled or seared, or materials drawn from cookware or utensils such as lead-glazed pots) While nutrition is indisputably a major contributing factor in the health and well-being of any population group, health risks relating to nutrition exceed the scope of this study and are not dealt with directly in this report

#### A1 Source of food contamination

Food can be contaminated by physical, chemical and biological agents at any stage of its production, transportation, storage, distribution, preparation or marketing Hence there are many potential vehicles for the spread of disease Available data on the contamination of food products at each of the these stages is limited The general consensus in developing countries is that the likelihood of the contamination of food products is greatest in their production, preparation and marketing phases More specifically, the consumption of food at outdoor food stands along public thoroughfares exposes customers to a high risk of food-borne disease This problem has become a major concern, not only to health officials, but to the public-at-large On the other hand, selling food at outdoor stands is both a significant source of employment and a valuable service to a large working and student population forced to take their meals outside the home Thus, food inspection efforts seek to protect human health while maintaining the economic value associated with street food

The main source of chemical contaminants in food is the improper use of pesticides and other farm chemicals, which cannot be removed by washing and thorough cooking The use of agricultural chemicals to preserve food crops is another potential source of chemical contamination In general, the food crops showing the highest levels of pesticide residues are tomatoes, grapes, apples, lettuce, oranges, potatoes and meat and dairy products

There are several factors accounting for the presence of heavy metals in food products One is their absorption by crops grown in contaminated soil or irrigated with water containing high concentrations of metals Another explanation is the application of pesticides and fertilizers with high metal contents Alternatively, metallic air pollutants may settle out onto food surfaces, either as the crops are grown in the field or when displayed for sale in outdoor markets in industrial or heavily trafficked areas Many of these will be easily washed off however

Many metals and pesticides may be bioaccumulative, sometimes multiplying concentrations of contaminants by several hundred thousand times through the course of the food chain DDT, for example, can build up from an initial level of 0 000003 ppm in sea water to concentrations as high as 2 ppm in certain large fish such as swordfish (Miller Tyler Jr , 1994)

The main sources of biological contamination in food products are the use of untreated waste water in farming, the washing and preparation of vegetables, seafood products and meat products with contaminated water, the handling and preparation of foodstuffs by persons suffering from contagious diseases or under unsanitary conditions, inadequate storage practices, the harvesting of seafood from contaminated ocean waters, contamination by insects and other vectors, etc The microorganisms most commonly found in contaminated food supplies are helminths or parasitic worms, *Vibrio cholerae, Staphylococcus aureus, Bacillus cereus, Clostridium perfringens, Salmonella* and fecal coliform organisms including *Escherichia coli* (Almeida, Claudio et al , 1996)

### A2 Health Risks

The chemical contamination of food supplies by heavy metals and pesticides can cause cancer in humans In 1987, the National Academy of Sciences in the United States showed that the active compounds in 90% of all fungicides, 60% of all weed killers and 30% of all insecticides used in the U S were capable of causing cancer in humans In some cases, the specific risk has been quantified Women with high levels of DDE (a byproduct of DDT) in their blood have a four times higher risk of contracting breast cancer than women with low levels of DDE (Miller Tyler Jr , 1994)

However, cancer is only one of the possible adverse health effects of consuming food products contaminated by metals or pesticides Mercury and lead in foods, for example, have been found to cause neurological impairments and reproductive difficulties There is mounting scientific evidence linking even low levels of prolonged exposure to chemical contaminants in food to possible genetic mutations, birth defects, nervous system disorders and damage to the human immune and endocrine systems

Bacteriological contamination of foods typically leads to transient gastrointestinal illnesses or longer term helminth infections

### A3 Risk Assessment

Health risks from the consumption of foods contaminated by metals and pesticides can be evaluated using standard risk analysis techniques To do this, we need to know the different foods and the amount of each that comprise the typical daily diet for the geographic area of concern We also need to gather data on concentrations of different types of food contaminants in these foods This data on the quantity and types of foods consumed and the concentrations of contaminants in each of the food items is then combined to estimate the daily amount of each contaminant that the average individual consumes With this information and the dose-response relationship for each contaminant, we can then proceed to estimate the corresponding health risk

Health risks posed by the consumption of foods subject to biological contamination, however, typically cannot be assessed on the basis of dose-response relationships This is due, among other factors, to wide variations in infective dose for different population groups Furthermore, the infective dose for a population group may vary over time, as its members develop or lose immune mechanisms Another problem in using standard dose-response relationships for foods subject to biological contamination has to do with the large variations in levels of biological contaminants detected in the same food at different times and places This makes it impossible to establish the exposure dose for any given individual We are quite certain, nevertheless, of the type of health effects produced by most microbial agents of concern Table IX-1 details the leading symptoms associated with different bacterial agents

Most cases of food-borne diseases are not serious and will generally produce mild symptoms disappearing after a few days On rare occasions however, certain food-borne diseases can have serious health effects, with serious sequelae or complications Enteric infections, for example, can trigger a host of complications ranging from an impaired food assimilation capacity and chronic malnutrition to symptoms of rheumatic disease and septicemia

**Table IX-1 Leading Disorders Associated with Microbiological Food Contaminants**

| Agent | Leading Medium | Clinical Signs and Symptoms |
|---|---|---|
| *Vibrio cholerae* | Water raw foods | Gastrointestinal disorders accompanied by acute diarrhea and, in many cases by abdominal pain Death in severe cases |
| *Staphylococcus aureus* | Persons with wounds on their hands and arms Foods stored for 2-4 hours at temperatures over 28 degrees centigrade | Intestinal disorders in most cases accompanied by nausea and vomiting |
| *Bacillus cereus* | Improperly cooked or slowly cooled food grain products | Gastrointestinal disorders |
| *Clostridium perfringens* | Raw meat which has not been thoroughly cooked or which is reheated at unduly low temperatures | Intestinal disorders in most cases accompanied by diarrhea and in rare cases by vomiting or a fever |
| *Salmonella* including Typhoid fever | Food and water - spread through the fecal to oral route | Gastrointestinal disorders in most cases accompanied by diarrhea Death in severe cases |
| *Escherichia coli -157 H2* | Food and water spread through the fecal to oral route | Gastrointestinal disorders, in most cases accompanied by diarrhea Death in severe cases |
| *Hepatitis A (virus)* | Food and water - spread though the fecal to oral route | Fever anorexia |

Source Adapted from Health Education and Welfare 1974

In view of the difficulty of using standard dose-response relationships as the basis for assessing health risks associated with the contamination of food supplies by biological agents, risk analysis for



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these agents will involve identifying the populations exposed to contamination levels exceeding reference values and the most likely environmental sources of this contamination

## B Overview of the Problem in Lima

The population of Lima, like that of other cities in developing countries, can contract a variety of diseases through the consumption of contaminated food products Concern among public health officials and the public-at-large over the safety of food products and the quality of public water supplies has mounted in the wake of the 1991 cholera epidemic in Peru During the epidemic, the scientific community was able to pinpoint the different ways in which food products can be contaminated by microbiological agents The following is a discussion of the leading causes of the microbiological contamination of food products identified at that time

### Food preparation in public eateries, particularly at outdoor food stands with unsanitary conditions

7 1%, 7 8% and 3 6% of all food samples collected from outdoor stands on Lima's city streets tested positive for *S aureus B cereus* and *S perfringens* respectively 54 9% of all food samples had over 3 fecal coliform organisms per gram or milliliter of food This suggests that these foods were prepared under unsanitary conditions (Almeida et al , 1996)

### Irrigation of cropland with polluted water and untreated waste water

An estimated 14 2 to 17 2 $m^3/s$ of waste water in the Lima area goes untreated At least 2 37 $m^3/s$ is believed to be used by farmers for the irrigation of food crops The data presented in Table IX-2 below provides an overview of the quality of the water used in selected farming areas of Lima

**Table IX-2 Selected Waste Water Quality Data for the Lima Area**

| Pollutant Source (Parameter) | Comas[1] | Centenario[1] | Laguna de San Juan |
|---|---|---|---|
| Fecal coliform organisms (MPN/100ml) | $1\ 40 \times 10^7$ | $1\ 92 \times 10^7$ | $1\ 2 \times 10^8$ $3\ 6 \times 10^9$ [2] |
| Fecal streptococci (MPN/100ml) | $1\ 12 \times 10^7$ | $5\ 54 \times 10^7$ | na |
| $BOD_5$ (mg/l) | 215 | 243 | 278 [2] |
| Total nitrogen (mg/l) | 45 0 | 50 2 | 19 25 [2] |
| Arsenic (mg/l) | 0 154 | 0 096 | 0 025 [3] |
| Cadmium (mg/l) | 0 014 | 0 014 | <0 00005 [3] |
| Mercury (mg/l) | 0 0005 | 0 0008 | na |
| Lead (mg/l) | 0 17 | 0 22 | 0 10 [3] |

Sources [1] PROMAR (study conducted in June and July of 1995) [2] CEPIS (study conducted over the period from 1988 to 1990) [3] CEPIS (study dating back to 1993)

As illustrated by the data presented in Tables IX-2 and IX-3, the levels of fecal coliforms, $BOD_5$ and lead in irrigation water in certain parts of Lima greatly exceed the water quality standards

set by Peruvian legislation This is not surprising, since the waste water used for irrigation is completely untreated

**Table IX-3 Selected Water Quality Criteria for Irrigation Water under Peruvian Legislation**

| Parameter | Value |
|---|---|
| Fecal coliform organisms | 1000 MPN/100 ml |
| $BOD_5$ | 15 mg/l |
| Cadmium | 0 05 mg/l |
| Lead | 0 1 mg/l |

Source General Water Act, Class III water

**Dumping of untreated waste water into the sea**

An estimated 12 4 $m^3/s$ of waste water is dumped into the sea without undergoing any treatment (see section XI) The quality of this waste water is comparable to that of the irrigation water analyzed in Table F-2 Hence fish and other foods harvested from the sea can be contaminated

**Use of contaminated water to wash or prepare fresh vegetables**

There are gaps in the data that preclude any sort of quantitative assessment of the specific effects of these activities on the quality of foods consumed in Lima The general consensus, however, is that washing foods such as carrots, garlic and certain types of onions with contaminated water increases the risk of contracting infectious diseases among consumers

**Food preparation in the home under unsanitary conditions**

The deficiencies in basic services such as water supply, sewerage and solid waste collection are some of the difficulties faced by many households in attempting proper food preparation The problem is compounded by failing to follow hygienic household practices

**Chemical contamination of food**

There is little evidence of concern among the general population about chemical contamination of food There is also very little technical information on this issue in Lima Nevertheless, some people think that the use of farm chemicals in crop-growing areas of Lima is a major factor in the chemical contamination of food supplies Some 548 different farm chemicals, registered with the Ministry of Agriculture are sold within the Lima area Because they are often used to kill pests and diseases, 8 7% of all agricultural chemicals are classified as extremely toxic and another 17 2% are classified as highly toxic (RAAA, 1995) The list of pesticides used in Lima area farming operations still includes a few of the "dirty dozen," namely Pentachlorophenol, Paraquat, Benzene hexachloride (BHC), Lindane, Heptachlor, Chlordane, Ethyl Parathion, Endrin, Dibromochloropropane, Ethylene Dibromide, 2,4,5 -



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T, DDT, Chlorcamphor and Chlordimeform Use of most of these chemicals is banned in developed countries

We must note that there are also many health benefits from use of agricultural chemicals on food crops By reducing pest damage to crops, these chemicals increase food supplies and improve the population's diet -- one of the most important factors in improving health

Use of untreated waste water in farming and the dumping of this waste water into area rivers, irrigation ditches and the sea also contribute to the chemical contamination of food products consumed within the city of Lima

Table IX-4 below shows concentrations of three pollutants in soil irrigated with water from irrigation ditches and untreated waste water The areas showing higher concentrations of these pollutants are San Martin de Porres and Callao, with lower concentrations in the farming areas of Cieneguilla and San Juan By comparison with typical levels of these pollutants in soils in the U S , these levels in Lima are not particularly high Lead concentrations in soil throughout the Lima area appear to be well below the normal range in the U S , while arsenic and mercury concentrations are generally within average values for the United States (U S EPA, 1993, Valle, 1986) The absence of significantly elevated concentrations of these pollutants in soil irrigated with water from irrigation ditches and waste water would seem to indicate that most irrigation water is only mildly contaminated with toxic chemicals Thus it is more like waste water produced by households than by industry

**Table IX-4 Pollutant Concentrations in Land Irrigated with Water from Irrigation Ditches and Untreated Waste Water, in ug/g**

| Area | Arsenic | Mercury | Lead |
|---|---|---|---|
| Callao | 87id 164ww | 0 21ww-0 47id | 0 18ww 0 28id |
| Cieneguilla | 25av | 0 02id | 0 07id |
| San Juan | 25av | 0 01ww | 0 10ww |
| San Martin de Porres | 37 5ww 67id | 0 18id 0 44ww | 0 22ww-0 9id |
| Typical in U S | 0 2 - 40 | 0 008 - 0 117 | 2 200 |

Source Castro de Esparza, Maria et al 1993
id = land irrigated with water from irrigation ditches
ww = land irrigated with untreated waste water
av = average

As mentioned above, available data on the use and effects of pesticides in food products consumed in the Lima area is extremely limited and primarily qualitative in nature The list of pesticides used in outlying farming areas of Lima includes Dieldrin, Aldrin, Endrin, Aldicarb and Heptachlor

The only available study of pesticide contamination of Lima's food involves the insecticide Aldicarb (2-methyl-2-(methylthio)-propionaldehyde-0-(methylcarbonyl)oxime) It is sold under the trade name "Temik 15G" or "Carbanolate 12 " Aldicarb is used to control various insects, mites and

nematodes on a wide variety of crops likely to be grown in Lima's outlying farming areas, such as potatoes, corn and onions The data presented in Table IX-5 below shows concentrations of Aldicarb in three widely consumed food items

**Table IX-5 Aldicarb Concentrations in Potatoes, Watermelons and Lemons, in µg/g**

| Item | Average | Minimum | Maximum | MRL [1] |
|---|---|---|---|---|
| Potatoes | 0 163 | 0 120 | 0 201 | 0 500 |
| Watermelons | 0 110 | 0 081 | 0 129 | 0 200 |
| Lemons | 0 183 | 0 084 | 0 231 | 0 200 |

Source Castillo Zegarra et al 1995
[1] Maximum residue level (CODEX/FAO/WHO 1989)

Data on the concentrations of metals in Lima's food is similarly limited as is the data for pesticides The following two tables show the levels of lead in several food crops and the levels of three metals in marine organisms

**Table IX-6 Lead Concentrations in Selected Food Crops, in µg/g**

| Area | Crop | | | | |
|---|---|---|---|---|---|
| | Corn | Spinach | Strawberries | Potatoes | Carrots |
| Callao | | | | | |
| Farming area | < 0 002 | 0 014 | na | 0 002 | < 0 002 |
| Marketplace | < 0 002 | 0 004 | 0 002 | 0 002 | < 0 002 |
| San Martin | | | | | |
| Farming area | < 0 003 | < 0 009 | na | na | na |
| Marketplace | 0 002 | 0 037 | < 0 002 | 0 002 | < 0 002 |
| San Juan | | | | | |
| Farming area | 0 003 | na | na | na | na |
| Cieneguilla | | | | | |
| Farming area | < 0 002 | na | na | na | na |
| Lima marketplaces | | | | | |
| Wholesale | < 0 002 | < 0 002 | < 0 002 | < 0 002 | < 0 002 |
| Central | < 0 002 | < 0 003 | < 0 002 | < 0 002 | < 0 002 |

Source CEPIS 1993
na = not available



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**Table IX-7 Metals in Marine Organisms, in µg/g**

| Source | Common Name | Scientific Name | Cadmium[4] | Copper[4] | Lead[4] |
|---|---|---|---|---|---|
| Pisco-Paracas[1] | Small mussel | Perumytilus Purpuratos | 0 93 | 1 60 | 0 76 |
| Callao[2] | Scallop | Argopecten Purpuratos | 0 97 | 0 83 | 0 50 |
| Callao[2] | Barnacle | Fissurella Lutimarginata | 0 61 | 2 99 | 0 25 |
| Callao[2] | Clam | Semele Corrugata | 2 46 | 1 00 | 0 57 |
| Callao[2] | Snail | Thais Chocolata | 0 23 | 2 90 | 0 60 |
| Ilo-Ite[3] | Croakers | Sciaena Deliciosa | - | 2 53 | 0 06 |
| Ilo-Ite[3] | Large mussel | Semymitilus Algosus | | 2 66 | 0 25 |

Source The Peruvian Institute of the Sea (IMARPE)
1 - sample taken on 4/24/92, 2 - sample taken on 4/24/92 3 sample taken on 9/26/96 4 - wet sample

Different types of fish and shell fish can also have high concentrations of pesticides in addition to heavy metals Certain large fish and molluscs, in other parts of the world in the past when DDT was more widely used, had been found to have concentrations from 70,000 to 660,000 times the level of DDT in sea water However, we can find no studies in or near Lima on concentrations of pesticides in fish and shell fish (Myller, 1994 and Valle, 1986) DDT is not commonly used in the Lima area

### Contamination of food by microbial agents

Two studies that sampled prepared foods sold at outdoor food stands found widespread contamination 55 % and 45 % of the samples in the two studies showed contamination with fecal coliforms exceeding acceptable levels Another study of produce in markets also showed frequent contamination

**Table IX-8 Percentage of Food Samples Contaminated by Helminths and Protozoa out of 73 Samples of Produce from Lima-area Marketplaces**

| Item | Protozoa (%) | Helminths (%) |
|---|---|---|
| Lettuce | 37 0 | 17 8 |
| Spinach | 34 2 | 15 1 |
| Parsley | 42 4 | 9 6 |
| Coriander | 37 0 | 8 2 |
| Radishes | 35 6 | 9 2 |

Source Sector study 1992 Office of the President PAHO/WHO

The conditions shown in Table IX-8 likely represent a major human health risk Parsley and lettuce samples showed the highest rates of contamination by protozoa and helminths, namely 42 4% and 17 8% respectively The risk of contracting a food-borne disease through the consumption of these foodstuffs is heightened by the common practice of consuming these items raw

## C Health risks for Lima's population

One of the first steps in estimating the risks from food contamination is to determine the amount of different foods consumed in the typical diet

Table IX-9 below presents an approximation of what may be considered to be the typical diet of Lima residents The second column of the table shows the percentage breakdown of daily calories from different food items according to data collected over the course of the fourth quarter of 1990 and the first quarter of 1991 The third column shows the estimated average daily caloric intake by a Lima area adult between the ages of 16 and 19 whose lifestyle includes moderate physical activity (equivalent to 2900 calories/day) This is based on a diet with the percentage breakdown shown in the second column of the table The right-hand column converts calories to food weight, expressed in grams

**Table IX-9 Daily Caloric Intake and Weights of Selected Typical Food Items Consumed in the Lima Area**

| Food Groups | % | Calories/day/Adult Equivalent[1] | Weight (grams)[2] |
|---|---|---|---|
| Bread and cereals | 47 7 | 1173 | 326 |
| Meat and meat products | 6 6 | 161 | 148 |
| Fish and shell fish | 1 2 | 30 | 32 |
| Milk, cheeses and eggs | 4 2 | 103 | 74 |
| Fats and edible oils | 8 0 | 196 | 20 |
| Fresh produce and vegetables | 3 2 | 79 | 113 |
| Fruits | 2 7 | 66 | 93 |
| Pulses and related products | 2 5 | 62 | 18 |
| Roots and tubers | 6 3 | 155 | 134 |
| Sugar | 12 7 | 313 | 83 |
| Miscellaneous | 5 1 | 124 | 55 |
| Total | 100 0 | 2462 | 1096 |

Source INEI 1995
[1] Includes caloric requirements (2900 calories/day) for an adult male between 16 and 19 years of age doing moderate physical activity [2] Conversions made specifically for purposes of this study

We found no study data on the quantity of water consumed by each Lima area resident We used an average of 2 2 liters of water per person per day as representative of a city with a temperate climate

Surveys show significant differences between the foods consumed from outdoor food stands and the remainder of the diet The data presented in Table IX-10 below shows the types of foods consumed at outdoor food stands along public thoroughfares

**Table IX-10 Food Preferences among Customers at Outdoor Food Stands in the Lima Area**

| Description | % |
|---|---|
| Meat products | 33 3 |
| Fruits and vegetables | 9 3 |
| Cereals and grains | 16 7 |
| Sweets | ng |
| Dairy products | ng |
| Natural juices | 13 3 |
| Ice cream | ng |
| Fish and shell fish | 27 3 |

Source Almeida, 1996
ng = consumed in relatively negligible quantities as of the date of the study

## C1 Chemical contamination

By combining information on the level of chemical contaminants in different foods with information on the daily amount of each food consumed in the typical diet, we can estimate the typical daily intake through food of the chemical contaminants Table IX-11 combines the information on chemical contaminants in foods in Lima from earlier tables

**Table IX-11 Average Levels of Selected Chemical Contaminants in Different Foods**

| Food Group | Aldicarb (mg/kg) | Cadmium (µg /g) | Copper (µg /g) | Lead (µg /g) |
|---|---|---|---|---|
| Fish and shell fish | ? | 1 04 | 2 073 | 0 43 |
| Fresh produce and vegetables | 0 183 | < 0 0003 | ? | 0 014 |
| Fruits | 0 110 | ? | ? | 0 002 |
| Tubers and roots | 0 163 | < 0 0003 | ? | 0 002 |

Source Based on all study data examined and presented in previous tables assuming the specific foods sampled are representative of their entire food groups

Combining this information with the estimated average dietary intake of each of these food groups, we can estimate the average daily intake of these contaminants These figures are based on the very limited information we could assemble in regard to different food items

**Table IX-11 Average Daily Intake of Selected Food Contaminants by Lima Residents**

| Food Group | Consumption (g/d) | Aldicarb (µg /d) | Cadmium (µg /d) | Copper (µg /d) | Lead (µg /d) |
|---|---|---|---|---|---|
| Bread and cereals | 326 | ? | ? | ? | ? |
| Meats and meat products | 148 | ? | ? | ? | ? |
| Fish and shell fish | 32 | ? | 33 28 | 66 34 | 13 76 |
| Milk cheeses and eggs | 74 | ? | ? | ? | ? |
| Fats and edible oils | 20 | ? | ? | ? | ? |
| Fresh produce, vegetables | 113 | 20 68 | <0 0339 | ? | 1 582 |
| Fruits | 93 | 10 23 | ? | ? | 0 186 |
| Pulses and related products | 18 | ? | ? | ? | ? |
| Tubers and roots | 134 | 21 84 | < 0 0402 | ? | 0 268 |
| Sugar | 83 | ? | ? | ? | ? |
| Miscellaneous | 55 | ? | ? | ? | ? |
| Total | 1096 | 52 75 | 33 28 | 66 34 | 15 796 |

Source Based on all study data examined and presented in previous tables
? = data not available

Cadmium and lead are present in small quantities in non-seafood products Fish and shellfish generally show the highest concentrations of heavy metals as a result of their bioaccumulative qualities

As is evident from the table, the available data include only few of the chemicals responsible for contamination of food products, and cover only a few of the food groups that people consume Even where some data does exist, all of the studies of pesticide or heavy metal concentrations in Lima address individual food items or crops rather than entire food groups Thus, the estimated totals likely significantly underestimate the actual levels of chemical contaminants consumed by a Lima area resident

As far as pesticides are concerned, we know, for example, that these food contaminants are present not only in fruits, vegetables and potatoes, but also in shellfish, meat and dairy products and other food items Moreover, Aldicarb is only one of several pesticides commonly used in the Lima area Table IX-12 below shows dietary exposure levels in Quito, Ecuador to various pesticides used there, where more data is available



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**Table IX-12 Overview of Exposure Levels to Pesticides Used on Food Crops in Ecuador***

| Pesticide | Level (µg /kg/day) | |
|---|---|---|
| | Primary Analysis | Secondary Analysis |
| Lindane | 0 22 | 0 1 |
| Heptachlor | 0 89 | 0 1 |
| Aldrin | 0 22 | 0 5 |
| Dieldrin | 0 069 | -- |
| DDT | 5 69 | 1 7 |

Source Arcia, Gustavo et al , 1993
* assuming a body weight of 50 kg per person

International data on lead concentrations in food also suggest that the doses calculated for Lima in Table IX-11 are significantly underestimated The daily exposure to lead in food in Egypt, Guatemala and Cuba, for example, is estimated at 8 5, 9 0 and 4 6 µg/kg/day respectively (Pride, 1994), compared with 0 225 µg/kg/day for the Lima area (15 8 ug/d as shown in the table, divided by an assumed 62 kg average body weight) Is dietary lead exposure in Lima really only one-twentieth to one-fiftieth as much as in these other countries? We doubt it Note that our limited data shows that the great majority of lead and other heavy metal consumption in Lima derives from seafood This is in contrast to a finding for the average world-wide diet that 75% of lead consumption comes from cereals, tubers, fruit and vegetables (UNEP, 1992) Thus, the data presented in Table IX-11 probably reflects only a small fraction of the actual levels to which the population of Lima is being exposed to through food

Table IX-13 details the assessment of risks caused by selected chemical contaminants present in food consumed in Lima

None of the chemical contaminants present in these food items has a hazard index (HI) for non-cancer effects over 1 0 Thus, based on the few food groups sampled, there is no significant risk of non-cancer health effects However, two of the hazard indices approach one -- aldicarb has the highest hazard index at 0 85 and cadmium is at 0 54 -- and with full information on contaminant levels in all food groups these hazard indices could easily exceed one Furthermore, aldicarb is both less toxic and less environmentally persistent than several other pesticides commonly used near Lima If the hazard index for aldicarb is near one, it is possible that the hazard indices for other pesticides would exceed one

There is no evidence that dietary exposure to any the four contaminants for which we have data (aldicarb, cadmium, copper or lead) cause cancer We do not therefore have evidence suggesting any cancer risks from chemical contaminants in Lima's food

We thus have no evidence of health risks from chemicals in food However, the very limited data on both pesticides and metals, in combination with hazard indexes for aldicarb and cadmium that begin to approach a level of concern despite the limited data, makes this an issue for which further information would be valuable

**Table IX-13 Assessment of Risks Caused by Chemical Contaminants in the Lima Area**

| Parameter | Chemical Contaminant | | | |
|---|---|---|---|---|
| | Aldicarb | Cadmium | Copper | Lead |
| Estimated daily intake (µg) | 52 75 | 33 28 | 66 34 | 15 796 |
| Dose (µg/kg/day) | 0 85 | 0 54 | 1 07 | 0 255 |
| Noncarcinogenic reference dose (µg/kg/day) | 1 | 1 | 46 | 1 4 |
| Noncarcinogenic hazard index | 0 85 | 0 54 | 0 0233 | 0 182 |
| Potential cancer risk (mg/kg/day) | i e | i e | i e | i e |
| Individual lifetime cancer risk | i e | i e | i e | i e |
| Annual cancer risk to the general population | i e | i e | i e | i e |

Source US Environmental Protection Agency IRIS for all doses and potential cancer risks
Individual body weight 62 kg
i e = insufficient evidence of any potential to cause cancer

### C2 Biological Contamination

The health effects produced by biological contamination of food items are reflected in the incidence of food-borne and waterborne diseases, as illustrated in Table IX-14 below It has been estimated that food is involved as a route of transmission in 70% of all cases of such diseases (Esrey and Feachem, 1989) These diseases have multiple causes and multiple routes by which infections agents can be transmitted from one individual to another Factors contributing to the spread of these diseases in Lima include many that involve food directly -- the irrigation of agricultural zones with untreated residual waters, poor food hygiene in homes, markets and food stands, washing vegetables with polluted water -- and others that may or may not involve food -- inadequate or contaminated water supplies, limited sewerage systems, etc



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**Table IX-14 Incidence of Waterborne and Food-borne Diseases in Lima and Callao, by Health Subdistrict (1995)**

| Lima subdistrict | North | East | City center | South | Callao |
|---|---|---|---|---|---|
| Total population | 2324470 | 804786 | 1492000 | 1400957 | 684135 |
| Population under 5 years of age | 293348 | 101564 | 188290 | 176801 | 86338 |
| **Disease** | | | | | |
| Infectious intestinal disorders | 47910 | 45407 | | 55581 | 22559 |
| Enteritis/colitis | 8431 | 7650 | | 9050 | 5569 |
| Helminthiasis | 8312 | 8601 | | 12147 | 3866 |
| Cholera | | | 947 | | |
| Typhoid and paratyphoid | | | 907 | | |
| Salmonellosis | | | 181 | | |
| Shigellosis | | | 132 | | |
| Amebiasis | | | 18 | | |
| Other intestinal disorders caused by protozoa | | | 895 | | |
| Intestinal disorders caused by other organisms | | | 36563 | | |
| Viral hepatitis | | | 1447 | | |
| Intestinal helminthiasis (ascariasis, trichuriasis) | | | 218 | | |
| Other forms of helminthiasis and intestinal parasitic infections | | | 6023 | | |
| Total cases of disease, by health subdistrict | 64653 | 61258 | 47331 | 76778 | 31994 |
| Overall incidence by subdistrict (per 1000 population) | 27 8 | 76 1 | 31 7 | 54 8 | 46 8 |

| | |
|---|---|
| Overall incidence in Lima (per 1000 pop ) | 41 5 |
| Overall incidence in Callao (per 1000 pop ) | 46 8 |
| Overall incidence Lima+Callao (per 1000 pop ) | 42 1 |

Source Health subdistricts of Lima and Callao

Lima East reported the highest incidence of diseases associated with the consumption of contaminated food and water for the year 1995, with 76 1 cases per 1000 population, among which infectious intestinal disorders were the leading cause of illness The incidence rate for these diseases was slightly higher on average in Callao than in Lima i e , 46 8 per 1000 population compared with 41 5 Helminthiasis from contaminated food and water accounts for an important share of the reported cases of waterborne and food-borne diseases

The data presented in Table IX-14 includes only officially reported cases of these disease in the Lima area for the year 1995 These statistics sharply under-count the number of cases of these generally mild and transient diseases that actually occur Most cases of these diseases are managed in ways that do not result in their being counted in the official statistics -- they go untreated, they are treated at home, or they are treated through pharmacies, nurses or private clinics that are not counted in the public statistics The degree of under-reporting of such diseases is discussed in more detail in Section VIII on

Water Pollution, in which an estimate is developed to the effect that only 2 % of the cases that occur are ultimately counted in the official statistics Applying a factor of 50 to account for this under-reporting, the real incidence of these diseases would be on the order of 2,100 per 1,000 population, or an average of 2 1 cases per capita per year If food is involved in 70 % of these cases, then there may be approximately 9 8 million cases per year of illnesses involving food contamination among Lima's population This estimate is highly uncertain, but the morbidity rate is certainly far higher than suggested by the data presented in the table

The people exposed to the highest risks are those eating foods under the least sanitary conditions those without services that can help them keep their homes clean (piped water, sewers, solid waste collection), those that consume food from street vendors, and those who commonly eat raw, unpeeled fruits and vegetables A recent study of 300 food stands along public thoroughfares in Lima (Almeida et al , 1996) found that they put about 340,000 persons at significant risk of contracting a food-borne disease

According to the data in Table IX-15, each food stand exposes approximately 1100 persons a year to the risk of contracting a food-borne disease

**Table IX-15 Annual Number of Consumers of Food at 300 Outdoor Stands at Risk of Contracting a Food-borne Disease**

| Contaminant | Population at Risk |
|---|---|
| *Staphylococcus aureus* | 182 000 |
| *Bacillus cereus* | 104 000 |
| *Clostridium perfringens* | 26 000 |
| *Salmonella* | 31 200 |
| Total | 343 200 |

Source Almeida et al , 1996

For purposes of this study, a significant risk of contracting a food-borne disease was defined to exist when the items sold by a food stand contained contaminants at levels above the threshold values indicated in Table IX-16 below

This assumes

- That the foods are prepared and sold at outdoor stands on city streets throughout the year under the same conditions as those prevailing at the time of the study,
- That the food stands preparing and selling the foods in question are open for business five days a week, 52 weeks a year,



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- That the sample analyzed for the purposes of the study is representative of all foods sold by the food stand, and
- That each customer consumes an average of 300 g or ml of food per day

**Table IX-16 Threshold Values for the Risk of Contracting a Food-borne Disease**

| Contaminant | Threshold Value |
|---|---|
| *V cholerae* | > $10^3$/g |
| *S aureus* | > $10^2$/g |
| *B cereus* | > $10^3$/g |
| *C perfringens* | > $10^3$/g |
| *Salmonella* | presence in 25 g |
| *E coli* | presence in 25 g |

Source Almeida et al , 1996

The study also considered the presence of more than 3 fecal coliform organisms per gram or milliliter of food as a reflection of poor food hygiene According to the data, 54 9% of the 300 food stands exceeded this threshold value Another study of 100 food samples prepared at outdoor food stands along public thoroughfares found 45% of the foods sold in Central Lima to have been prepared under conditions failing to meet acceptable standards of food hygiene, as reflected by levels of over 100 fecal coliforms per gram or milliliter of food (DIGESA, 1996)

## D Discussion of Study Findings

Chemical and biological contamination of food supplies in the Lima area comes from a variety of sources It is impossible to calculate the share of different polluting activities in undermining food quality

Data on levels of chemical food contamination is scarce The only available figures refer to concentrations of four chemical agents (Aldicarb, cadmium, copper and lead) in a selected group of food items Considering only the portions of the average diet for which data are available, none of these chemical contaminants are consumed in quantities exceeding established safety limits Among these food contaminants, Aldicarb has the highest hazard index of just under 1 0 (0 85), suggesting that full data on all food groups might show it to be present in the average diets at levels that may pose health risks Other pesticides for which no data is available might also pose threats The limited available data appear to show consumption of heavy metals to be farther away from exceeding safe levels In sum, though, the major gaps in available information preclude any confident assessment of risks from chemical contaminants in food

Studies of food safety rightly concentrate on the presence of biological contaminants This is due to widespread contamination of foodstuffs and the huge number of illnesses likely transmitted

through contaminated food A 1991 study for example, found 42 5% of all parsley samples contaminated by protozoa and 17 8% of all lettuce samples contaminated by helminths (intestinal worms) These foods are generally consumed in their raw state and this heightens the risk of contracting a serious food-borne disease

The effects of biological food contamination are reflected in the significant reported incidence of food and waterborne disease This is 46 8 and 41 5 cases per 1,000 population per year in the Callao and Lima areas respectively Actual incidence of these diseases is far higher, at perhaps 2,100 per 1,000 population per year In general, food is involved in approximately 70% of all cases of diarrheal disease (Esrey and Feachem, 1989)

In the Lima area, the risk of contracting a food-borne disease through consumption of foods sold at outdoor stands along public thoroughfares is significant Each stand preparing and selling foods on Lima streets puts 1,140 area residents per year at risk of contracting a food-borne disease The population at risk of contracting a food-borne disease as a result of biological contamination of food encompasses the entire Lima area population, with the risk lowest among breast-fed infants

## E Limitations of the Study

Unfortunately, all available data falls into one of the following two categories, both of which represent extremes It is either (i) overly general, or (ii) highly specific General data is that which is not based on specific studies conducted in the Lima area and, in nearly all cases, is drawn from studies mounted in other countries with no attempt made to adapt it to the specific realities of Lima For example, there are a number of studies (or, more accurately, compilations of data) on the health effects of pesticides with no indication whatsoever of corresponding exposure doses or of the at risk population in the Lima area

Isolated data is data which is not collected on a regular or routine basis and thus any generalizations made on the basis of this data could be highly inaccurate This is especially true in this case

The limitations include

- The assumption that a typical diet for Lima area residents consists of the items shown in Table IX-9, which, in fact, is a diet representative of youth between the ages of 16 and 19,

- The assumption that levels of the pesticide Aldicarb in three food products, namely in watermelons, lemons and potatoes, reflect its average concentration in fruits, vegetables and tubers respectively This may invalidate our assessment of the risk posed by this contaminant but may nevertheless be indicative of a general trend,



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- The assumption that levels of cadmium, copper and lead in the only fish tested (croakers) and in the shell fish shown in Table IX-7 represent their average concentrations in all fish and shell fish consumed in the Lima area,

- The assumption that the food subgroup "fish and shell fish" represents the only or the leading pathway of exposure to cadmium, copper and lead in foodstuffs,

- The assumption that the reported health statistics for food and water-borne diseases represent only about 2 % of actual incidence,

- The assumption that this data corresponds to health subdistricts covering an area larger than Lima and Callao

A series of follow-up studies is needed to improve the basic study data More specifically, the following is needed

- Establish the typical diet for the general population of Lima, broken down into at least three broad age groups, namely <5, 5-65 and >65,

- Establish the volume and type of pesticides applied to crops in outlying farming areas of Lima or determine the average concentration of pesticides in different subgroups of food items (vegetables, fresh produce, dairy products, etc ),

- Establish the average concentration of heavy metals in different subgroups of food items consumed in the Lima area, and

- Determine more accurately the degree of under-reporting of food and water borne diseases, and the contribution of food contamination to the total

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# SECTION X
# AIR POLLUTION

## A General Definition of the Problem

Over the past 30 years we have improved our understanding of the relationship between air pollution and human health Air pollutants inhaled or absorbed by human beings produce health effects ranging from eye and respiratory tract irritations to an increased risk of lung or other cancer, as well as a wide variety central nervous system problems Although their effects are frequently more irritating than pathogenic, atmospheric toxins can compromise epidermal and mucosal tissues

Indirect effects may also be important, as in the case of CO (carbon monoxide), which reduces the ability of hemoglobin to carry oxygen, and other allergic effects caused by fine particles that can cause sensitization of the immune system, allergic rhinitis, asthma attacks, etc

The main atmospheric contaminants are CO, $CO_2$, $SO_2$, total suspended particulates (TSP), ozone ($O_3$), nitrogen oxides (NO, $NO_2$ and others), toxic organic compounds (e g , benzene, formaldehyde) and heavy metals, in addition to $CH_4$, $H_2S$, $NH_4$, etc

Due to its particularly significant impact on human health, atmospheric lead has been analyzed in a separate section (Section XV) of this report

## B Overview of the Problem in Lima

### B1 General Aspects

Data on atmospheric pollution in Lima is scarce At present, only two entities (DIGESA and SENAMHI) conduct systematic air quality monitoring SENAMHI has carried out a monthly program to monitor dustfall at 50 stations in all of the municipal districts of Lima For other air pollutants, spot monitoring has been conducted episodically by MITINCI, private laboratories or universities and, since 1993, the Ministry of Energy and Mining has monitored air quality in the vicinity of hydrocarbon transformation facilities Table X-1 shows the typical ranges of concentration of the principle pollutants that have been monitored at the two DIGESA stations located at Cahuide and Conaco The table compares the concentration ranges against both U S standards and WHO allowable levels

Airborne biological pollutants, although not widely studied, also produce adverse health effects Efforts to date have detected more than 40 types of fungi and an indeterminate number of bacteria caused by the open-air incineration or decomposition of garbage, which in addition produces other air pollutants such as methane, sulfuric acid, and ammonia

**Table X-1 Ranges of Air Pollutant Concentrations in Metropolitan Lima ($\mu g/m^3$)**

| Pollutant | Concentration (max/min), DIGESA | | Concentration (max/min), SENAMHI | | U S Standards | | WHO Maximum Levels | |
|---|---|---|---|---|---|---|---|---|
| CO | 18,589<br>14,312 | p a | 57,250 | p a | 40,000 | p l h | 10,000 | p 8 h |
| $NO_2$ | 95 2<br>32 36 | p a | - | - | 100 | p a | 320 | p l h |
| $SO_2$ | 204 0<br>28 6 | p a | 442 0<br>182 0 | p a | 80 | p a | 40-60 | p a |
| TSP | 218<br>32 94 | p a | - | - | 75 (1) | p a | 40-90 | p a |
| Lead | 1 683<br>0 608 | p a | - | - | 1 5 | p a | 0 5-1 0 | p a |
| Cadmium | 0 006<br>0 002 | p a | - | - | - | - | 0 010 a<br>0 020 (2) | p a |
| Chromium | 0 032<br>0 0043 | p a | - | - | - | - | - | - |
| Manganese | 0 089<br>0 012 | p a | - | - | - | - | 0 3 | p a |
| Zinc | 1 481<br>0 146 | p a | - | - | - | - | - | - |
| Copper | 0 082<br>0 037 | p a | - | - | - | - | - | - |
| Iron | 3 73<br>0 534 | p a | - | - | - | - | - | - |

(1) As of 1989, U S standards were replaced by new standards for small particles only
(2) Allowable limits in urban areas In rural areas, from 0 001 to 0 005 $\mu g/m^3$

### B2 Contamination sources

The principle anthropogenic polluting activities in Lima are transportation, industry (including mining and petrochemical activities), littering and open-air incineration of garbage Industry and the vehicle fleet account for approximately 80% of the air pollutants in Lima, including carbon monoxide, sulfur dioxide, nitrogen oxides, settleable solids and others The burning of solid waste is estimated to account for between 7 and 10% of these pollutants, and other sources contribute the remainder

### B3 Vehicle fleet

The vehicle fleet is a significant source of pollutants, including CO, $NO_2$, particulate matter (TSP) and lead From 1993 to 1995, the number of vehicles in operation in Lima increased by 138,000, reaching a level of 588,072 in 1995, with a rate of 88 vehicles per 1,000 inhabitants (CIDAT 1995)

With regard to public transportation, in March 1992 Lima had a fleet of 9,210 units operating over 268 routes, of which 130 passed through downtown Lima In 1994, the number of units had increased to 29,859, while for 1996 the total estimated figure is approximately 47,100

In 1994, gasoline consumption ranged between 750 and 800 million gallons (CUANTO 1995) Of this total, it is estimated that 87 5% is leaded gasoline and 15% unleaded For the entire nation, 10 7 % of the gasoline sold is 97 octane leaded, 14 6% is 90 octane unleaded, and 74 6% is 90 octane leaded (Ministry of Transportation and Communication, 1995)

Most vehicles in Lima are not equipped with catalytic converters Studies conducted in Switzerland have shown that a vehicle not equipped with a catalytic converter can emit an average of 15 g of CO, 2 g of HC, 4 g of $NO_2$ and 0 002 g of lead for each liter of gasoline burned Annual emissions from vehicles in Lima may reach 7,128 tons of CO, 1,900 tons of $NO_2$, 950 tons of HC and approximately 1 ton of lead

The age of the vehicle fleet constitutes an additional problem with regard to pollution The average age is 8 years for automobiles and light trucks (*camionetas*) and 16 years for microbuses Studies conducted in Mexico have shown that an automobile with an average of 8 years of use produces from 10 to 15% more CO than a new car and between 15 and 20% more $NO_2$ This problem is exacerbated by increased fuel consumption due to heavy traffic and poor driving habits The average traffic speed has been estimated to have declined from 15 km/hour in 1994 to 12 5 km/hour in 1996 (Iturregui, 1996) Other studies have calculated a rate of 9 km/hour during peak hours in the city (Lona 1990)

### B4 Industry

In 1995 there were 33,385 industrial facilities in Metropolitan Lima, accounting for 68% of the national total The most heavily industrialized areas are located in the Northern and Northeastern sectors of the city, representing 60% of the total These are the districts of Cercado, Ate, San Martin de Porres, San Juan de Lurigancho and Comas See Table X-2

**Table X-2 Industrial Infrastructure in Metropolitan Lima, by Sub-Regions**

| Sub-Region | Establishments by Work Force Size | | | | | | Total | |
|---|---|---|---|---|---|---|---|---|
| | Small (< 5 employees) | | Medium (5-19 empl ) | | (Large (> 20 empl ) | | | |
| | Number | % | Number | % | Number | % | Number | % |
| Callao I | 1,369 | 4 8 | 259 | 6 8 | 118 | 12 3 | 1,746 | 5 2 |
| South II | 4,241 | 14 8 | 481 | 12 6 | 77 | 8 0 | 4,799 | 14 4 |
| North III | 9,443 | 33 0 | 806 | 21 1 | 143 | 14 9 | 10,392 | 31 1 |
| East IV | 2,950 | 10 3 | 487 | 12 8 | 190 | 19 8 | 3,627 | 10 9 |
| City Center V | 10,603 | 37 1 | 1,786 | 46 8 | 432 | 45 0 | 12,821 | 38 4 |
| Total | 28,606 | 100 0 | 3,819 | 100 0 | 960 | 100 0 | 33 385 | 100 0 |

Source Census, 1995

### B5 Formal and Informal Commerce

The formal and informal establishments that prepare food are another source of air pollution in Lima Kitchens and ovens emit mainly CO, $CO_2$, $SO_2$, $NO_2$, TSP and volatile organic compounds (VOCs) depending of the type of fuel used (kerosene, gas, wood or coal)

In 1993, 9,080 establishments were registered as restaurants, cafeterias, grills, etc (INEI 1995) Generally, they are located in zones of high car and pedestrian traffic in Lima The informal establishments are located on the street or in houses, nearly always in densely populated zones

### B6 Scattering and burning domestic, industrial and hospital waste

Burning garbage is very common in Lima Garbage containing large amounts of paper, plastic, rubber and assimilated industrial wastes produces particulate matter and toxic gases such as ammonium salts, sulfur compounds, nitrogen oxides, uncombusted HC and methane The burning of one ton of garbage generates 8 kg of TSP, 0 5 tons of $SO_2$, 3 kg of $NO_2$, 15 kg of uncombusted HC and 40 kg of CO To understand the extent of the pollution problem, one needs only consider an estimated average of between 400 and 500 tons of garbage incinerated per day, with the resulting load of between 20 and 30 tons of pollutants introduced daily into Lima's atmosphere

## C Carbon Monoxide

Carbon monoxide associates with hemoglobin in the blood, reducing its ability to carry oxygen The effects of carbon monoxide (CO) are reversible, i e , they do not lead to chronic poisoning or

irritation of the upper respiratory tract But if an individual is exposed to high levels of CO it can lead to asphyxiation and death

### C1 Emissions and Environmental Concentration

The three most important sources of CO pollution are the automobile fleet, industry, and indiscriminate incineration of solid waste A significant percentage of emissions are produced by gasoline-powered vehicles, particularly because of incomplete combustion of gasoline in poorly tuned, older vehicle engines

Table X-3 shows ambient CO data from various monitoring sites in Lima The most extensive data at a single site is from the Conaco site at Ave Abancay, where concentrations have typically ranged from 12 5 to 50 ppm of CO The highest level observed was 100 ppm at this site during a rush hour in 1992 (DIGESA 1995, SENAMHI 1993) There is little information on the concentration of CO in industrial zones and no information on air quality near major solid waste dump sites

### C2 Dose-Response Relationships and Health Effects

Individuals exposed to CO for longer than three hours to concentrations of 12 5 ppm may accumulate blood concentrations of carboxyhemoglobin (COHb) of as much as 1 5 to 2% Effects among healthy individuals at this level are generally quite mild Blood concentrations of COHb of 2 3 - 7% cause decreased maximal short-term exercise duration in healthy people, resulting in mild fatigue Individuals exposed for periods in excess of 8 to 12 hours to concentrations of 20 ppm (perhaps street vendors, those living in close proximity to factories, public transportation operators, etc ) may attain an average level of COHb of 5%, which affects cardiopulmonary functioning and can affect visual acuity and motor and sensori-motor performance (EPA, 1994)

Cardiac patients and others who suffer angina pectoris are sensitive to short exposures to CO when they raise COHb concentrations from about to 3 to 6% (RISCPT, 1984) At these COHb levels, cardiac patients suffer increased likelihood of angina pain and decreased time until onset of angina pain when exercising

Other studies on the effects of exposure to CO raise the possibility of more chronic effects and alterations in psycho-motor functions (Rylander, 1992)

In a study realized in Lima's center by the Chemistry Faculty of UNMSM in 1995, it was determined that bus drivers, street vendors and transit police, typically showed a range of 1 5% to 1 72% of COHb Elderly people and smokers revealed concentrations of 4 7% of COHb in their blood

## Table X-3 Ambient Carbon Monoxide in Metropolitan Lima

| Station | Average Concentration (ppm) | Interval | Characteristics of the Area |
|---|---|---|---|
| Conaco (DIGESA) | **16 20** (1991)<br>20 00 (26/8/1991)<br>20 00 (8/92)<br>**12 50** (Jan-Jun 93)<br>100 (12/6/92)<br>22 00 (15 6 92) | monthly<br>daily<br>monthly<br>semi-annually<br><br>daily max | Av Abancay, Lima Heavy pedestrian and vehicular traffic, commercial zone, sidewalk artisans<br><br><br><br>Los Olivos, Northern Lima |
| Cahuide (SENAMHI) | 24 20 (1991)<br>24 74 (1992)<br>50 00 (1992) | (2)<br><br>(2) daily max | Metropolitan Lima thoroughfares Heavy traffic from public transportation |
| Other Studies (3) | 23 86 (1995) (1) | daily | Downtown Lima Commercial area Sidewalk vendors Heavy vehicular and pedestrian traffic |
| | 22 43 (1995) | daily | District of La Victoria Commercial area with abundant light industry Heavy traffic |
| | 19 57 (1995) | daily | District of Miraflores Commercial area, heavy vehicular traffic, restaurants, shops |
| | 1 08 (1995) | daily | La Molina Eastern Lima Moderate vehicular traffic Abundant landscaped areas Residential area |
| Mobile Monitoring (DIGESA) | 5 00 (1995) | daily | Av Abancay, Lima Commercial area, heavy vehicular and pedestrian traffic |
| | 25 00 (1995) | daily | See above |
| | 18 00 (1995) | daily | See above |
| | 23 00 (1995) | daily | See above |
| | 10 00 (1995) | daily | Av Universitaria and Av Peru Northern subregion Heavy traffic, commercial area artisans |
| | 28 66 (1992) | bimonthly | Primary thoroughfares of Lima - City |
| | 20 00 (1992) | bimonthly | Primary thoroughfares of Lima - Northern Sector |
| | 15 00 (1992) | bimonthly | Av Larco/Calle Shell Miraflores Heavy vehicular and pedestrian traffic commercial area |
| | 17 75 (1993) | daily | Principle thoroughfares of Lima Commercial area, sidewalk vendors, heavy pedestrian and vehicular traffic |
| Industrial Areas | 1 8 (1995) | daily | Industrial area of Lima-eastern Sector (Ñaña) |
| | 16 45 (1995) | 24-hour | Industrial area of Callao |
| | 3 75 (1994) | annual | La Pampilla (Callao) |



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### C3 Characterization and Calculation of Risk

Risks from CO in Lima are estimated by relating the ambient concentrations likely to be encountered by different segments of the population to resulting COHb levels to resulting health impacts Drawing on the available monitoring information for CO, we have constructed four exposure scenarios for different portions of the population

The first includes most of the general population of Lima who are not exposed to any unusual sources of CO We assume that these individuals are exposed to 8-hour peak concentrations of CO at levels represented by the lowest of the longer term monitoring results at the Conaco site (12 5 ppm) The Conaco site is significantly more heavily trafficked than most of the remainder of the city, so assuming the Conaco concentrations as typical for most of the city likely overestimates the risks faced by this population group We estimate that about 4,200,000 inhabitants are represented by this scenario

The second scenario includes the population living in heavily trafficked areas similar to Av Abancay at the Conaco site We assume these individuals are exposed to 8-hour peak concentrations of CO at levels represented by the higher of the longer term monitoring results at Conaco (16 2 ppm) We estimated the population exposed to higher levels of traffic to be all individuals living within 60 meters of any of Lima's major streets [1] By graphical analysis, we estimated that there are about 1,300,000 such inhabitants

The third category includes people who work in the street (approximately 300,000 individuals, including sidewalk vendors, drivers, taxi drivers, traffic police, etc ) as well as those members of the general public that spend at least several hours per day in the street We assume that these individuals are exposed for 8 - 12 hours to CO concentrations at levels of 25 - 30 ppm

The final population group includes those individuals among the three previous groups that are also exposed to high levels of CO during a 1- 2 hour commute each day in heavy traffic Based on results from mobile monitoring (by DIGESA and others), we assume that individuals while commuting might be exposed for up to two hours to concentrations of 30 to 50 ppm Alternately, these individuals may be exposed to CO levels as high as 100 ppm for up to one hour We estimate the number of commuters to be approximately 2,000,000 by subtracting the numbers of workers unlikely to commute during rush hours (e g , informal chefs, non-compensated relatives, etc ) from the aggregate number of employed workers (INEI, 1995)

For each of these four groups, we project the level of COHb that is likely to result from their hypothesized level and duration of exposure to CO Figure X-1 shows the relationship as developed by the U S Environmental Protection Agency (NAPCA, 1971)

Table X-4 shows the resulting health risks for each of the four groups of people

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[1] CO dissipates fairly rapidly as one moves away from major vehicular sources The 60 meters assumption was used in a recent study of environmental health in Quito (Arcia et al , 1993)

**Figure X-1 Effects of CO Exposure on Level of COHb**

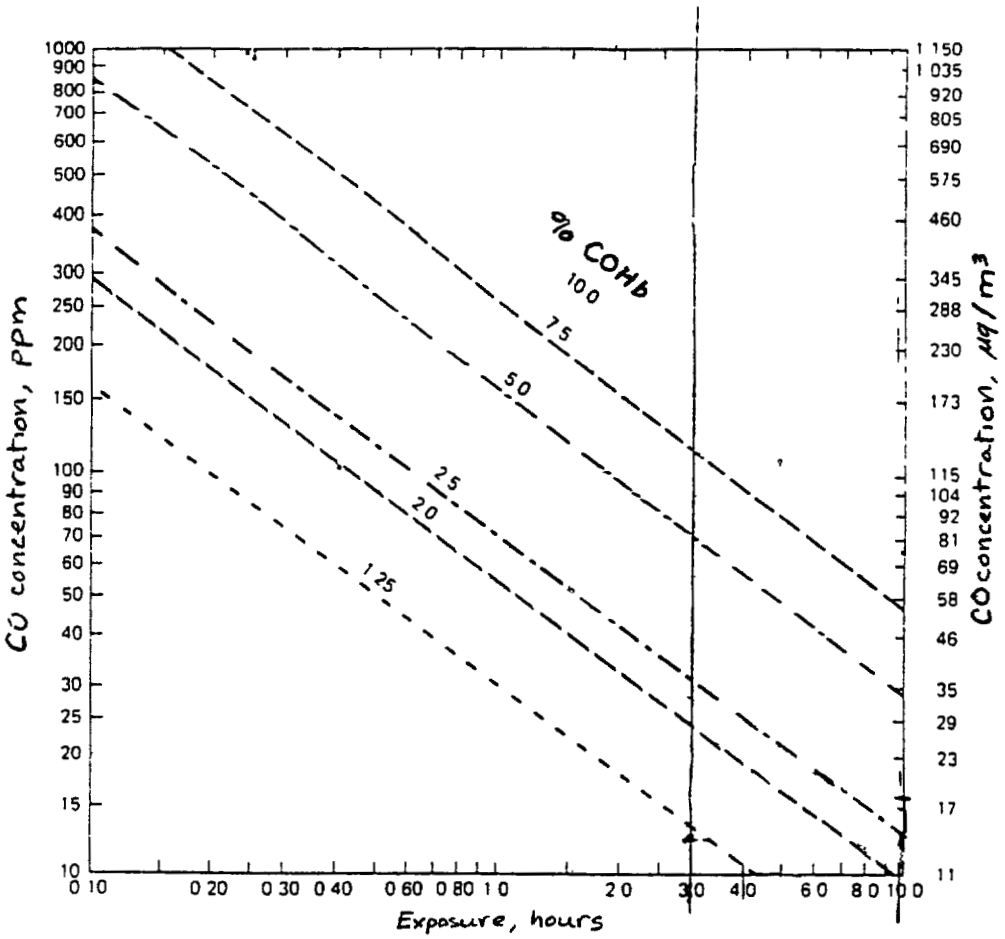




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**Table X-4 Estimated Risks from Carbon Monoxide**

| Exposed Population | | Exposure (ppm and duration) | Resulting COHb in blood (a) | Health Effects | |
|---|---|---|---|---|---|
| **Inhabitants** | **Category** | | | **In healthy people** | **In cardiac patients** |
| 4,200,000 | General population | 12 5 for 8 hrs (b) | 1 5 to 2 5% | None | None |
| 1,300,000 (c) | Live near major streets | 16 2 for 8 hrs | 2 5 to 3 5% | Decreased maximal short-term exercise duration | Increased likelihood and reduced time to onset of angina pain |
| 2,000,000 (d) | While commuting | 100 for 1 hour (e)<br>30 to 50 for 1-2 hrs (f) | 2 5 - 3 5%<br>1 25 - 3 0% | | |
| 300,000 | Work in street | 25 - 30 for 8 - 12 hrs | 2 5 to 5 5% | Headaches, fatigue<br>May affect visual acuity and motor/ sensory performance | |

(a) Based on the ratio between concentration in the air and concentration in the blood, by NAPCA
(b) Average of the lowest figures recorded by DIGESA (first six months of 1993)
(c) Population residing in the immediate vicinity of heavily traveled streets similar to Avenida Abancay
(d) Population traveling at peak hours with exposure to traffic
(e) Reading taken from a mobile monitoring unit by SENAMHI (PROCCONT Project) in June 1992
(f) Average of measurements taken at peak hours on the principle thoroughfares of Lima Cercado, La Victoria, Independencia, Miraflores, Panamericana Sur, etc

### C4 Discussion

In Table X-4 we observe health impacts of three types

- Decreased maximal short-term exercise duration in healthy people who live near major streets or are exposed while commuting This may affect the 1 3 million people who live near major streets and the 2 million people who commute and spend one or more hours in heavy traffic each day

- Increased risk of angina pain This may affect approximately 8,000 persons in Lima who have cardiovascular problems and work in the streets This effect is likely only when they are participating in demanding physical activities

- Likelihood of fatigue, headaches and difficulty concentrating for all 300,000 people who work in the streets

## D Nitrogen Dioxide

The most common nitrogen oxides are NO and $NO_2$ NO is emitted in the greatest quantity, but it is very unstable and degrades rapidly to $NO_2$ which is stable Nitrogen oxides are oxidizing



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agents In contact with water they form nitrous and nitric acids which are strong irritants to mucous membranes

### D1 Emissions and Environmental Concentration

Nitrogen oxides are produced by high-temperature combustion processes such as those involving automobiles, power plants and certain industrial applications and to a lesser degree gas and kerosene stoves and solid waste incineration

Monitoring performed by DIGESA at the Conaco site in 1995 revealed concentrations of 0 0112 ppm, 0 027 ppm and 0 064 ppm (months of September, December, and August respectively) (DIGESA, 1995) Several other measurements are also reported in Table X-5 There has been no systematic long-term monitoring of nitrogen oxides in Lima, and it is quite uncertain whether the measurements reported in the table are representative of those prevailing more generally throughout Lima

**Table X-5 Measurements of $NO_2$ in Metropolitan Lima**

| Station | Avg Conc (ppm) | Interval | Characteristics of the Area |
|---|---|---|---|
| CONACO (1) | 0 065 | month (Aug 95) | Downtown Lima<br>Heavy traffic (50 to 85 veh/min), winds 0 5 - 1 5 m/s 60 to 70% RH |
| | 0 126 | 1 hour (Aug 95) | |
| | 0 0112 | month (Sep 95) | |
| | 0 027 | month (Dec 95) | |
| | **0 05** | annual max | |
| | **0 017** | annual min | |
| Other Studies (2) | 0 092 | 24 hr (1993) | Lima-City Heavy traffic, highway interchange sector, distant dwellings |
| Industrial Areas | 0 077 | 24 hours | Lima-City Heavy traffic, far removed from dwellings |
| | 0 105(2) | 24 hours | Lima-Eastern Sector High industrial density, heavy traffic, dwellings 300 m away |
| | 0 103(3) | 24 hours | Lima-City Heavy traffic, located close to dwellings |
| | 0 026(3) | 24 hours | Lima-Northern Sector Heavy traffic, dwellings at 100m |
| | 0 002(3) | 24 hours | Callao Located next to dwellings, moderate traffic, industrial area, heavy traffic |
| | 0 01257(4) | annual | Callao Moderate traffic, far removed from dwellings |

(1) Readings taken by DIGESA
(2) Panduro, Mendoza, Vilchez (masters thesis in Environmental Management, FIA-UNI)
(3) Readings taken at the request of MITINCI (an average figure of 24 is assumed)
(4) Readings taken by the School of Petroleum Engineering – UNI

WHO s guideline for $NO_2$ is 0 170 ppm as an hourly mean, while the U S standard is 0 053 ppm as an annual average Levels of $NO_2$ in Lima appear to exceed these standards occasionally

Nitrogen oxides are also important as contributors to the formation of photochemical smog and ozone Ozone is a secondary air pollutant produced by complex atmospheric reactions of nitrogen oxides and reactive volatile organic compounds (such as are emitted from gasoline combustion) under the influence of sunlight Ozone is a respiratory irritant causing impairment of lung functions and lower respiratory symptoms such as cough and chest discomfort Ozone has not been monitored systematically in Lima Concentrations of ozone are likely to build to harmful levels during periods of thermal inversion and stable air (DIGESA, 1991)

### D2 Dose-Response Relationships and Health Impacts

Evidence of adverse impacts from exposure to $NO_2$ is much clearer for short-term exposures to high levels of the gas than it is for longer-term exposures to low levels Among asthmatics, some adverse but reversible constriction of airways may occur at concentrations between 0 2 and 0 5 ppm, whereas such acute impacts are felt by healthy individuals only at levels exceeding 1 ppm These levels do not appear to be reached in Lima

Chronic exposure to lower levels of $NO_2$ may cause a reduction in the capacity to restore lung tissue after damage by bacteria or viruses, as well as inhibition of the immune system during an infection Studies have produced conflicting evidence on the effect of $NO_2$ on rates of respiratory disease One study found that increasing indoor levels of $NO_2$ in bedrooms increased respiratory disease rates among children at 0 01 to 0 07 ppm Other studies found that similar or higher levels outdoors had no impact Another study concluded that only at higher concentrations (0 15 to 0 30 ppm) did $NO_2$ increase the frequency of respiratory diseases in children (Ackermann, 1987)

### D3 Risk Calculation and Characterization

To estimate risks in Lima from exposure to $NO_2$, we have applied one of the dose-response relationships estimated from an epidemiological study conducted elsewhere We repeat that the evidence is conflicting across such studies, and we caution therefor that the risk estimates developed here should be interpreted as suggestive only Schwartz and Zeger (1990) developed an association between $NO_2$ and the probability of increasing respiratory symptoms in adults from data in Los Angeles, California Their model was further adapted by Ostro (1994) and we use the dose-response function from this study for Lima

$\Delta$ in annual incidence of respiratory symptoms per adult = $\beta$ x $\Delta$ in $NO_2$ concentration

Where

$\beta$ = coefficient developed by Ostro (10 2, where the $NO_2$ concentration is measured in ppm)

To establish upper and lower estimates of risks from $NO_2$, we apply this relationship to both an assumed maximum $NO_2$ concentration to which the population of Lima might be exposed (0 05 ppm, the annual maximum concentration observed at Conaco) and an assumed minimum concentration (0 017 ppm, the annual minimum level observed at Conaco)



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- As an upper bound we therefore calculate that $NO_2$ may be responsible for 10 2 x 0 05 = 0 51 additional cases per year of respiratory symptoms (cough, phlegm) for each adult in Lima

- As a lower bound we calculate that $NO_2$ may be responsible for 10 2 x 0 017 = 0 173 additional cases per year per adult

Multiplying these rates of illness by the adult population of Lima (4 6 million over the age of 14 as of 1995), we estimate that $NO_2$ may be responsible for between 0 8 million and 2 3 million cases per year of respiratory symptoms among the entire city population

### D4 Discussion and Results

The calculations suggest that ambient $NO_2$ in Lima may be responsible for 0 17 - 0 51 additional cases of respiratory symptoms (phlegm production, cough or other symptoms of infection) per year per adult The range between the maximum and minimum risk estimates is broad because of uncertainty about the levels of $NO_2$ prevailing throughout Lima Furthermore, the epidemiological relationship on which this estimate is based is speculative

Monitoring by MITINCI of $NO_2$ levels near industrial facilities has, in some cases, found higher levels than those on which we based our calculations This monitoring, however, has been short term and unsystematic Without additional information we have not attempted to estimate the potentially higher health risks to residents living near these industries Ultimately, we decided that health risks due to $NO_2$ in Lima's atmosphere can be considered moderate

## E Sulfur Dioxide ($SO_2$)

Sulfur dioxide is a colorless gas that is neither flammable nor explosive At concentrations exceeding 0 3 ppm it has a noticeably pungent odor and taste Easily absorbed through the respiratory tract, at concentrations in excess of 3 ppm this gas is irritating, with its effects becoming more pronounced in combination with suspended particulate matter (total suspended particulate, or TSP) and ambient humidity It is highly soluble in water (forming sulfurous acid) and can be oxidized to sulfur trioxide (forming sulfuric acid in water) Sulfur oxides also commonly adsorb onto particles in the air, and the resulting suspended sulfates are thought responsible for much of the adverse health impacts from chronic exposures when there are low or moderate ambient levels of sulfur dioxide Airborne sulfates also cause reductions in visibility, and wet or dry deposition of acidic sulfates can cause ecological harm and damage materials such as stone or mortar Sulfur dioxide is clearly a pollutant causing economic and ecological damages as well as damages to human health

### E1 Emissions and Environmental Concentration

$SO_2$ emissions come from combustion of fuels containing sulfur by vehicles and industry In Lima, the main fuels responsible for sulfur emissions are residual petroleum #5 and #6 used by industry and power plants, diesel #1 (kerosene) for stoves and ovens, and diesel #2 used in diesel-powered motor vehicles The use of coal in ovens and restaurant stoves is also an important source of $SO_2$ emissions

in Lima Process emissions from smelting or baking raw materials (e g , ores) containing sulfur can also be a source

The monitoring performed at three stations in Lima (east cone, Lima-Cercado, Callao) revealed $SO_2$ concentrations of 0 011 to 0 0124 ppm (Holguin, 1994) Using DIGESA's monitoring data, an annual median of 0 0785 ppm can be estimated for central Lima (commercial zones and intense vehicle traffic)

MITINCI (ICDEVCO, 1995) monitored $SO_2$ in industrial zones and found levels of 0 09, 0 319 and 0 0592 ppm in Lima city, Callao and East Lima, respectively Finally, the VICON program (1992) measured levels of 0 18 ppm in zones like Cajamarquilla-El Ayllu, east of Lima

Table X-6 shows $SO_2$ concentrations in Metropolitan Lima's atmosphere Levels of $SO_2$ occurring in Lima appear frequently to exceed the WHO guidelines

### E2 Health effects and dose-response

$SO_2$ may produce both acute and chronic effects

Acute effects include bronchio-constriction and breathing difficulties The most sensitive individuals are asthmatics, who can suffer constriction of airways while pursuing heavy exercise when ambient concentrations of $SO_2$ exceed 0 4 ppm over short periods For asthmatics at rest and for healthy individuals while exercising, no effects are expected at concentrations of $SO_2$ less than about 1 ppm In some industrial zones of Lima, 24 -hour concentrations have been found at 0 319 ppm Short-term peak concentrations are undoubtedly higher than this, so it can be assumed that some asthmatics in Lima will experience some difficulties in breathing and perhaps asthma attacks as a result of $SO_2$ In general, though, $SO_2$ levels are not sufficient to cause acute effects among the healthy population

**Table X-6 Measurements of $SO_2$ in Metropolitan Lima**

| Station | Avg Conc (ppm) | Interval | Characteristics of the Area |
|---|---|---|---|
| CONACO (1) | 0 035 (1992)<br>0 018 (1993)<br>0 011 (1993)<br>0 09 (8/14/95)<br>**0 0785** (1995) | 24 hr<br>24 hr<br>annual<br>24 hr<br>annual | Downtown Lima<br>Heavy traffic (50 to 85 veh/min), winds 0 5 to 1 5 m/s, 60 to 70% RH |
| CAHUIDE (2) | 0 07 (1992)<br>0 0185 (1992) | 24 hr<br>annual | Av Salaverry, Jesus Maria district, heavy traffic (45 to 80 veh/min), areas containing no industry |
| Other Studies | 0 0124 (1990/1) | annual | Lima-Eastern Sector, A Von Humbolt Station, semi-rural |
| | 0 008 (1990/1) | annual | Lima-City, H Unanue Station, residential |
| | **0 011** (1990/1) | annual | Lima/Callao (San Marcos Station), semi-commercial |
| Mobile Stations | 0 066 | hour | Campo de Marte, Jesus Maria, Lima, residential |
| | 0 07 | hour | Panamericana Norte (Tomas Valle) |
| | 0 07 | hour | El Ayllu Huachipa, Lima-Eastern Sector |
| | 0 087 | hour | Av Salaverry-Jesus Maria/Lima |
| | 0 035 | hour | Los Proceres, Lima-Southern Sector, industrial, heavy traffic |
| | 0 06 | hour | Commercial (Ovalo Miraflores), heavy traffic (50 -70 veh/min) |
| Industrial Zones | 0 0592 (1995) | 24 hours | Industrial, Lima-Eastern Sector (3) |
| | 0 319 (1995) | 24 hours | Industrial, Callao (3) |
| | 0 09 (1995) | 24 hours | Industrial, Lima-City (3) |

(1) Monitoring conducted by DIGESA
(2) Monitoring conducted by SENAMHI
(3) Monitoring conducted at the request of MITINCI
Guidelines suggested by WHO = 0 015 to 0 023 ppm (annual average)

Longer-term exposures to sulfur dioxide have been linked by epidemiological studies to increased mortality and hospital admissions from respiratory diseases No exact causative links have been determined, but positive correlations have been found between $SO_2$ concentrations and rates of respiratory illness, hospital admissions, and death for individuals with pre-existing respiratory illness A clear independent impact of $SO_2$ on respiratory disease rates appears to exist at 24-hour concentrations of $SO_2$ exceeding about 0 2 ppm There is equivocal evidence for increases in respiratory illnesses in children and increased hospital admissions beginning at about 0 05 ppm on an annual average basis Table X-7 presents an inventory of the possible effects at different concentrations of $SO_2$ in the atmosphere

**Table X-7 Health Effects Associated with $SO_2$ Exposure**

| Concentration | Effects | Reference |
|---|---|---|
| 0 0538 to 0 088 ppm annual average | Mixed evidence for Increase in frequency of respiratory illnesses in children | Ackerman (1987) |
| 0 11 ppm for 24 hours | Increase in admissions of elderly to hospitals, due to respiratory disturbances | Walk & Wagner (1996) |
| 0 192 to 0 269 ppm for 24 hours | Increase in respiratory morbidity rate and hospitalizations | AQG (1987), EHC, 8 1972 Environmental Health Criteria N# 8 |
| 0 25 ppm for 24 hours | Increase in daily mortality rate and a marked elevation of the morbidity rate Respiratory difficulties in asthmatics | NAPCA Air Quality for Sulfur Dioxide, AP 50 Washington DC (1970) |
| 0 4 to 0 6 ppm | Changes in lung function in asthmatics with moderate-intense physical exercise | Toxics from A to Z Harte y Col University of California Press (1988) |
| 0 6 to 0 75 ppm | Changes in lung function in asthmatics with low-moderate physical exercise | Toxics from A to Z |
| 0 96 ppm | Narrowing of airways in healthy people | EPA (1989) |
| 1 0 to 2 0 ppm | Changes in lung function for asthmatics at rest | Toxics from A to Z |

### E3 Risk Calculation and Characterization

To estimate the health risks associated with exposure to $SO_2$ in Lima, we used a method developed by Ostro (1994) that has been applied in other cities also (e g Jakarta, Santiago, and Cairo)

Because of the great range in ambient concentrations of $SO_2$ observed in Lima, we performed the calculations assuming both a lower bound and an upper bound for the concentrations to which most of the population is exposed As a lower bound we chose 0 011 ppm (28 6 ug/m$^3$), the lowest annual average $SO_2$ concentration that has been monitored As an upper bound we chose 0 0785 ppm (204 ug/m$^3$), the highest annual average concentration that has been monitored

Table X-8 shows the results of the risk calculation using Ostro's methodology to estimate the annual number of three different health impacts caused by $SO_2$ 1) premature deaths, 2) cough and respiratory symptoms in children, and 3) upper respiratory irritation in adults

**Premature mortality** This represents the number of persons who die prematurely because of exposure to $SO_2$ These individuals are typically vulnerable because of pre-existing health problems, and $SO_2$ exposure hastens their death To calculate premature mortality risk, we applied Ostro's dose-response function that gives the percentage change in death rates for each 1 ug/m$^3$ change in the average $SO_2$ concentration

*% change in annual mortality = $\beta$ x $\Delta$ in $SO_2$ concentration (in ug/m$^3$)*

Where

mortality is based on a current annual rate of about 35/10,000 inhabitants in Lima, or about 23,448 deaths/yr among the population of 6 71 million

$\beta$ = coefficient developed by Ostro Ostro gives three values for $\beta$ to establish a range 0 020 for a lower bound value, 0 048 for a central estimate, and 0 121 for an upper bound

concentration of $SO_2$ is based on our assumed range for Lima of 28 6 $\mu g/m^3$ to 204 $\mu g/m^3$

**Cough and respiratory symptoms in children** We applied the dose-response function for these effects in children using the max-min $SO_2$ concentrations and Ostro's lower, central, and upper coefficient estimates ($\beta$) of 0 010, 0 0181 and 0 0262, respectively The formula is

*$\Delta$ in # of respiratory symptoms per 1,000 children/year = $\beta$ x $\Delta$ in $SO_2$ concentration (in ug/m$^3$)*

**Upper respiratory irritation in adults** We applied the dose-response function for these effects in adults over the age of 40 using the max-min $SO_2$ concentrations and Ostro's lower, central, and upper coefficient estimates ($\beta$) of 0 005, 0 010 and 0 015, respectively The formula is

*$\Delta$ in # of upper respiratory symptoms per adult/year = $\beta$ x $\Delta$ in $SO_2$ concentration (in ug/m$^3$)*

**Table X-9 Calculation of Risks from Exposure to Sulfur Dioxide in Metropolitan Lima**

**Premature Mortality**

| Affected Population | | $SO_2$ Concentration | | Range of Coefficient Estimates ($\beta$) | Risk Estimate $\Delta$ Deaths = $\beta$ * $\Delta$ $SO_2$ (in $\mu g/m^3$) * Deaths |
|---|---|---|---|---|---|
| # People | #Deaths/yr | $\mu g/m^3$ | Interval | | |
| 6,706,348 | 23,448 | 204 | annual avg | 0 00121 high | 5,788 deaths from $SO_2$ |
| | | | | 0 00048 medium | 2,296 |
| | | | | 0 00020 low | 956 |
| 6,706,348 | 23,448 | 28 6 | annual avg | 0 00121 high | 811 |
| | | | | 0 00048 medium | 321 |
| | | | | 0 00020 low | 134 |

**Respiratory Symptoms in Children**

| Affected Population | $SO_2$ Concentration | | Range of Coefficient Estimates (β) | Risk Estimate Δ Symptoms/yr/1,000 persons = β * Δ $SO_2$ (in μg/m³) |
|---|---|---|---|---|
| Children Under 14 | μg/m³ | Interval | | |
| 1,951, 547 | 204 | annual avg | 0262 high | 10,422 cases/year |
| | | | 0181 medium | 7,160 cases/year |
| | | | 010 low | 3,977 cases/year |
| 1,951,547 | 28 6 | annual avg | 0262 high | 1,461 cases/year |
| | | | 0181 medium | 1,004 cases/year |
| | | | 010 low | 558 cases/year |

**Irritations of the Upper Respiratory Tract in Adults**

| Affected Population | $SO_2$ Concentration | | Range of Coefficient Estimates (β) | Risk Estimate Δ Irritations/yr/person = β * Δ $SO_2$ (in μg/m³) |
|---|---|---|---|---|
| Adults Age 40 + | μg/m³ | Interval | | |
| 1,691,000 | 204 | annual avg | 015 high | 3 06 times/yr/adult (5 17 million total cases/yr) |
| | | | 010 medium | 2 04 times/yr/adult (3 45 million total cases/yr) |
| | | | 005 low | 1 02 times/yr/adult (1 72 million total cases/yr) |
| 1,691,000 | 28 6 | annual avg | 015 high | 0 429 times/yr/adult (725,000 total cases/yr) |
| | | | 010 medium | 0 286 times/yr/adult (484,000 total cases/yr) |
| | | | 005 low | 0 143 times/yr/adult (242,000 total cases/yr) |

### E4 Discussion of Results

Uncertainties in both the levels of $SO_2$ prevailing throughout Lima and in the dose-response relationships between ambient concentrations and health effects result in very broad estimated ranges for the resulting health risks among Lima's population We have chosen to use Ostro's central or medium estimates for coefficients in combination with the maximum and minimum $SO_2$ concentrations, and thus estimate that $SO_2$ in Lima is responsible for

- 321 to 2,296 cases of premature death per year,
- 1,004 to 7,160 cases involving respiratory symptoms in children per year, and
- 29 to 2 04 cases per year of upper respiratory tract irritation for each adult over 40 (or 484,000 to 3 45 million cases per year across the entire population)

These estimates are quite uncertain We should note that some of the higher $SO_2$ concentrations observed in Lima were found in industrial areas Industrial zones generally correspond to areas of greater population density and lower income, so it may be the case that the higher risks from $SO_2$ affect large numbers of poorer people who can least afford to prevent or treat the potential health impacts In addition to the uncertainties discussed previously, researchers often find it difficult to attribute health



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impacts separately for $SO_2$ and for particulate matter High humidity, $SO_2$ and particulate matter act synergistically to increase health risks

## F Total Suspended Particulates (TSP)

TSP are generated mostly by the combustion of hydrocarbon fuels, such as from diesel powered vehicles, industries consuming residual fuel oil #5 and #6 (cement, food, etc ), and cooking of foods in homes, restaurants or food stands Industrial process emissions can also be important sources, such as from metal working plants, smelters, glass plants, etc Incineration of solid waste is particularly important in Lima Finally, construction activities and natural sources (wind erosion, weathering of rocks) can contribute large amounts of particulates

TSP may themselves cause irritation and damage to the respiratory system when inhaled, and additional toxic effects can appear because numerous toxic substances (heavy metals, hydrocarbons, acids, sulfates, fibers) can be contained within the particles or adsorb to them

Particulates come in different sizes and cause different types of health effects Larger particles of diameter greater than 10 microns are retained in the nasal or pharyngeal mucosa Particles of between 3 and 10 microns are deposited in the pulmonary trachea Finally, the particles of less than 3 microns are transported to the pulmonary alveoli and lodge there, aggravating existing respiratory and cardiovascular disease and prompting other adverse biological responses

In addition to posing greater health risks, smaller particles can remain suspended in the atmosphere indefinitely and can travel great distances from their source Large particles tend to fall out of the atmosphere quickly

### F1 Emissions and Environmental Concentration

Relative to other large cities, some factors in Lima tend to cause high ambient concentrations of particulate matter and others tend to reduce the concentrations Factors contributing to significant particulate concentrations include

- Lack of rain As it rains infrequently in Lima, particulate matter is not washed out of the atmosphere and may remain suspended for long periods of time
- Exposed rock and soil Winds pick up dust and soil from the extensive barren areas in Lima
- Burning of solid waste This practice contributes several tons/day of particulate load to the atmosphere

Factors reducing the concentration of particulates include

- Lack of industry Metropolitan Lima includes much less highly polluting industry (e g , smelters, steel mills, cement plants) than many other cities

- Lack of fossil-fuel power plants Most of Lima's electricity comes from hydroelectric plants Coal or oil-fired power plants in other cities are among the very largest sources of particulate emissions

- Little need for home heating In many cities, dispersed combustion of coal or heating oil in residential boilers is also a major source of particulate emissions

TSP concentrations found in Lima through longer term monitoring have varied from 32 94 $\mu g/m^3$ (DIGESA station) up to 218 $\mu g/m^3$ (CONACO station) The levels measured for shorter periods in industrial zones ranged from 200 to 476 80 $\mu g/m^3$ Levels up to 799 80 $\mu g/m^3$ have been measured Table X-9 presents the most significant results found in Lima The levels of TSP found in Lima fairly consistently exceed the WHO guidelines of 60 - 90 $\mu g/m^3$

**Table X-9 Measurements of TSP in Metropolitan Lima (μg/m³)**

| Station | Avg Conc | Interval | Characteristics of the Area |
|---|---|---|---|
| CONACO (1) | 165 73 | month (Apr 95) | Lima-City (downtown), heavy traffic (50 to 85 veh/min) winds 0 5 to 1 5 m/s, 60 to 70% RH |
| | 248 01 | month (May 95) | |
| | 142 89 | month (Aug 95) | |
| | 237 97 | month (Sep 95) | |
| | 231 23 | month (Oct 95) | |
| | 284 21 | month (Dec 95) | |
| | **218 00** | annual (95) | |
| | 278 98 | month (Jan 96) | |
| | 314 66 | month (Feb 96) | |
| | 342 82 | month (Mar 96) | |
| | 309 63 | month (Apr 96) | |
| CONAGEN (1) | 156 30 | monthly | Lima-City, District of Jesus Maria, heavy traffic (50 to 85 veh/min) |
| | 161 10 | monthly | |
| | 126 80 | monthly | |
| | 148 28 | annual avg | |
| DIGESA | 64 05 | month (Mar 95) | Lima City, Disctrict of Lince, moderate traffic (6 - 10 veh/min) |
| | 20 45 | month (Apr 95) | |
| | 14 34 | month (May 95) | |
| | **32 94** | annual (95) | |
| Industrial Areas | 128 5(2) | annual | Callao, from 69 to 85% RH , wind 3 05 m/sec, heavy traffic, located a distance from dwellings |
| | 350 00(3) | 24 hours | Lima-Eastern Sector, high industrial density, heavy traffic, dwellings at 100 m |
| | 49 8(3) | 24 hours | Callao Moderate traffic (15 to 20 veh/min), far away from dwellings |
| | 250 09(4) | ND | Callao, location not specified |
| | 799 8(4) | ND | Lima-Eastern Sector, location not specified |
| | 476 3 | ND | Callao, location not specified |

(1) Monitoring conducted by DIGESA
(2) School of Petroleum Engineering (UNI)
(3) Panduro, Mendoza, Vilchez (masters thesis in Environmental Management, FIA-UNI)
(4) Monitoring conducted at the request of MITINCI (an average level of 24 is assumed)
WHO Guideline = 60 to 90 μg/m³ annual average

## F2 Health effects and dose-response

TSP may produce both acute and chronic health effects

Exposure to TSP over short periods of time will cause irritation of the mucosa of the respiratory tract, nose and eyes At a concentration of 180 $\mu g/m^3$ TSP may reduce lung functions In sensitive individuals this may exacerbate asthma, bronchitis or common colds (SAPALDIA, 1993, IFESAGE, IGE-EPFL, 1994) In sensitive non-smokers, a concentration of 200 $\mu g/m^3$ may bring on initial symptoms of bronchitis or asthma, while in smokers a concentration of 100 $\mu g/m^3$ may be sufficient It is possible that concentrations of 300 $\mu g/m^3$ in patients with chronic bronchitis may lead to an acute intensification of symptoms (Air Quality for Particulate Matter, 1969)

Research into the chronic health effects of exposure to particulate matter has consisted mostly of epidemiological studies that investigate the statistical relationships between concentrations of ambient particulate matter and various adverse health outcomes, including mortality, admissions or visits to hospitals, "restricted activity days" for adults, lower respiratory illness for children, asthma attacks, and other measures of chronic disease Among these studies, statistically significant relationships have been found using several alternative measures of particulate matter, including TSP, particles of less than 10 microns diameter (PM10), particles of less than 2 5 microns diameter (fine particles), British Smoke, coefficient of haze, and sulfates (Ostro, 1994) The studies have been conducted in several different cities and seasons, thereby incorporating a wide range of climates, chemical compositions of particulate matter, and populations Conclusions about the mathematical relationships between particulate matter concentrations and the frequency of a wide range of respiratory health outcomes have been reasonably consistent across these studies The studies have been conducted in Beijing, Sao Paulo, Santiago (Chile) as well as numerous locations in developed countries (Ostro, 1995) We are reasonably confident in extrapolating the results of these studies to Lima

These epidemiological studies, however, demonstrate only correlation and not necessarily causation The biological mechanisms that might underlie the correlation are not well understood, but plausible explanations involve both effects resulting from the physical nature of inhaled particles (e g , irritant effects, altered mucous secretion and flow leading to increased susceptibility to acute infections) and effects related to the particular chemicals comprising the particles (perhaps even including toxicity involving non-respiratory system organs and functions)

Children may be at highest risk from TSP exposure They tend to inhale particles more deeply in their respiratory system and have a higher breathing rate than do adults

## F3 Characterization and Calculation of Risk

To calculate a range of risks associated with TSP in Lima's air, we assumed that Lima's population is exposed to an annual average TSP concentration of between 32 94 and 218 $ug/m^3$ We calculated the chronic health risks that would result from exposure to these levels of TSP by using dose-response relationships described in Ostro (1994)

Ostro's equations project health risks as a function of particulate matter concentrations with particulate matter measured as PM10 As there is no monitoring data on PM10 for Lima, we assumed that PM10 in Lima would bear the same relationship to TSP as prevails in other cities Studies in other cities have found that 30 to 65% of TSP is of a diameter than smaller than 10 microns Table X-10 shows for several cities the percentage of TSP that consists of PM10 We assume that an average of 45% of Lima's TSP consists of PM10

**Table X-10 Percentage of Total Particulate Matter Consisting of PM10 in Several Cities**

| City | % PM10 of Total TSP |
|---|---|
| Los Angeles | 61% |
| Mexico, DF | 40 to 65% |
| Santiago | 55% |
| Denver | 30 to 45% |

Ostro provides dose-response functions relating ambient PM10 concentrations to three sorts of health effects premature mortality, "restricted activity days"[2] for adults, and bronchitis in children Ostro's formulas include lower bound, central and upper bound estimates for the coefficients, and we apply them to the assumed minimum and maximum ambient PM10 concentrations in Lima (45 % of 32 94 and 218 ug/m$^3$)

**Premature mortality** This represents the number of persons who die prematurely because of exposure to PM10 These individuals are typically vulnerable because of pre-existing health problems, and exposure to particulate matter hastens their death To calculate premature mortality risk, we applied Ostro's dose-response function that gives the percentage change in death rates for each 1 ug/m$^3$ change in the average PM10 concentration

*% change in annual mortality = $\beta$ x $\Delta$ in PM10 concentration (in ug/m$^3$)*

Where

mortality is based on a current annual rate of about 35/10,000 inhabitants in Lima, or about 23,448 deaths/yr among the population of 6 71 million

$\beta$ = coefficient developed by Ostro Ostro gives three values for $\beta$ to establish a range 0 062 for a lower bound value, 0 096 for a central estimate, and 0 130 for an upper bound

concentration of PM10 is based on our assumed range for Lima of 14 8 to 98 1 ug/m$^3$

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2 Restricted activity days include all days on which activities are significantly restricted due to illness The individual may stay home from work, may observe bed rest, or may work while ill at less than normal capacity

concentration of PM10 is based on our assumed range for Lima of 14 8 to 98 1 ug/m$^3$

**Lower respiratory illness or bronchitis in children** We applied the dose-response function for these effects in children using the max-min PM10 concentrations and Ostro's lower, central, and upper coefficient estimates (β) of 0 0008, 0 00169 and 0 00238, respectively The formula is

*Δ in # of lower respiratory illnesses per child/year = β x Δ in PM10 concentration (in ug/m$^3$)*

**Restricted Activity Days** We applied the dose-response function for these effects in adults using the max-min PM10 concentrations and Ostro's lower, central, and upper coefficient estimates (β) of 0 0404, 0 0575 and 0 0903, respectively The formula is

*Δ in # of restricted activity days per adult/year = β x Δ in PM10 concentration (in ug/m$^3$)*

There are other similar equations used in Canada and the U S that estimate the relationships between TSP and asthma attacks or hospital admissions or emergency room admissions due to respiratory illnesses (Ostro, 1994) However, these dose-response relationships are particularly sensitive to culture-specific asthma rates or patterns of medical treatment, and so we will not extrapolate them to Lima

Risk estimates for exposure to particulate matter are summarized in Table X-11



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## Table X-11 Risk Estimates for Exposure to TSP in Metropolitan Lima

### Premature Mortality

| Affected Population | | PM10 Conc | | Range of Coefficient Estimates (β) | Risk Estimate Δ Deaths = β * Δ PM10 (in μg/m³) * Deaths |
|---|---|---|---|---|---|
| # People | #Deaths/yr | μg/m³ | Interval | | |
| 6,706,348 | 23 448 | 98 10 | annual avg | 0 00130 high | 2,990 lives saved |
| | | | | 0 00096 medium | 2,208 |
| | | | | 0 00062 low | 1,426 |
| 6,706,348 | 23,448 | 14 82 | annual avg | 0 00130 high | 452 |
| | | | | 0 00096 medium | 334 |
| | | | | 0 00062 low | 215 |

### Lower Respiratory Illness/Bronchitis in Children

| Affected Population | PM10 Conc | | Range of Coefficient Estimates (β) | Risk Estimate Δ Cases/yr/child = β * Δ PM10 (in μg/m³) |
|---|---|---|---|---|
| Children Under 15 | μg/m³ | Interval | | |
| 1,951,547 (1) | 98 10 | annual avg | 00238 high | 0 23 cases/yr/child (0 46 million total cases/yr) |
| | | | 00169 medium | 0 17 cases/yr/child (0 32 million total cases/yr) |
| | | | 00080 low | 0 08 cases/yr/child (0 15 million total cases/yr) |
| 1 951,547 (1) | 14 82 | annual avg | 00238 high | 0 035 cases/yr/child (0 07 million total cases/yr) |
| | | | 00169 medium | 0 025 cases/yr/child (0 05 million total cases/yr) |
| | | | 00080 low | 0 012 cases/yr/child (0 02 million total cases/yr) |

### Restricted Activity Days

| Affected Population | PM10 Conc | | Range of Coefficient Estimates (β) | Risk Estimate Δ RADs/yr/person = β * Δ PM10 (in μg/m³) |
|---|---|---|---|---|
| Adults Age 25 + | μg/m³ | Interval | | |
| 2,965,000 | 98 10 | annual avg | 0903 high | 8 86 times/yr/adult (26 3 million total cases/yr) |
| | | | 0575 medium | 5 64 times/yr/adult (16 7 million total cases/yr) |
| | | | 0404 low | 3 96 times/yr/adult (11 8 million total cases/yr) |
| 2 965,000 | 14 82 | annual avg | 0903 high | 1 34 times/yr/adult (4 0 million total cases/yr) |
| | | | 0575 medium | 0 85 times/yr/adult (2 5 million total cases/yr) |
| | | | 0404 low | 0 60 times/yr/adult (1 8 million total cases/yr) |

(1) population ages 0 - 14 in metropolitan Lima

### F4 Discussion of Results

As in the case of $SO_2$, applying Ostro's range of coefficients to the minimum and maximum possible levels of TSP in Lima results in a very broad estimated range of health effects resulting from

exposure to particulate matter We have chosen to use Ostro's central or medium estimates for coefficients in combination with the full range of TSP concentrations, and thus estimate that TSP in Lima is responsible for

- 334 to 2,208 cases of premature death per year,
- 50,000 to 320,000 cases per year of lower respiratory illness among children, and
- 0 85 to 5 64 days per year of restricted activity per adult (or 2 5 - 16 7 million cases per year across the entire population)

These estimates are quite uncertain They appear to be of the same general order of magnitude as the risks from $SO_2$ and significantly higher than the risks from the other air pollutants

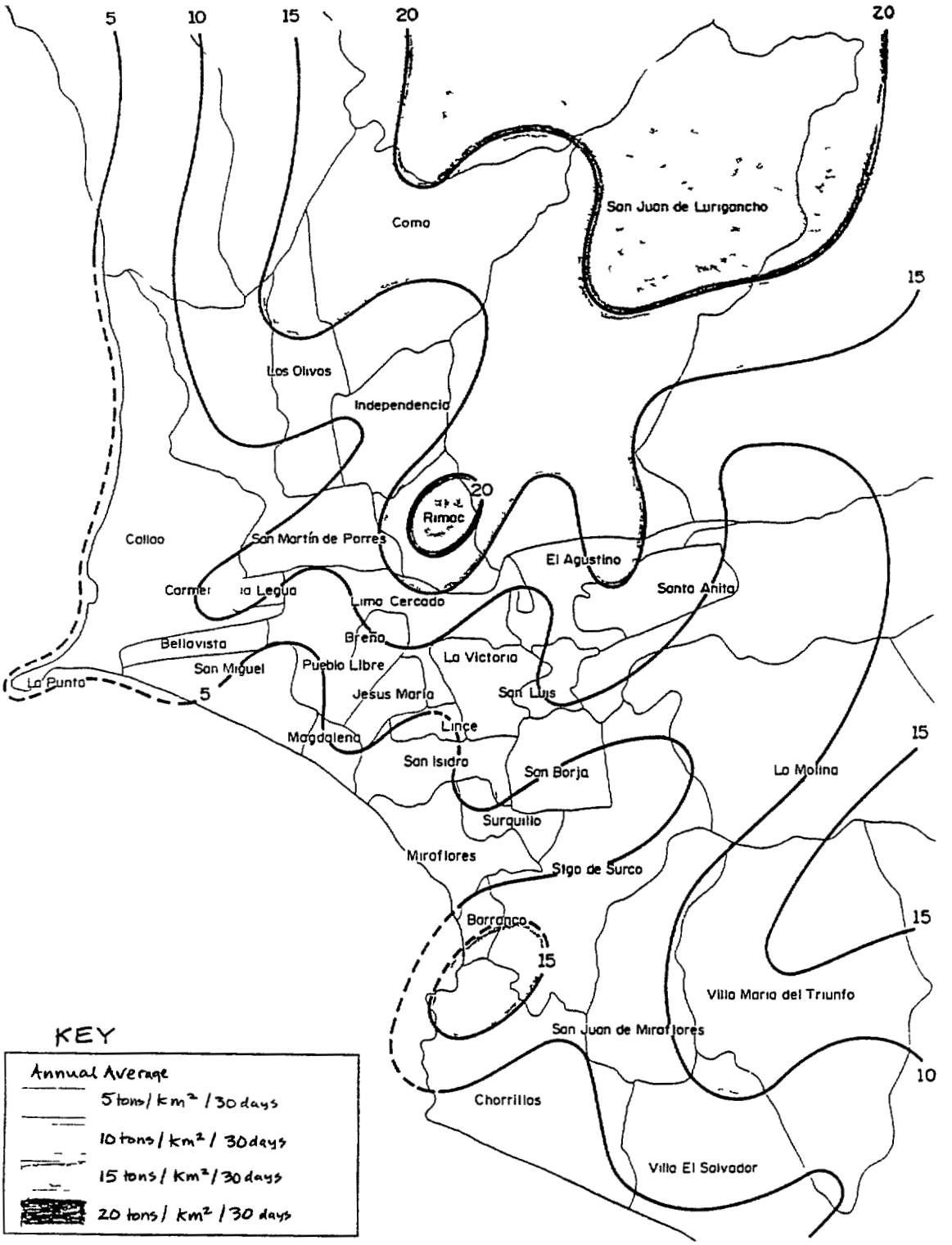
## G Dustfall

Though dustfall (particulate matter that settles out of the atmosphere) does not have direct effects on health, it provides a general indicator of air pollution and it is the parameter relating to air pollution that has been monitored most extensively in Lima Through Project VICON, SENAMHI has systematically monitored dustfall in nearly every district in Lima since 1989 The accumulated data show the spatial distribution of dustfall in Metropolitan Lima, reflecting the interaction between the locations where dust is generated and how it is transported in the atmosphere as a function of local meteorological conditions While other air pollutants may show a different geographic pattern of sources than does dust, many of the factors affecting transport will be similar for other pollutants as for dust We thus believe we may be able to learn something useful about the dispersion of other pollutants from information on the spatial distribution of dustfall

As an example at one point in time, Figure X-2 shows the concentration isolines of dustfall in March, 1992 The level of dustfall in 8 districts alone (Carabayllo, Rimac, Comas, San Juan de Lurigancho, La Perla, Los Olivos, Villa Maria del Triunfo) equals the amount of dustfall in the other 41 districts In the Rimac district, dustfall was 26 tons/km$^2$/30 days, exceeding WHO's suggested guidelines fivefold We speculate that the significant variability in dustfall across the metropolitan area suggests that a similar wide spatial variation in ambient concentrations prevails for other air pollutants also If so, the broad ranges between the minimum and maximum concentrations that we assumed for risk calculations for other pollutants seem appropriate

Across the entire metropolitan area, dustfall averaged 11 4 ton/km$^2$/30 days in 1992 and 10 5 ton/km$^2$/30 days in 1993, both well above the WHO guideline

**Figure X-2 Dustfall in Metropolitan Lima (March 1992)**



No significant relationship has been shown between dustfall and health effects In studies elsewhere, dustfall has generally been found to correlate only modestly with TSP and has not correlated well at all with health impacts On the other hand, it is evident that allergic persons can be sensitive to dust carried by the wind or by mechanical action (e g fans) Exposure routes through ingestion and cutaneous absorption are possible Heavy metals and other toxic substances may adsorb to airborne dust and indirectly cause health effects through deposition on food or water

## H Other Toxic Air Pollutants

Numerous other toxic air pollutants such as lead, benzene, formaldehyde, asbestos, cadmium and benzo-a-pyrene that may also cause adverse health effects can likely be found in Lima's ambient air Sources of these pollutants are widespread in Lima motor vehicles, industry, use of solvents and paints, evaporation and incomplete combustion of liquid fuels, etc No systematic monitoring has been performed for these pollutants in Lima, nor are they routinely monitored elsewhere in the world These pollutants can produce carcinogenic and other effects at very low levels

The only data available on these toxic air pollutants in Lima are for metals The remainder of this section addresses metals, with the exception of lead which, because of its very significant health impacts, is highlighted in a separate section of this report Many metals can cause adverse health effects when they are inhaled, for example cadmium, arsenic, manganese, mercury, chromium and vanadium Others -- for example copper and iron -- cause adverse impacts only when they are ingested Inhaled metals affect humans in distinct ways and, in most cases, with irreversible results Table X-12 shows some of the characteristics of these pollutants and the scientific bases for their health effects (IFESAGE-IGE-EPFL, 1994)

**Table X-12 Characteristics of Certain Metals and Their Effects on Health**

| |
|---|
| Aluminum Aluminum salts irritate the respiratory tract mucosae Accumulation of aluminum in brain tissue is suspected to contribute to Alzheimer's disease Long-term exposure can lead to weakening of the bones |
| Arsenic Carcinogen Cancer of the skin, lungs and liver Category A (WHO) Arsenic is stored in the liver, kidneys, heart and lungs Teratogenic effects have been shown in animals |
| Cadmium Probable carcinogen[3] (lungs, prostate) Teratogenic, can lead to decreased fertility High short-term doses can produce pneumonia, while long-term exposure to 50 $\mu g/m^3$ causes renal dysfunction A single short-duration dose of 20 to 50 $\mu g/m^3$ leads to diminished pulmonary functioning, particularly in smokers[4] |
| Copper Of concern primarily through ingestion |
| Chromium High degree of toxicity Chromium VI is carcinogenic |
| Iron Of concern primarily through ingestion |
| Manganese A cross-sectional study (EHC 17 1991) shows that long-term exposure to doses of 0 4 - 0 7 $\mu g/m^3$ can cause pneumonia Bronchitis irritation diminished pulmonary capacity may occur at higher exposures |

[3] Michaels 1988, WHO 1992

[4] Rylander 1992



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### H1 Emissions and Environmental Concentrations

Metals, though little studied in Lima, contribute significantly to air pollution Primary sources include the metal working industry, galvanoplastics, leather tanning, manufacture of electrical components, paints, glasses and pesticide components, etc Monitoring data collected by DIGESA and in industrial areas by MITINCI are shown in Table X-13

**Table X-13 Measurements of Metals in Metropolitan Lima's Air μg/m³)**

**CONACO Station, Lima-city (heavy traffic, 50 to 85 veh/min)**

| Month, Year | Copper | Iron | Zinc | Manganese | Chromium | Cadmium |
|---|---|---|---|---|---|---|
| April, 1993 | 0 1184 | 4 3414 | 1 7152 | 0 1170 | 0 0200 | 0 0137 |
| May | 0 0953 | 3 7615 | 1 4847 | 0 0861 | 0 0117 | 0 0061 |
| June | 0 1160 | 4 8840 | 2 5790 | 0 1060 | 0 0150 | 0 0100 |
| July | 0 0763 | 2 8422 | 1 9469 | 0 0658 | 0 0127 | 0 0030 |
| August | 0 0675 | 3 2747 | 1 4993 | 0 1521 | 0 0066 | 0 0031 |
| September | 0 0695 | 4 4034 | 1 4384 | 0 0783 | 0 0126 | 0 0066 |
| October | 0 0758 | 5 5198 | 0 9801 | 0 0936 | 0 0142 | 0 0075 |
| November | 0 0490 | 3 3566 | 0 7525 | 0 0564 | 0 0095 | 0 0018 |
| December | 0 0708 | 1 1908 | 0 9315 | 0 0494 | 0 0155 | 0 0037 |
| Ann avg , 1993 | **0 0821** | **3 7305** | **1 4808** | **0 0894** | 0 0131 | **0 0062** |
| March 1995 | 0 0930 | 1 3580 | 0 2670 | 0 0080 | 0 0030 | 0 0000 |
| April | 0 0810 | 2 8200 | 0 4640 | 0 0570 | 0 0110 | 0 0040 |
| May | 0 1110 | 4 1180 | 0 5810 | 0 1000 | 0 0110 | 0 0030 |
| September | - | - | 0 4060 | 0 0680 | 0 1040 | - |
| Ann avg , 1995 | **0 0370** | 2 7653 | 0 4295 | 0 0583 | **0 0323** | 0 0023 |

**DIGESA Station, Lima-City (light traffic, 6 to 10 veh/min)**

| | | | | | | |
|---|---|---|---|---|---|---|
| March 1995 | 0 0930 | 1 3580 | 0 2670 | 0 0080 | 0 0030 | 0 0000 |
| April | 0 0190 | 0 2190 | 0 1240 | 0 0020 | 0 0020 | 0 0010 |
| May | 0 0180 | 0 0270 | 0 0470 | 0 0270 | 0 0080 | 0 0050 |
| Ann avg , 1995 | 0 0433 | **0 5347** | **0 1460** | **0 0123** | **0 0043** | **0 0020** |

**Industrial Zones (2)**

| | | | | | | |
|---|---|---|---|---|---|---|
| Maximum Level | 2 3900 | - | 4 4000 | 0 0292 | 0 0200 | 0 0400 |
| Minimum Level | 0 4000 | - | 2 6600 | 0 0202 | - | 0 0200 |

(1) In the subsequent risk calculations, maximum and minimum levels from this table have been used
(2) Levels of 0 24 μg/m³ of aluminum and 3 4 μg/m³ of arsenic have also been found



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Health-based guidelines have been established by the WHO for only two of the six metal air pollutants for which monitoring data in Lima is available Cadmium levels in Lima appear frequently to exceed WHO guidelines (0 002 $\mu g/m^3$), while manganese concentrations in Lima seem to be below the guideline level (0 3 $\mu g/m^3$)

## G2 Characterization and Calculation of Risk

Risk estimates for these airborne metals in Lima appear in Table X-14, in which USEPA risk information from IRIS (Integrated Risk Information System) was applied to the monitored concentrations in Table X-13 As can be seen in the table, the annual number of cancer cases potentially caused by the two carcinogens -- cadmium and chromium VI -- is modest at a maximum of about 34 cases/year across the entire population [5]

Non-cancer health effects are unlikely from any of the metals with the exception of chromium, since their non-cancer Hazard Indices (HI) are generally significantly less than one The HI for the maximum concentration of manganese in residential areas is 1 78, however, the HI for the minimum concentration is well below one at 0 24 Similarly, both the maximum and minimum HIs for manganese in industrial areas are below one For chromium the hazard index is either 2 15 (minimum) or 16 15 (maximum), indicating some (probably modest) risk of adverse non-cancer health effects

In general, exposures at Hazard Indices exceeding one are not necessarily safe, but neither are they unsafe Because of safety factors incorporated when establishing a reference concentration (RfC) for non-cancer effects from a pollutant, health risks can typically be expected to begin to appear only when exposures exceed the RfC by two or more orders of magnitude We judge that it is unlikely that there is any significant risk related to exposure to chromium or manganese at Hazard Indices of 16 15 or 1 78, respectively

For other metals for which we have monitoring data (copper, iron, arsenic and aluminum) there is no evidence that inhalation can cause cancer and no reference concentration (RfC) for non-cancer effects by inhalation has yet been determined

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[5] Only the chromium VI portion of total chromium is carcinogenic To estimate cancer risks from chromium VI, therefore, we had to estimate the fraction of the total chromium monitored in Lima's atmosphere that was hexavalent We developed a lower and an upper bound by making two assumptions the USEPA's estimate that 5% of total chromium is hexavalent, and a second estimate by Mancuso (1975) that a maximum of 63 % of total chromium is hexavalent

## Table X-15 Calculation of Risks from Metals in Lima's Air

| Agent | Concentration | | Cancer Effects | | | | Non-cancer Effects | |
|---|---|---|---|---|---|---|---|---|
| | | | Unit Risk per µg/m³ | Lifetime Individual Risk | Individual Risk per Year of Life (a) | Pop Risk (cases of cancer/year) (b) | Reference Concentration RfC (µg/m³) | Hazard Index (HI) |
| Cadmium - residential area | Max | 0 006 | 0 0018 | 1 08E-05 | 1 71E-07 | 1 1467 | 1 80 | 0 003 |
| | Min | 0 002 | 0 0018 | 3 60E-06 | 5 71E-08 | 0 3839 | 1 80 | 0 001 |
| Cadmium - industrial area | Max | 0 040 | 0 0018 | 7 20E-05 | 1 14E-06 | 7 6448 | 1 80 | 0 022 |
| | Min | 0 020 | 0 0018 | 3 60E-06 | 5 71E-08 | 0 3839 | 1 80 | 0 011 |
| Total Chromium - residential area | Max | 0 0323 | - | - | - | - | 0 002 | 16 15 |
| | Min | 0 0043 | - | - | - | - | 0 002 | 2 15 |
| Hexavalent Cr - residential area (c) | Max | 0 0203 | 0 0120 | 2 44E-04 | 3 87E-06 | 25 95 | - | - |
| | Min | 0 0002 | 0 0120 | 2 40E-06 | 3 81E-08 | 0 2555 | - | - |
| Total Chromium - industrial area | Max | 0 0200 | - | - | - | - | 0 002 | 10 00 |
| | Min | - | - | - | - | - | 0 002 | - |
| Hexavalent Cr - industrial area (d) | Max | 0 0126 | 0 0120 | 1 51E-04 | 2 40E-06 | 16 09 | - | - |
| | Min | - | - | - | - | - | - | - |
| Manganese - residential area | Max | 0 089 | - | - | - | - | 0 05 | 1 78 |
| | Min | 0 012 | - | - | - | - | 0 05 | 0 24 |
| Manganese - industrial area | Max | 0 029 | - | - | - | - | 0 05 | 0 58 |
| | Min | 0 020 | - | - | - | - | 0 05 | 0 40 |
| Zinc - residential area | Max | 1 481 | - | - | - | - | 700 00 | 0 002 |
| | Min | 0 146 | - | - | - | - | 700 00 | 0 0002 |
| Zinc - industrial area | Max | 4 400 | - | - | - | - | 700 00 | 0 006 |
| | Min | 2.660 | - | - | - | - | 700 00 | 0 004 |

(a) Avg Life expectancy = 63 years
(b) Population = 6,706,000 people
(c) Hexavalent Cr is 5 - 63% of total Cr Applied 63% to total Cr max and 5% to the total Cr min to get max/min estimates of hexavalent Cr
(d) See above Assumed 63% of maximum total Cr was hexavalent

## H Conclusions and Recommendations

1 As previously indicated, there are no standardized practices for air quality monitoring in Lima Many of the reported results do not specify the sampling period, the exact location, or the analytical method The very limited amount of monitoring information together with this common lack of precision as to the specific meaning of the information that does exist combine to create a great deal of uncertainty regarding the maximum and minimum levels of air pollution to which citizens of Lima are typically exposed

2 The risks we have calculated have an even greater margin of uncertainty Although the dose-response functions and analytical methods applied enjoy worldwide recognition, they are subject to inherent uncertainties that are compounded by extrapolating them to Lima When this uncertainty in dose-response relationships is added to uncertainty regarding the ambient concentrations of the pollutants in Lima, our estimates of risk become suggestive only

3 Biological air pollution is an area not addressed by this report, since no information was available in this regard It is assumed, however, that ARIs and other diseases such as tuberculosis and pneumonia result primarily from poor hygiene, medical care, nutrition and housing If so, it is probably not fruitful to think of addressing biological air pollutants in the same way as one typically addresses other sorts of air pollutants -- by reducing their emissions

4 The growth in the size of the automobile fleet due to policies governing the importation of used vehicles, the increase in investments in the industrial and commercial sectors, and the trend toward centralization in Lima all contribute to increasing concentrations of atmospheric pollutants, with a corresponding increase in health risks

Carbon Monoxide

5 The CO risk calculation has a high degree of uncertainty It is questionable whether the DIGESA data (from the high traffic CONACO station and mobile monitoring in high traffic zones) should be assumed to be representative for most of the population of the Metropolitan area Thus far, CO has tended to be monitored in locations where it is expected to be found in unusually high concentrations

6 Very modest health risks from CO are likely to occur among the general population that lives near busy streets or commutes in congested areas Individuals in the streets for long periods (e g street vendors) are likely exposed to levels near the threshold at which they will show symptoms of fatigue and headache More than 8,000 individuals with cardiac disease may develop signs of angina pectoris, if they are exposed to intense traffic in some of Lima's major streets

7 Since CO dissipates rapidly over time and space, infrequent mobile monitoring during periods of high traffic is not a reliable indicator of the concentrations to which most of the population is exposed More monitoring intended to characterize typical exposures is recommended

8 The area assumed to be affected by traffic on major streets (60m on both sides), can vary according to the height of the buildings, the roads and green area density

9 The relationship between COHb in the blood and the level and duration of exposure to CO (developed by NAPCA) applies for average individuals Others may show lesser or greater responsiveness to CO

Nitrogen dioxide

10 The risks estimated for $NO_2$ exposure appear modest (0 173 to 0 51 cases of respiratory symptoms per year per adult) We feel there is significant uncertainty about this The available ambient $NO_2$ measurements have not been sufficient to characterize the variation in concentrations across seasons Concentrations and risks might increase substantially in the summer due to unfavorable thermal inversions Also, studies have indicated that $NO_2$ risks are more prominent indoors than outdoors The indoor studies have concentrated on risks to young children, among whom $NO_2$ can cause increased incidence of ARIs, especially cases of acute bronchitis and pneumonia However, we have not included impacts on children in our outdoor risk assessment due to the lack of accepted dose-response relationships for these impacts

Sulfur Dioxide

11 The estimated premature mortality attributable to $SO_2$ of 321 to 2,296 individuals per year is significant The risks estimated for symptoms such as "cough in children" and upper respiratory irritations in adults appear to be consistent with the high rate of ARIs in Lima

12 There has been controversy among researchers as to whether these sorts of health impacts can be attributed to $SO_2$ specifically, or whether they are due to a combination of $SO_2$, particulate matter and humidity We are therefore more confident in the summed risk estimates for $SO_2$ and TSP than in the risk estimates for either pollutant individually There is clear evidence, however, that $SO_2$ by itself can exacerbate health risks for allergic or asthmatic individuals, by aggravating rhinitis, pneumonia and bronchitis in children and elderly persons

13 The scattered available monitoring data show levels of $SO_2$ in Lima that vary over a wide range (by a factor 7 to 8 from low to high), making it difficult to characterize the level to which most of the population is exposed Systematic and representative monitoring is necessary, especially in the residential areas of industrial zones

Particulate matter (TSP)

14 The estimated risks in terms of premature mortality and increase in respiratory symptoms are of the same general magnitude as those from $SO_2$, making these two pollutants the most important in terms of the health risks they pose As for $SO_2$, the range of estimated health risks is broad due both to uncertainty in dose -response relationships and uncertainty in the levels at which most of the population is exposed

Metals

15 Using DIGESA's data, with the exception of chromium (and lead, discussed elsewhere), airborne metals do not present important risks to Lima's population However, areas of the city affected by major industrial sources may experience higher risks, as limited MITINCI monitoring data near industrial sites show higher concentrations

Air Pollution in General

The general public's lack of awareness about the air pollution problem (those in technical circles are aware) has meant little support for air pollution monitoring in Lima and for investigation of the health consequences of air quality in Lima We recommend development of an information campaign focused on this problem

The rapid growth in the size of the vehicle fleet suggests that air quality is likely to worsen in the future in Lima

To date, air pollution monitoring has been quite limited in Lima Existing monitoring is insufficient to characterize the spatial and temporal variability in air quality Future monitoring efforts should choose sampling locations systematically Appropriate analytical methods should be used Averaging times should be noted carefully (e g , annual average vs daily peaks vs hourly peaks, etc ) Monitoring should include several parameters that we suspect may cause significant health impacts in Lima that have not heretofore been monitored PM10, fine particles, ozone

There is evidence that high risk population groups (e g , the poor, large numbers of children) are located in critical zones (industrial areas or urban centers) We recommend that priority be given to monitoring suspected areas that have high concentrations of both people and air pollution

We think it useful to focus an epidemiological study on individuals, especially children, that spend substantial time in the streets with high pollutant concentrations This study could associate ambient air levels, lead and COHb concentrations in blood, and medical, clinical, socio-economic and cultural data

## SECTION XI
## OCEAN POLLUTION

### A The Problem in Lima

The coastal valley in which Lima lies is suitable for relatively limited agricultural activity and spans only 90,000 hectares With the exception of the Rimac, Chillon and Lurin river valleys, Lima has a desert ecosystem It is flanked on the east by the Andes mountain range, and on the west by the Pacific Ocean Lima's coast has two principal bays, Callao Bay and Miraflores Bay

The coastal location was a strategic factor in the founding of the city The ocean continues to strongly affect the economic and social dynamics of the capital and the coastal waters are a valuable resource for the city Aside from transportation and commerce, coastal waters provide a major food resource In addition, over the past twenty years, they have become the principal recreation area for most of Lima's population, especially during the summer As many as 10 different uses for the coastal waters have been cited (Punto Focal Peruano, 1994), some of them mutually conflicting

The ocean is regarded as a key attribute of the city, however, the effects of urban activity are not always favorable Because of Lima's population growth and the increase in human activity, the coastal waters have become the principal receptacle of its liquid and solid waste Projections of economic and population growth for the next few years indicate that the pollution load will increase if this situation is not remedied

Calculating the combined flow from all outfalls into the ocean (domestic and industrial sewers and polluted rivers), we can estimate that the Lima's coastal area receives 52 7 $m^3/s$ of highly polluted water during the highest river flow periods The organic load is approximately 95,000 tons per year of BOD Estimates indicate that households contribute a substantially greater proportion of organic and solids loads than industrial activities (Table XI-1)

Callao Bay -- which has been categorized as "highly" polluted -- receives water from the Rimac It also receives waste from the fishing industry, which has high organic content, from manufacturing industries, which discharge various effluents, accidental spills of oil and hydrocarbons that occur during port operations, and from household effluents, which have high organic and bacterial loads (CUANTO, 1996)

**Table XI-1 Pollution Load along the Coast of Lima, 1986**

| Parameter, unit | Household | % | Industrial | % | Total |
|---|---|---|---|---|---|
| Total volume, $m^3$/yr | 278,327 | 90 07 | 30,691 | 9 93 | 309,018 |
| BOD5, tons/yr | 85,448 | 90 14 | 9,348 | 9 86 | 94 796 |
| COD, tons/yr | 192,084 | 96 19 | 7,599 | 3 81 | 199,683 |
| TSS, tons/yr | 105,612 | 91 13 | 9,269 | 8 07 | 114,881 |
| Dissolved solids, tons/yr | 208,050 | 64 17 | 116,181 | 35 83 | 324,231 |
| ST, tons/yr | - | - | 2,862 | 100 | 2,862 |
| Grease & oils, tons/yr | - | - | 14,974 | 100 | 14,974 |
| Alkali, tons/yr | - | - | 2,006 | 100 | 2,006 |
| Ammonia, tons/yr | - | - | 16 | 100 | 16 |
| Sulfide, tons/yr | - | - | 5,298 | 100 | 5,298 |
| Nitrate, tons/yr | 18,810 | 100 | - | - | 18,810 |
| Phosphates, tons/yr | 2,280 | 100 | - | - | 2,280 |
| Other, tons/yr | - | | 4,800 | 100 | 4,800 |

Source Loayza and Sanchez 1989

The quality of the ocean waters and sediments, as well as the presence of metals in marine organisms, are indicators of pollution problems The Ministry of Health, the Peruvian Ocean Institute [Instituto del Mar del Peru] (IMARPE), the Office of Hydrography and Navigation (DIHIDRONAV) and the Municipality of Miraflores all periodically monitor the water quality along the beach, especially during the summer Due to the effects of a complex series of meteorological, climatic and hydrogeologic factors (in addition to the volume and characteristics of the polluting effluents), the quality of the water, and therefore its suitability for swimming, is highly variable

Numerous samples have detected indicators of fecal contamination well above the maximum recommended for bathing (5000 MPN/100 ml) A study conducted on the Costa Verde in 1987 found fecal coliform bacteria present on all beaches in the region, and 41% of the samples exceeded the recreational water quality standards (Vergara, 1987) Studies conducted by PROMAR on the spread of sea pollution indicate the following high-pollution areas (fecal coliform bacteria >5000 MPN/100 ml)

- From La Pampilla to La Punto in Northern Lima,
- South of the Costanero outfall for approximately 2 5 km, and
- Around the Surco outfall for approximately 3 km

The pollution levels on the remaining beaches vary, but their water generally does not exceed allowable limits

Some beaches have been declared unfit for recreation, on both the north and south coast During the summer of 1996 (Week 10), DIGESA closed the San Judas Tadeo and Mar Brava beaches in Callao,

Marbella (Costa Verde), La Chira and Club Cultural Lima (Chorrillos) It declared as unfit the beaches at Ancon and Playa Hermosa (Ancon), Carpayo 1 and 2 (Callao), Agua Dulce, Pescadores, Club Regatas 1 and 2 (Costa Verde) and Mamacona, Caballeros Sur, San Bartolo, Pucusana and Bujama Norte (Playas del Sur)

Samples of water quality, sediments and marine organisms taken in 1992 in the two principal bays show the impact of the concentrated industrial activity in the northern part of the city (Punto Focal, 1994) In Callao Bay, the concentrations of BOD and organic matter in sediments are substantially higher than in Miraflores Bay Moreover, traces of hydrocarbons and heavy metals were found in the water, sediments and marine organisms (Table XI-2)

**Table XI-2 Concentration of Pollutants in Callao and Miraflores Bays**

| Parameter | Callao Bay | Miraflores Bay |
|---|---|---|
| **In water** | | |
| BOD5 (mg/l) | 0 51-5 8 | 0 80-3 64 |
| Sulfides (µg S-SH2/l) | 0 23-0 69 | - |
| TSS | 103-496 | 102-335 |
| Hydrocarbons | 0 21-5 73 | - |
| **In sediment** | | |
| Sulfides (µg S-SH2/l) | 0 26-4 12 | - |
| Organic matter (%) | 1 46-28 28 | 1 36-8 81 |
| Hydrocarbons (aromatic content) µg/g | 1 18-50 27 | - |
| Mercury (µg/g) [sic] | 0 4-0 7 | - |
| Copper (µg/g) | <20 mg/kg | - |
| Cadmium (µg/g) | 0 1-6 0 | - |
| **In living organisms** | | |
| Petroleum hydrocarbons (ng/g) | | |
| *A purpuratus* (scallop) | 0 45 | - |
| *Fissurella lutimarginata* (limpet) | 0 18 | - |
| *Semele corrugata* (clam) | 0 20 | - |
| *Thais chocolata* (snail) | 0 16 | - |
| Mercury (ng/g) | | |
| *Semimytilus algosus* | 10-140 | - |
| *Argopecten purpuratus* | 5-25 | - |
| *Gari solida* | 15-100 | - |
| Copper (µg/g) | | |
| *Semimytilus olgosus* | 1-2 | - |
| *Gari solida* | 2-3 | - |
| Cadmium (µg/g) | | |
| *Semimytilus olgosus* | 1-4 5 | - |
| *Gari solida* | 1-3 | - |

Readings taken in the coastal waters by IMARPE and CORDECALLAO (1994) detected species of *Vibrio* on different northern beaches This did not, however, indicate the presence of toxigenic *Vibrio cholerae* It is presumed that the species of vibrio found are part of the microflora characteristic of the marine waters of the mixing zone (IMARPE, 1994a, 1994b)

## B Health Risks from Pollution of the Ocean

The direct pathways by which marine pollution may cause adverse health effects include direct contact (e g , while swimming), ingestion of water, and respiration of aerosols Other, indirect pathways involve fish and seafood used for human consumption or processed for animal feed (fish meal) In addition, toxins are produced by cyanobacteria that proliferate as a result of the polluting organic load It has also been shown that sediments on beaches can be a major source of bacteria in recreational areas The movement of the waves or the activity of bathers help to resuspend the organisms deposited as sediment (Seyfried, unpublished) People most commonly put themselves at risk of exposure to marine pollution through any of these pathways by 1) Swimming or otherwise recreating at marine beaches, and 2) Eating seafood We discuss risks associated with contaminated seafood in the section on food contamination In the remainder of this section, we develop a rough estimate of the number of cases of illness stemming from recreation at Lima's beaches

Establishing a precise correlation between the level of contamination in sea water and the likelihood of contracting an illness from swimming in it is extremely difficult This is due to the many confounding factors involved In the 1950s, epidemiological studies conducted by Stevenson showed that the incidence of respiratory and gastrointestinal illnesses among swimmers in relatively polluted waters was higher than the incidence among swimmers in clean waters (Stevenson, 1953) Subsequently, it was found that although the risk of contracting a wide variety of respiratory, eye, ear, nose, throat and skin ailments seemed to increase with swimming in contaminated water, the swimming-related illness that correlated most directly with water pollution was gastroenteritis (Cabelli, 1977) It was also shown that morbidity among swimmers is related to the counts of staphylococcus, fecal coliform bacteria and, to a lesser extent, fecal streptococci (Seyfried et al , 1985)

The correlations between water quality and cutaneous and ophthalmologic diseases are not yet clear While some studies report that there is no relationship between levels of fecal coliform bacteria, enterococci and *Pseudomonas aeruginosa* and the incidence of otitis externa, others indicate that the total count of fecal streptococcus, coliform bacteria and staphylococcus in fresh surface water can be correlated with morbidity (Seyfried et al , 1985)

An epidemiological study of risk in a population exposed to the waters of polluted beaches, conducted in Miraflores Bay in 1995, found that bacteriological pollution caused a statistically significant increase in the rates of digestive and respiratory illnesses, although at marginal levels ($p<0\ 05$) The authors conclude that there is a morbidity effect of very little magnitude (no significant clinical repercussions) from exposure to polluted waters on the beaches of Miraflores Bay It was further concluded that the beach-morbidity risk ratio is higher for respiratory than for digestive

conditions, and that the general risk of morbidity is at least twice as high in children under 10 (Gastañaga et al , 1995)

In summary, these and many more existing studies on the relationship between pollution of recreational waters and disease show some consistent conclusions and some contradictions While almost all research on the topic has demonstrated that swimmers are much more likely than non-swimmers to contract gastrointestinal illnesses and probably also respiratory, eye, ear and skin infections, the statistical correlation between the risk of illness and the density of indicator bacteria in recreational waters varies between studies Many of the studies are limited to correlating illness rates with swimming-related activities, and do not attempt to correlate illness rates and organism densities In studies that do attempt to develop a dose-response relationship between the risk of illness and the level of water pollution, the numerical data vary between study sites, and no single microbiological indicator has been identified by a majority of the researchers as the best for indicating disease risk The source of these differences is uncertain, it is unclear whether they arise from inherent differences between the study sites or study populations, or from differences between the approach researchers have taken in evaluating the relationship between water-related illnesses and water quality (Environomics, 1995)

In estimating the number of cases of swimming-related illnesses that occur in Lima from pollution of the beaches there, we have chosen to reflect this uncertainty about dose-response relationships by using two different relationships to provide a range of estimates

The first dose-response relationship we use was developed by Cabelli and Dufour (1983) through studies at several sites in the U S They have worked out relationships that correlate the frequency with which "highly credible gastrointestinal illnesses (HCGI)" occur among swimmers and the concentrations of enterococci and *E coli* in the water in which the swimming occurred

*# of HCGI symptoms / 1000 swimmers = 5 88 + 6 3 log (mean E coli concentration/100 ml)*

The second relationship was developed by Cheung et al (1990) from studies at beaches in Hong Kong It relates the frequency of gastrointestinal (GI) and skin infections to the concentration of E coli in the bathing water

*(# of GI + skin infections) / 1000 swimmers = -14 99+10 85 log (mean E coli concentration/100 ml)*

To estimate the number of illnesses among Lima's population that result from swimming in contaminated sea water, we combine these two dose response functions with additional information from the international epidemiological literature (Environomics, 1995) and information specifically from Lima on the frequency with which people swim and the bacteriological quality of water at the beaches

- Based on the literature, we assume that there will be approximately 2 5 cases of other illnesses per GI case, or 1 4 cases of other illnesses per (GI + skin) case

- Also based on the literature, we assume that there will be 30 % as many secondary infections among non-swimmers as there are primary infections occurring among swimmers *Primary infections* are illnesses from contact with or accidental ingestion of polluted sea water Individuals who contract these infections may then transmitted them to other individuals who had no contact with the contaminated medium, resulting in *secondary infections*

- The number of people swimming each year at Lima's beaches is estimated by assuming that
  i) summer in Lima lasts 14 weeks,
  ii) an average of 200,000 persons come to Lima's beaches each Sunday (the most crowded day) during the summer (newspaper sources),
  iii) Half as many people (100,000 persons) come on Saturdays,
  iv) 10% as many (10,000 persons) come on weekdays, and
  v) only half the people on Lima's beaches go into the water

  With this information, it can be calculated that there are 3,500,000 visitors to the beach during a summer season, of whom half (1,750,000) are at risk

- Based on the available monitoring information, we have assumed 20% of this population use beaches that are highly contaminated with fecal organisms (>1000 MPN/100 ml) with an average exposure of 1000 MPN/100 ml, 20% visit beaches with a medium pollution level (500-1,000 MPN/100 ml) and an average exposure concentration of 750 MPN/100 ml, 20% visit beaches with low contamination (0-500 MPN/100 ml) and an average exposure concentration of 250 MPN/100 ml, and 40% use unpolluted beaches

Applying the two dose-response ratios for *E coli* (assuming that concentrations of fecal coliform bacteria are equal to those for *E coli*), it can be calculated that swimming at Lima's beaches causes between 50,000 and 150,000 cases of gastrointestinal and other illnesses each summer Given the uncertainties in the underlying dose-response functions and the numerous assumptions made in applying these relationships to Lima, this estimate is highly uncertain

## SECTION XII
## HAZARDOUS SOLID WASTE

### A Identification of the Problem

This report discusses hazardous solid waste from three sources (HSW) hospitals and clinics, industry, and households The primary types of hazardous waste from clinics and hospitals are biocontaminated materials and chemicals such as pharmaceuticals and disinfectants Industry produces a very broad range of hazardous wastes including toxic metal and organic compounds, acids, ignitable materials and many others Household hazardous wastes include cleaning products, pesticides, paints and some biocontaminated material HSW can cause illnesses through a wide variety of pathways it can contaminate water, air, or food, and can cause illness via direct contact and transport by vectors The health problems caused by HSW range from acute effects to chronic illnesses from longer term exposure, such as cancer, kidney and liver malfunctions and disorders of the nervous system

### B The Problem of Hazardous Solid Waste in Metropolitan Lima

Of the waste produced each day in Metropolitan Lima, about 300 MT (8 5%) is toxic hospital or industrial waste The volume of domestic HSW produced is unknown, but we estimate that there is probably more domestic HSW produced than there is hospital waste, and much less than the amount of industrial HSW Since for the most part HSW is not regulated or managed distinctly from other varieties of wastes in Lima, there is very quantitative information about its generation and disposition Of the three sources (hospitals, industry, homes), information about hospital waste is the most detailed and reliable

Lima has no special collection procedures for HSW In general, households, hospitals and some industries make no effort to separate their hazardous wastes from non-hazardous wastes, and the combined mixed wastes are collected together Different wastes are mixed in the same collection vehicle Nearly 5,500 municipal workers collect 60% of the solid waste Lima generates Some waste is collected informally Informal workers use trucks or tricycles to collect household hazardous and nonhazardous waste and then separate valuable recyclable components out of the mixture under unprotected conditions Details available on the collection of HSW are insufficient for our purposes

Most HSW is thus managed in the same manner as solid waste generally (see the section on Solid Waste) Only about 65 % of solid waste is collected, with the remainder being left in the streets, dumped in nearby vacant areas, or burned Of the amount collected, about one third is transported to one of two sanitary landfills These are "El Zapallal" in the Carabayllo district, in northern Lima, and "Portillo Grande," 55 km south of Lima, in the Lurin district At both sanitary landfills, there are special cells for HSW Generally these cells receive wastes from hospitals, consisting of mixed hazardous and non-hazardous materials "El Zapallal" receives approximately 812 tons of waste/day This is 24% of the household solid waste generated in Lima "Portillo Grande" receives 300 tons/day The remaining

two thirds of wastes that are collected is dumped elsewhere, perhaps in one of 17 identified informal dumps, or perhaps simply in a convenient open area

There are two exceptions to the general practice of mixing hazardous wastes with non-hazardous wastes and co-disposal of the two First, some hospitals mix their hazardous and non-hazardous wastes, but then have the combined waste transported to and disposed at the HSW cells at the two sanitary landfills Second, many industries, because of their large volume of waste generated, manage their HSW on-site through recycling or disposal in piles or impoundments rather than have the waste transported elsewhere

Of the two sanitary landfills, only Zapallal permits recycling About 400 people participate in this activity at Zapallal About 2,000 recyclers work at other dumps Another 2,600 people collect recyclable materials in their homes, businesses, offices, streets, open areas, and along the shores of the Rimac and Chillon rivers These 5,000 people, along with 5,500 municipal workers and an unknown number of *tricicleros* and others who provide services informally, are at high risk from the toxic, caustic or infectious constituents in hazardous solid waste

### B1 Hospital Hazardous Solid Waste

Hospitals and clinics are major sources of biocontaminated waste Of the 3,535 MT of solid waste generated daily in Lima (IPES, 1996), 491 health facilities generate about 30 MT/day Over half of this is contaminated (15 4 MT) or hazardous (1 MT) However, minimal separation of these wastes from ordinary wastes occurs in these facilities, and the resulting mixed waste should be considered as hazardous The resulting hospital wastes are typically collected rather than disposed on-site, but ultimate disposal can then occur at sites ranging from the special cells at the sanitary landfills to informal roadside dumps Thus, it is unlikely that most of the waste is treated properly either inside or outside the facility

The General Directorate of Environmental Health (DIGESA) has advocated a system for classifying medical waste (DIGESA, 1995) Biocontaminated waste includes waste from patient care, biological material, human blood or substances derived from blood, surgical and anatomical waste, puncturing and cutting instruments, and contaminated animals Special waste has three components hazardous chemicals, pharmaceuticals, and radioactive waste Ordinary waste includes other waste materials such as paper, cardboard, glass, plastics, etc Another hospital waste classification system, the Integrated System for Hospital Waste Management (SIRES), has also been proposed, but it has not been implemented

Special waste (chemical, pharmaceutical and radioactive) from hospitals poses a relatively insignificant threat to human health There is only a small quantity of this type of waste generated and it is generally not disposed of in populated areas, reducing the risk of exposure The only citizens at risk would be the 10,500 who work in refuse collection and recycling Of those, only a few would have significant exposure levels

### B2 Industrial Hazardous Solid Waste

Industry is the principal source of hazardous waste chemicals, perhaps about 270 MT/day The industrial sectors producing this waste are metal products (68 7%), metals (11%), printers (10 6%), oil refineries (6%), and textiles and tanneries (2%) Ate Vitarte -- where 4% of the population of Metropolitan Lima lives -- produces the most chemical solid waste The Ate Vitarte district has the highest number of metal product, textile and tanning factories in Lima It also has the second largest number of printing and paper plants Table XII-1 summarizes available data on the location and nature of hazardous solid wastes generated by the most important industries Table XII-2 indicates how these industries manage their hazardous wastes A majority of metal industry wastes are recycled, with significant proportions dumped on-site Organic hazardous wastes from other industries are frequently burned for energy recovery

We estimate that over 30% of the population of Lima lives in districts with more than 20 metal product factories That industry generates nearly 70% of the non-biocontaminated hazardous solid waste from industrial sources

Solid waste of industrial origin can cause adverse health impacts through direct contact as well as by contaminating air and water The analysis of air and water contamination and the resulting health effects are discussed in the air and water sections of this report

### B3 Hazardous Household Solid Waste

Studies on the production and composition of solid waste in Lima have not analyzed the characteristics and volume of domestic HSW In addition, there are no studies on routes and mechanisms used to dispose of this waste However, we have assumed that domestic HSW receives the same treatment as normal solid waste The public cleaning service in Lima does not provide a way for the population to separate HSW from other waste for collection Household HSW is put into the same containers as other refuse

Because of the common lack of flush toilets and/or consistent water availability, in many residences toilet paper is not disposed of in toilets, but in garbage cans If it is assumed that each person produces an average of 5 grams of biocontaminated material per day (including toilet paper, sanitary napkins and syringes or other material contaminated with blood or feces), then 37 5 MT of biocontaminated waste is produced daily in Lima This is more than double the amount of biocontaminated waste from the city's hospitals and clinics Most of this is disposed of in illegal or informal dumps In addition to waste handlers, there are several subgroups of the population who are more likely to come into direct contact with this informally handled biocontaminated waste Children who play in or near informal dumps risk exposure There is also an unknown number of people who live on the dumps Finally, informal recyclers who scavenge the dumps for recyclable materials are also at risk All of these people will have a high risk of direct contact with biocontaminated waste The likelihood that they or vectors will come into contact with biocontaminated material is higher in the

informal dumps This is because the waste at the informal dumps is not covered over as is usually done at controlled landfills

It is more difficult to estimate the amount of hazardous chemical waste produced in the home Since it is rare for a product to be thrown away before it is used up, most of the hazardous solid waste from homes consists of residues in containers The greatest danger comes from interactions between the residues from an original product and an introduced substance when the container is reused Despite this, because of its small quantity (in comparison with biocontaminated waste), hazardous chemical waste from household sources poses a fairly low risk

## C Health Effects Caused by Hazardous Solid Waste

For the above reasons, and in comparison with the other environmental problems currently being experienced in Metropolitan Lima, we do not believe that hazardous chemical waste from household or hospital sources has a serious impact on the health of the average citizen Generally speaking, the volume of hazardous chemical waste produced or stored in homes, clinics and hospitals is not sufficient to cause considerable harm

The population most exposed to chemically contaminated HSW is factory workers Waste handlers and public cleaning personnel are much more likely to be exposed to biocontaminated HSW

Biocontaminated solid waste presents a high risk to health This is because of the volume produced and number of sources that produce it (each house is a potential source of pathogenic residue when toilet paper is not disposed of in the toilet) It is considered that direct contact with contaminated substances is the main risk to health Vectors may also spread biocontaminants to food or water Due to Lima's scarce precipitation, it is improbable that pathogenic organisms from HSW will reach surface or underground water supplies

Contact with biocontaminated waste via the fecal-to-oral pathway can cause diarrhea and other illnesses such as cholera and parasitic infections The effects vary from mild illness of a few hours duration to occasionally severe incapacity and death It is not possible to quantify illness from this source, however, health statistics show that infectious diseases, especially diarrheal diseases, are one of Lima's most serious health problems

## D Discussion

Biocontaminated household solid waste represents the major threat to health from HSW This is because of its volume and the lack of proper mechanisms for its disposal The population directly exposed to HSW is a minimum of 10,500 This includes workers from the public and informal cleaning sectors and people exposed due to inadequacies in collection, treatment and disposal services

There is more uncertainty about health effects associated with hospital waste Although collection and disposal plans and regulations seem to be adequate, the extent to which they are complied with is uncertain

The lack of data on toxic industrial solid wastes precludes making any estimates of associated health effects We expect that rather limited populations are exposed to these wastes

## E Limitations of the Analysis

The limited information on production, storage, transport routes and disposal of HSW does not permit any estimates of illness and risk in Lima

It would be beneficial to develop a comprehensive plan on the handling and treatment of different types of HSW in Lima Special attention could be given to the following

- The study of HSW generation and management for each industrial sector
- An integrated collection, disposal and treatment service for HSW
- The use of dedicated, secure cells for HSW in sanitary landfills
- Improved collection and disposal of domestic HSW, involving public participation
- Revision of the institutional and legal framework for the handling and treatment of HSW

**Table XII-1 Summary of Hazardous Industrial Solid Waste Generation**

| Industry | % of Total[1] | Districts w/ Factories w/ 20+ Workers | Important Constituents in Hazardous Solid Waste[1,2,3] |
|---|---|---|---|
| Metal products | 69% | Ate<br>San Martin de Porres<br>Lima District<br>La Victoria<br>San Luis<br>San Juan de Lurigancho<br>Chorrillos | metal waste (slag) & metal dust<br>inorganic sludges w/ heavy metals<br>halogens<br>emulsified oil<br>organic<br>polychlorobenzenes<br>explosive waste |
| Common metals | 11% | Ate | sludge from scrubbing, w/ heavy metals |
| Printing and paper | 11% | Lima District<br>Ate | sludges w/heavy metals<br>acid sludge<br>phenols<br>NDMA<br>xylene<br>pentachlorophenol |
| Oil refining | 6% | | alkalines and acids<br>inorganic solids<br>oily clays<br>phenols<br>xylene<br>nitrobenzene |
| Textiles and tanning | 2% | Ate<br>La Victoria<br>San Martin de Porres<br>San Juan de Lurigancho<br>Chorrillos | hardened sludge<br>NDMA<br>xylene<br>naphthalene |
| Chemicals, rubber & plastic | 2% | Ate<br>Lima District<br>Chorrillos<br>Los Olivos<br>San Martin de Porres<br>San Juan de Lurigancho | sludges w/ heavy metals<br>phenols<br>NDMA<br>xylene<br>pentachlorophenol<br>hexachlorobenzene<br>insecticide residues |

1 ICDEVCO Desarrollo Industrial y Uso Sostenible del Ambiente [Industrial Development and Sustainable Use of the Environment] MITINCI Lima, June 1995

2 Oroza, Jorge and Zucchetti, Anna Microempresa y Medio Ambiente [Microenterprise and the Environment] PAMIS-COPEME Lima 1994

3 ATSDR Declaraciones de Salud Publica de Sustancias Peligrosas [Declarations on Public Health and Hazardous Substances] Atlanta 1995

4 IPES La Basura en Lima, problemas y soluciones [Garbage in Lima, Problems and Solutions] Lima 1996



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**Table XII-2 Industrial Hazardous Waste Management**

| Industry | Recycling | Sanitary Landfill | Open-Air | Other |
|---|---|---|---|---|
| **Metal Products** | 54 5% | 18 2% | 27 3% | |
| **Common Metals** | 61 5% | 3 9% | 23 1% | 11 5% |
| **Printing and Paper** | 27 9% | 19 0% | 13 1% | 40 0% |
| **Oil Refining** | 10 5% | 2 6% | 21 2% | 65 7% |
| **Textiles and Tanning** | 28 7% | 12 1% | 8 3% | 50 9% |
| **Chemicals, Rubber and Plastic** | | | | |

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IPES La Basura en Lima, Problema y soluciones [Garbage in Lima, Problem and Solutions] Lima 1996

DIGESA Diagnostico Situacional del Manejo de los Residuos Solidos de Hospitales Administrados por MINSA [Situational Study of Solid Waste Handling in Hospitals Administered by MINSA) Loan 741/OCPE Lima 1995

Integrated Coastal Development Company Peru S A (ICDEVCO) Proyecto Desarrollo Industrial y Uso Sostenible del Ambiente [Project for Industrial Development and Sustainable Use of the Environment] MITINCI Lima, June 1995

Aranda Study of the United Nations Center for Human Settlements 1990

# SECTION XIII
# RESIDENTIAL INDOOR AIR POLLUTION

## A Overview

Indoor air pollution in enclosed spaces can be a considerable public health problem It is estimated that an average citizen spends 16 hours in residences, offices, workshops, stores, schools or other enclosed spaces, breathing contaminants from indoor sources and from outdoors that have migrated indoors

The sub-populations at greatest risk from indoor air pollution include children, the elderly, and hyper-sensitive individuals (e g asthmatics) In comparison with the levels found in occupational settings, residential indoor air pollutants are generally found in lower concentrations Nevertheless, the exposure periods are much longer, as people often spend from 12 to 16 hours per day at home

Indoor air pollution varies from one setting to another Its effects depend on outdoor air quality, house construction and layout, and the occupants' activities and sensitivities Most contaminants are classified as either chemical or biological Biocontaminants include fungi, microbials, mites, bacteria and allergens Chemical contaminants include VOCs, CO, $NO_2$, $SO_2$, particulate matter, breathable fibers, pesticides and radon, among others

Generally, these contaminants are inhaled and first affect the respiratory system (local action) Some are absorbed and distributed where they can affect other organs (systemic action) Health effects caused by indoor air pollutants include hypersensitivity illnesses (pneumonia, asthma, allergic rhinitis), infectious diseases (colds, bronchitis, german measles), intoxication syndromes (carboxyhemoglobin in blood, pesticide poisoning), and a wide variety of other impacts (e g , cancer, toxic effects from lead) The relationship between an indoor air pollutant and an illness is rarely direct and obvious In most cases there are many possible causes of any particular illness, with indoor air pollution usually being only one of several possible contributors to the illness (Bernard 1993)

## B Major Sources of Indoor Air Pollution in Lima

Information specifically relating indoor air quality to health problems in Lima does not exist, and information on the levels of indoor air pollution in Lima is very limited Because of this lack of data, we begin our discussion with a review of the major sources that will determine the quality of indoor air in Lima This is a complex issue to summarize, due in part to the significant variation between population subgroups in Lima with regard to socio-economic level, housing characteristics, consumption (e g , of fuel, food, water), hygiene conditions, activities, etc

### B1 Indoor combustion of kerosene, wood and other materials

Kerosene, wood, and other fuels burned for cooking, lighting, heating, and also burning of wastes in the home all produce gases and particulate matter (organic and non organic emissions) High temperature combustion of these fuels can also produce nitrogenated species (Traynor, 1983) The most common combustion gases are $NO_2$, CO and $SO_2$ Particulate matter (TSP) and volatile organic compounds (VOCs) can be found in high concentrations in non-ventilated areas, especially in workshops within the homes These workshops may use furnaces, welding equipment, forges, and other equipment that emits pollutants which compromise indoor air quality

These pollutants from combustion are often produced in enclosed spaces with little opportunity for dissipation People, especially women, children and the elderly, may spend long periods of time in the spaces where the pollutants are generated, for example around a stove in the kitchen

In Lima it is estimated that approximately 2,400,000 people cook with kerosene, 3 628,000 use propane gas, and 15,200 people use wood For lighting, 82,900 people use burners or small kerosene lamps and 64,000 inhabitants use wax candles or other material Table XIII-1 and Table XIII-2 present data on the types of fuel used for cooking and lighting, respectively

**Table XIII-1 Sources of Energy for Cooking**

| Type of Residence | Electricity | | Propane Gas | | Kerosene | | Wood or Other | |
|---|---|---|---|---|---|---|---|---|
| | Quantity | % of Total (1) | Quantity | % of Total (1) | Quantity | % of Total (1) | Quantity | % of Total (1) |
| Detached Houses | 31,006 | 2 90 | 443 121 | 41 1 | 329,736 | 30 84 | 681 | 0 06 |
| Apartments | 9,236 | 0 860 | 84,717 | 7 92 | 9,470 | 0 88 | 1,257 | 0 117 |
| "Quinta" Housing | 2,067 | 0 193 | 30,330 | 2 83 | 12,635 | 1 18 | 0 | 0 |
| "Vecindad" Housing | 0 | 0 | 11,864 | 1 11 | 23,396 | 2 18 | 0 | 0 |
| Other Types | 0 | 0 | 13,558 | 1 26 | 59,872 | 5 6 | 878 | 0 082 |
| Total | 42,309 | 3 95 | 583,590 | 54 58 | 435,109 | 40 68 | 2,816 | 0 259 |

Source INEI, 1995
(1) Percentage of all residences in Lima 1,069,069

**Table XIII-2 Sources of Energy for Lighting**

| Type of Residence | Electricity | | Kerosene | | Candles or Other | |
|---|---|---|---|---|---|---|
| | Quantity | % of Total (1) | Quantity | % of Total (1) | Quantity | % of Total (1) |
| Detached House | 792,269 | 74 10% | 7,322 | 0 68 | 8,040 | 0 752 |
| Apartments | 105,831 | 9 89% | 0 | 0 | 0 | 0 |
| "Quinta" Housing | 43,904 | 4 1% | 1,128 | 0 105 | 0 | 0 |
| "Vecindad" Housing | 35,366 | 3 308% | 0 | 0 | 901 | 0 084 |
| Other types | 64,360 | 6 02% | 6,904 | 4 08 | 3,044 | 0 284 |
| Total | 1'041,730 | 97 42% | 15,354 | 4 865 | 11,985 | 1 12 |

Source INEI, 1995
(1) Percentage of all residences in Lima

Many residences in Lima double as workshops, some kind of economic activity takes place in about 180,000 homes in Lima (12 9%) It is estimated that approximately 50,000 children and elderly persons are directly exposed to indoor air pollution associated with these home-workshops (INEI, 1995)

Burning of solid waste, whether inside the home or just outside of the home, can radically affect indoor air quality In marginal neighborhoods in Lima (inhabited by approximately 1,870,000 people), solid waste is estimated to be burned in 35 - 40% of the homes (Fitzgerald, 1994)

### B2 Tobacco smoke

Tobacco smoke produces various gases and particulate matter More than 4,500 compounds have been identified in tobacco smoke with only 50 of them having been studied for their health impacts CO, $CO_2$, benzene, toluene, formaldehyde, and acetone have been studied in their gaseous phase Nicotine, phenol, aniline, benzopyrene, cadmium, nickel, polonium 210, benzoic acid, and lactic acid have been studied in the fine particle phase

In Lima 34% of men and the 7 3% of women are smokers (Boffeta, La Vecchia et al , 1993) Some studies in poor neighborhoods have established an average smoking rate of 11 to 16 cigarettes/week/smoker (Fitzgerald 1994) The highest average smoking rate occurs in the middle class

### B3 Volatile organic compounds (VOCs)

The USEPA has identified more than 500 VOCs that can be found in indoor air They come from a wide variety of sources and activities, such as

- Construction and decorating materials, such as parquet, glue, paint, varnish and lacquer, etc (formaldehyde, benzene, toluene, ethylbenzene, etc )

- Furniture made with mixed wood, contact glues, dissolving agents, etc (formaldehyde, methyl-chloroform, etc )

- Products for domestic use cosmetics, deodorizers, lotions, cleaners, solvents, pesticides (methylchloroform, styrene, trichloroethylene, benzene)

- Products of incomplete combustion, from burning of wood, kerosene, foods, trash (formaldehyde, nitronaphthalene, dioxins)

### B4 Types and construction of housing

The degradation of construction materials and the use of low quality materials can contribute to physical pollutants and toxic chemicals in indoor air Such pollutants include dust, asbestos fibers, synthetic mineral fibers like those from textiles (curtains, carpets, wall paper), and temporary construction materials, such as straw and wood planks, etc Paint containing lead or formaldehyde may release these pollutants into the indoor environment The dirt floor stores biological and chemical agents that are transmitted via dermal contact or ingestion, children are particularly at risk here

In Lima, 167,502 (12 2%) families live in inadequate housing (excessive humidity, poor ventilation and sun exposure, poor construction) Table XIII-3 shows the predominant construction materials in Lima's houses 19 3% have dirt floors, 12 4% have wooden and straw walls and 13 8% have straw and cane roofs In marginal neighborhoods, more than 100,000 children under 5 years old live in houses with straw walls and roofs Around 100,000 young children also live in homes with excess humidity

**Table XIII-3 Leading Construction Materials in Houses**

| Walls | | Floors | | Roofs | |
|---|---|---|---|---|---|
| **Predominant material** | **(%)** | **Predominant material** | **(%)** | **Predominant Material** | **(%)** |
| Bricks and cement | 73 | Parquet | 17 2 | Concrete | 52 |
| Stone or ashlar | 0 6 | Linoleum | 3 8 | Wood | 9 7 |
| Sun dried clay brick | 9 1 | Tile | 12 9 | Roof tile | 1 0 |
| Reed walls and adobe | 1 6 | Wood | 2 2 | Corrugated iron | 13 9 |
| Wood | 4 2 | Cement | 43 6 | Cane and straw | 13 8 |
| Straw | 8 2 | Dirt | 19 3 | Others | 9 6 |
| Others | 3 3 | Others | 3 2 | | |
| TOTAL | 100 | TOTAL | 100 | TOTAL | 100 |

Room location (especially for the kitchen and toilets) and ventilation capacity also influence health risks 12 8% of Lima's houses do not have a separate cooking area, while 5% share the kitchen with another domestic function 10 2% of the houses do not have toilets and 70% of the houses in shanty towns are only "half constructed", (a house must have at least one completed story of living space to count as "constructed")

### B5 Biological air pollutants

People with infectious diseases and the presence of domestic animals generate microorganisms that contaminate indoor air (bacteria, viruses and fungi) Excrement from insects and mites can be inhaled by those in the house and may cause an allegic reaction The fungic endotoxins in poorly ventilated and humid environments can potentially increase allergies The custom of sprinkling the floor (cement or dirt) with water can accelerate the growth of fungi and other microorganisms

Overcrowding worsens the biocontamination of indoor air (Fitzgerald 1994) 165,000 homes in Lima (inhabited by approximately 800,000 persons) are estimated to be overcrowded Nearly 10% of the dwelling units are occupied by two or more families Table XIII-4 shows the extent of overcrowding (INEI,1995)

**Table XIII-4 Overcrowding in Metropolitan Lima's Houses**

| # Families/Dwelling Unit | (%) | Averages | (%) | Type of Space for Kitchen | Houses (%) |
|---|---|---|---|---|---|
| 1 | 91 | # persons/unit | 5 1 | Exclusive space to cook | 80 2 |
| 2 | 6 5 | # rooms/unit | 3 23 | Shared space to cook | 5 2 |
| 3 | 1 2 | # persons/room | 1 57 | No space to cook | 12 8 |
| 4 or more | 0 8 | # persons/bedroom | 2 29 | ND | 1 8 |
| ND | 0 5 | | | TOTAL | 100 |
| TOTAL | 100 | | | | |

Source INEI Statistic Compendium 1994-1995
(1) INEI has calculated that 11 9% homes in Lima and Callao are overcrowded (approx 170,000 homes)

## C Levels of Indoor Air Pollutants and Health Effects

### C1 Nitrogen Dioxide ($NO_2$)

A study performed in 10 houses that used kerosene for cooking in the shanty town of Bayovar, in San Juan de Lurigancho, northeast of Lima (Languasco and Maldonado, 1993) found average values lower than 0 1 ppm for $NO_2$ in indoor air Health studies have found only very equivocal evidence of an increase in rates of respiratory infections among children exposed to $NO_2$ concentrations of less than 0 1 ppm However, another study performed in the shanty town Huascar (Canto Grande) did not rule



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out the possibility that $NO_2$ produced by kerosene stoves could increase risk of respiratory symptoms in children under 30 months of age (Fitzgerald 1994)

### C2 Carbon Monoxide (CO)

A study in Guatemala looked at CO levels in kitchens where wood was the primary cooking fuel source (Veras et al 1989) They found an average of 4 5% COHb (5 4mg/dl) in mothers that cooked using wood as a fuel source Such levels would be sufficient to produce symptoms of headaches, fatigue and poor visual perception This was an average of 1 2% more COHb in blood than for those who cooked with propane gas

Monitoring by Languasco and Maldonado in the shanty town of Bayovar in northeastern Lima found very low concentrations of CO, with averages of 0 5 ppm at a distance of one meter away from the gas ring For enclosed spaces, WHO has set a 5-minute limit of 87 3 ppm EPA has set a 1-hour standard of 35 ppm and an 8-hour standard of 9 ppm The concentrations of CO in indoor air in Bayovar houses were quite low due to high rates of ventilation CO quickly dissipates to the outside because residences in the shanty town are usually made of straw or are unfinished, and generally do not have glass in windows

### C3 Sulfur Dioxide ($SO_2$)

$SO_2$ is produced by combustion of fuels containing sulfur Houses with small, informal or formal workshops often show concentrations of $SO_2$ higher than other residences, and kerosene and charcoal stoves may also yield $SO_2$ emissions Monitoring in the shanty town of Bayovar revealed levels of between 0 and 0 1 ppm $SO_2$ at one meter from kerosene and charcoal stoves (this distance is considered to represent a typical exposure for a person working at the stove) Such levels of $SO_2$ are not high enough to cause any acute health effects There is weak evidence that long-term exposure at this level may increase susceptibility to respiratory infections These values are similar to those found by Leaderer et al (1984) in the U S between 0 023 and 0 057 ppm $SO_2$ in houses that used kerosene heaters and <0 00076 ppm in houses that do not use kerosene

For exposure to $SO_2$, WHO has set a 10-minute limit of 0 19 ppm, a one-hour limit of 0 13 ppm, and 24-hour limit of 0 04 ppm during warm weather The USEPA has set a 3-hour limit of 0 5 ppm, a 24-hour limit of 0 14 ppm, and annual average of 0 03 ppm

### C4 Carbon Dioxide ($CO_2$)

Sources of $CO_2$ in indoor air include gas or kerosene stoves, tobacco smoke and outdoor air The typical values in the indoor environment vary from 700 to 800 ppm and in non-ventilated areas can exceed 2,000 to 5,000 ppm (Fernandez and Caldas, 1992) The typical concentration for ambient outdoor air in an urban area is 400 ppm Languasco and Maldonado did not monitor $CO_2$ levels in their study in Bayovar

### C5 Particulate Matter

When there is tobacco smoke present, indoor air can have particulate matter concentrations of up to 1000 ug/m$^3$ (Cost, 1989) The values found in Lima by Languasco and Maldonado (1993) reach averages of 304 ug/m$^3$ in houses with kerosene stoves measured at one meter from the gas ring during cooking In the houses with briquette stoves an average of 458 ug/m$^3$ was found The values found outdoors averaged 332 ug/m$^3$ Any of these levels are sufficient over the long term to increase rates of respiratory illness The study concluded that both outdoor air and the type of stove were important in determining the concentration of particulate matter in indoor air

### C6 Tobacco Smoke

Tobacco smoke is harmful to the health of both those who smoke and others near those who smoke ("second-hand smoke" or "passive smoking")

Many studies show that levels of CO, particulate matter, $NO_2$ cadmium and other harmful compounds in smokers' homes are much higher than in those of non-smokers In the shanty town of Huascar, 41% of children live with light smokers (1 to 20 cigarettes a day) and 3 2 % with heavy smokers (>21 cigarettes per day) (Fitzgerald 1994) Children whose parents smoked showed significantly more respiratory symptoms (like coughing, breathing difficulties, and bronchitis) compared to children not exposed (RR=1 94 in children of 12 to 30 months of age) A study in Brazil determined that in the 11 9% of children with parents who smoke, there was significantly higher incidence of bronchitis than in those whose parents were non-smokers Other studies conclude that tobacco smoke can increase susceptibility to other indoor air pollutants (Holland et al 1978)

In Lima, the incidence of lung cancer (likely related to tobacco use) is currently about 4 - 7 cases per year per 100,000 inhabitants in the 35 to 64 year old age group This rate appears to have declined from about 10 cases per year per 100,000 in 1967 (Boffeta, La Vecchia et al , 1993) The incidence in men is 3 times higher than in women

### C7 Volatile Organic Compounds (VOCs)

There is virtually no information about levels of VOCs in indoor air in Lima Nevertheless, we know that products that can result in VOC emissions are widely used , such as paints, solvents, floor waxes, glues, disinfectants, cosmetics, and construction materials produced by informal industry Another important source of VOCs is economic activities taking place in workshops in residences Here, residents are continuously exposed to VOCs, and sensitive populations like young children, the elderly and those who are sick may face major health risks

In normal houses, Languasco and Maldonado found levels of formaldehyde of between 0 12 and 0 20 ppm at a distance of 20 cm from the gas ring of kerosene stoves, but did not detect it at the one meter distance representing a typical respirable zone No hydrocarbons were detected WHO's permissible limit for formaldehyde is 0 1 ppm



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### C8 Biocontaminants

Biocontamination in Lima's indoor air can be caused by many factors Overcrowded conditions affecting at least 900,000 people increase the likelihood of their contracting infectious illnesses by inhalation

Kozak et al (1985), assert that outdoor air is the most important source of biocontamination and that infectious agents can be transported via the air over long distances However, different studies have identified overcrowding and housing conditions as the main causes of biocontamination of residential indoor air For example, Fitzgerald (1994) finds an important relationship between overcrowding, socioeconomic factors, floor humidity and tobacco smoke, which all result in increased incidence of coughing, difficulty breathing, and risk of contracting pneumonia and bronchitis in children under 6 years of age

Health risks caused by biocontaminants can also be associated with commercial preparation or storage of food in houses

## D Risk Characterization and Calculation

In this section we develop some rough estimates of risks from indoor air pollution in Lima, using cause-effect relationships developed in other contexts In addition to uncertainties stemming from limited world-wide understanding of the health impacts of indoor air pollution, there is additional uncertainty due to several characteristics of housing in Lima

- Housing conditions vary widely across socio-economic strata Luxurious residences fully equipped apartments, single-family homes, casas-quinta, half constructed houses, and houses with provisional and inadequate roofs and partitioned walls are all representative of housing in Lima

- The temperature variation between summer and winter is less extreme than in more temperate climates There is little need for tight housing and mechanical heating and cooling systems Air exchange from the inside to the outside is high and in many cases indoor air pollution is highly related to outdoor air quality

It should be noted that the activities, habits and physiological characteristics of residents of Lima may also differ importantly from those of the populations where indoor air pollution studies have taken place Such factors as how often individuals use household pesticides and nutritional level and immunologic response, are also important factors in estimating risk

Despite these cautions, we have developed rough risk estimates for indoor air pollution in Lima resulting from the following conditions combustion products from cooking stoves, indoor burning of wastes, passive and active smoking, overcrowded and improper living conditions, and maintenance of workshops in homes

### D1 Risks from combustion products

**Table XIII-5 Risk Calculation for Combustion Products in Kitchens**

| Risks | Exposed population | Scientific basis | Risk estimation |
|---|---|---|---|
| Respiratory infection cases in children from 2 to 4 years of age | 162,900 children in Lima in homes with gas stoves and no separate kitchen Assumed level of 0 1 ppm $NO_2$ | Speizer Infection rate increased by 35/1000 upon proximity to gas stoves, at an average concentration of 0 9 ppm $NO_2$ | Assuming linear relationship, about 630 respiratory infections per year are due to gas stoves |
| Increase of respiratory symptoms due to gas stoves in children from 0 to 4 years of age | 325,000 such children in Lima in homes with gas stoves and no separate kitchen About 9,500 such children from shanty towns | Neas et al (USA) Increase of 5% to 29% in incidence of respiratory symptoms in children (cough or phlegm) due to the use of gas stoves rather than electric stoves | Assume incidence of cough in shanty towns is 10 22 cases/child/year (Fitzgerald, 1994) Change from gas stoves to electric could avoid 4,800 to 28,000 cases of cough/yr in Lima's shanty towns |
| COHb increase in blood of mothers that cook with wood This might be extended to people that work in restaurants and poultry shops also | 11,937 homes in shanty towns use wood for cooking Average values of 5 7 mg/m$^3$ of CO | Veras et al (Guatemala) Concentration of 5 4 mg/m$^3$ of CO resulting in 4 5% COHb | 11 937 mothers with more than 4 5% COHb will suffer fatigue, headaches and difficulty concentrating |

### D2 Risks from waste incineration

Fitzgerald found an increased likelihood of coughing among children in homes where wastes were burned indoors relative to those in homes where this practice did not occur (relative risk of 1 257) This study was performed in shanty towns in Lima, in which there are 164,000 children under 30 months of age This practice occurs in roughly 35 % of the homes in these areas, affecting perhaps 59,000 young children These children could avoid 2 6 cases per year of cough if waste incineration were no longer practiced in their homes ( 257 x 10 22 cases of cough/child/yr on average)

### D3 Risks from tobacco smoke

The following table estimates risks of three sorts

- Cancer in male and female smokers,
- Cough in young children in shanty towns with parents who smoke, and
- Acute respiratory infections in children throughout Lima with parents who smoke

**Table XIII-6 Risk Calculation for Tobacco Smoke**

| Risk | Exposed population | Scientific basis | Risk estimation |
|---|---|---|---|
| Cancer risk in smoker population in Lima (22 5% of the adult pop ) | Smoking prevalence in men is 34% and women 7 13% | International Journal of Epidemiology 1993 | 268 to 469 cases of lung cancer and other organs per year |
| Increase of incidence of cough of children that live with smokers (shanty towns) | Among 95,000 children less than 30 months old in Lima, approximately 39,000 are exposed to ETS | Fitzgerald RR=1 94 times more incidence of cough in children not exposed 10 22 cases of cough/child/year | Each of the 39,000 exposed children would avoid 6 5 cases/yr of cough if they were not exposed |
| Increase in the incidence of respiratory infections in children 0 to 4 years of age of smoking parents | It is estimated that 589,00 children live with a smoking relative (average of 11 - 80 cigarettes/week) | Victoria et al (Pelotas Brazil) RR=1 70 for children of smokers of this frequency | 589,000 children would have 41% fewer RIs were they not exposed In Lima the average child has about 4 RIs/yr (INEI) |

### D4 Risks from overcrowding

In his study, Fitzgerald concluded that 40,000 children under 30 months of age in overcrowded houses may develop 2 16 - 3 5 times as many cases of pneumonia per year as they would if they lived in non-crowded houses

### D5 Risks from economic activities in houses

The prevalence of these activities is not officially measured in Lima They are conventionally referred to as "little industries" Suspended particulate levels exceeding 50 ug/m$^3$ have been measured in conventional workshops (Huapaya and Soto 1995), but no comparison was presented in this study between indoor and outdoor levels at this location Outdoor concentrations in Lima are frequently higher than this We estimate that 33,000 to 39,000 children of pre-school age and 18,000 to 21,600 persons of >60 years of age may live in homes with workshops These groups may be exposed to pollutants from workshop activities for more than 8 hours during the workday

## E Discussion and Conclusions

The risk calculations have a considerable margin of uncertainty Indoor air monitoring data from Lima by Languasco are very limited and not necessarily representative The dose-response relationships that are used in the U S and other contexts were developed for very different residential settings and conditions Nevertheless, the extrapolations we have made and Fitzgerald's study in Lima suggest important health risks from indoor air pollution

Fitzgerald's work should not be interpreted as making a definitive case for the risks posed by indoor air pollution, however His study typically does not include information sufficient to disentangle effects from among a variety of possible causes, including poverty, malnutrition, limited access to health

care, poor housing, overcrowding and indoor air pollution The air pollution-related correlations he develops appear strongest for passive smoking

There is insufficient information available to determine with precision the relationship between indoor pollution and health risks in Lima Based on available information, the primary indoor air risks facing Lima residents appear to be

- Biocontamination risks due to inadequate housing conditions, domestic animals, and overcrowding
- Risks due to stove emissions and waste incineration
- Risks from both active and passive smoking (even though the cancer rate from smoking in Peru is the lowest in Latin America)
- Risks faced by children, elderly, the ill, and others who spend a significant amount of time in homes with workshops or other commercial activities

## SECTION XIV
## LOSS OF AGRICULTURAL LAND AND GREEN AREAS

### A Definition of the Problem

A full evaluation of the health impacts from the loss or mismanagement of agricultural land and green areas is an extremely difficult task and beyond the scope of this study However, this loss is a sensitive issue for all city dwellers and for Lima residents in particular As a result, it is an issue we could not overlook

The care and protection of agricultural land and green areas within city limits is becoming an increasingly important issue in cities with high levels of environmental pollution and desert-like environments This issue is particularly relevant in light of the growing worldwide concern with protecting our planet Loss of these areas can have a direct impact on the day-to-day lives of city dwellers Not only do green areas serve an aesthetic function, but they also provide local residents with perhaps their only opportunity to experience nature or to engage in outdoor recreational activities Likewise, surrounding farmlands serve an aesthetic, as well as practical, function, a peaceful landscape helps visitors from the city and other travelers escape from the stresses of the urban setting Green areas and outlying farming areas provide benefits to both city residents and the urban environment

We have no exact figures on the impact of farm proximity on food prices, but it is readily accepted that because transportation costs from nearby farms will be lower than those from more remote areas, these peri-urban farms can provide food at a lower cost In addition, these areas can boost the rate at which the water table recharges, increasing the amount of available groundwater and potentially lowering the cost of public water supplies Agricultural land and other green areas also help reduce air pollution by increasing oxygen production and helping to lower carbon dioxide levels Agricultural land can also be used to recycle treated waste water and to convert organic solid wastes into organic fertilizer (compost)

Despite the advantages of maintaining green areas and outlying farming areas, the size of these areas has been steadily shrinking due to the pressures of urban expansion The ratio of the urban to rural population has steadily increased over the course of this century 70% of the population of Latin American and Caribbean countries currently lives in urban areas

### B Overview of the Problem in and Around Lima

The city of Lima is located in a subtropical desert and receives essentially no rain It occupies an area of 59,820 hectares Elevation ranges from zero to 500 m above sea level (ONERN, 1986) The Chillon, Rimac and Lurin river valleys cut through the city

Experts stress the importance of proper management of farming areas within metropolitan Lima

The river valleys cutting through the capital contain the country's best farmland The great shortage of agricultural land in Peru, with a mere 3% of the country's total area devoted to farming activities, has prompted the investment of US$20,000 per hectare in projects for the recovery and expansion of farming areas (Iturregui, 1996)

Agricultural activity within metropolitan Lima involves primarily food cultivation There are no data on crop production in these areas, but the primary crops are mostly foods, including lettuce, cauliflower, tomatoes, onions, Indian corn, cob corn, avocados, flowers, and fruits, such as apples and strawberries In contrast, farmland in the Department of Lima is devoted primarily to agro-industrial crop production 21 7% of its cropped area is planted in cotton and 15 8% in yellow corn (INEI, 1996) These differences in cropping patterns can be explained by the fact that the peri-urban farms are geared toward satisfying the demands of the urban market Selling fruits and vegetables in Lima markets gives farmers a better economic return on their investment and ultimately lowers prices to the consumer

Lima has lost vast tracts of outlying farmlands to housing for its swelling urban population Farmland, as a percent of urban area, has shrunk from 90% to 5% over the last fifty years This trend is illustrated below in Table XIV-1, which shows historical land use patterns in the Rimac valley, the largest of the three river valleys in the Lima area

**Table XIV-1 Historical Land Use Patterns in the Rimac River Valley**

| Year | Population (000) | Urban Area (%) | Farming Area (%) |
|---|---|---|---|
| 1940 | 645 | 10 | 90 |
| 1961 | 1846 | 15 | 85 |
| 1972 | 3303 | 65 | 35 |
| 1981 | 6100 | 75 | 15 |
| 1992 | 6500 | 95 | 5 |

Source Rios, 1993

In 1990, an average of 1,000 hectares of farmland per year were being developed in Lima (CIPUR, 1990) At that time the population of Lima had grown to over ten times its size in 1940, leaving the following tracts of farmland (Iturregui, 1996)

| | |
|---|---|
| Chillon Valley | 5,600 ha |
| Rimac Valley | 1,500 ha |
| Lurin Valley | 4,000 ha |
| Total | 11,100 ha |

In the Rimac valley, the 15,000 hectares of farmland reported in 1950 had shrunk to 1,500 hectares by 1991 Similarly, the 18,000 hectares of farmland in the Chillon valley were reduced to 5,600 hectares over the same period If this trend continues unchecked, Lima's outlying farming areas will virtually disappear by the year 2010 These losses of farmland are attributable mainly to the growing



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value of the land for development and the mobility of the population Development can increase the land's value from four to twenty times

The effects of the loss and mismanagement of these farming areas on the environment, on human health and on the economy of the city are impossible to calculate Each hectare of farmland lost means an additional hectare of urban land, with all its environmental burdens, and a mounting demand for basic resources (e g food, water and energy)

While agricultural lands provide important economic, aesthetic, and environmental benefits, they have also been transformed into pollution sources for the urban environment and local residents Heavy use of pesticides on farms in Lima is a good example of this problem There is mounting evidence of excess use of chlorinated and phosphoric pesticides For example, Tamaron is often applied to tomato plants week after week to counter the effects of the "mining" fly, even though the manufacturer recommends that it be applied "at least 30 days prior to the harvest" (Arana, 1996) Not only can pesticide overuse eliminate the pest's natural enemies, but it also fosters pesticide resistance Farmers are battling the growing pesticide resistance by applying ever larger quantities Pesticides and agricultural nutrients (sewage and chemical fertilizers applied to crops) are significant causes of ground-water pollution and food contamination

## C Loss of Landscaped or Green Areas within Lima

The loss of landscaped or green areas within the Lima metropolitan area is quite different than the loss of farmland Lima residents are generally well aware of the benefits of maintaining adequate amounts of landscaped areas Shortfalls in these open spaces have become increasingly pronounced over the past few decades due to inadequate city planning and water management policy The situation is aggravated by shortages of water

The irrigation channels from the Rimac, which helped maintain landscaped areas within the city earlier this century, have more or less vanished In many cases, the use of flood irrigation prevails over more efficient methods In others cases, treated drinking water is used to maintain parks and gardens Without underestimating the significance of limitations in the infrastructure for irrigation, it can be said that certain districts have been unable to maintain larger tracts of landscaped areas simply due to lack of foresight

With regard to the availability of landscaped areas, Lima was already lagging behind some world cities by 1980 This is illustrated by the data presented below in Table XIV-2 Lima had only 4 2 square meters of landscaped areas for each resident, well below an recommended level of 8 square meters per person (Rios, 1993)

**Table XIV-2 Per Capita Availability of Landscaped Areas in Selected Cities, in 1980**

| City | $m^2$ per Person |
|---|---|
| Lima | 4 2 |
| Paris | 7 4 |
| London | 9 0 |
| Mexico City | 10 0 |

Source Rios, 1993

Since the 1980s, the per capita availability of landscaped areas in Lima has fallen to 1 9 square meters per person Table XIV-3 presents data on the availability of landscaped areas in 32 of the districts of the city, however, this table may understate the problem This is because in many cases "available" landscaped areas may be designated as such on local government plans and maps while in actuality, many of these areas are nothing more than vacant lots, suffering from neglect and shortages of irrigation water

Table XIV-3 nevertheless provides some idea of the severity of shortfalls in landscaped areas on a district-by-district basis As can be seen, only three districts (Santiago de Surco, La Molina and San Borja) exceed the recommended value of 8 square meters per person (Rios, 1993)

The Lima districts with the most severe shortages of landscaped areas are Carmen de la Legua Reynoso, Provincia del Callao, Villa Maria del Triunfo, Breña and San Martin de Porres Of these districts, Carmen de la Legua Reynoso and Breña are so developed that they have no space available for the establishment of new landscaped areas

**Table XIV-3 Per Capita Availability of Landscaped Areas in Selected Districts of Lima**

| District | Landscaped Area ($m^2$) | District | Landscaped Area ($m^2$) |
|---|---|---|---|
| Carmen de la Legua Reynoso | 0 22 | Independencia | 2 20 |
| Villa Maria del Triunfo | 0 26 | San Miguel | 2 53 |
| Breña | 0 43 | El Agustino | 2 54 |
| San Martin de Porres | 0 87 | Bellavista | 2 60 |
| San Juan de Miraflores | 1 02 | Comas | 3 23 |
| Rimac | 1 03 | Callao | 3 94 |
| Magdalena del Mar | 1 06 | Miraflores | 4 10 |
| La Victoria | 1 15 | Pueblo Libre | 4 28 |
| Ate-Santa Anita | 1 31 | Chorrillos | 4 30 |
| La Perla | 1 49 | La Punta | 4 81 |
| Villa El Salvador | 1 53 | San Luis | 5 05 |
| Surquillo | 1 61 | Jesus Maria | 5 20 |
| San Juan de Lurigancho | 1 80 | San Isidro | 7 95 |
| Lima (District) | 1 83 | San Borja | 8 76 |
| Lince | 2 00 | La Molina | 9 46 |
| Barranco | 2 15 | Santiago de Surco | 11 04 |

Source Cuanto, 1995

## C Health Effects

Losses of landscaped green areas and surrounding farmlands may have many indirect effects on the health of Lima residents Properly managed landscaped areas within the city limits provide the open spaces which have been shown to reduce air pollution They also provide opportunities for city residents to pursue outdoor recreational activities, particularly in the districts with relatively high ratios of landscaped areas (see Table XIV-3) However, as illustrated by the data presented in Table XIV-3, only four urban districts in the metropolitan area have adequate landscaped areas The lack of these spaces could aggravate city-wide air pollution problems, thus inducing additional air pollution-related health risks

Although surrounding farmlands provide many benefits to the urban community, in some cases, mismanagement of outlying farming areas can aggravate city-wide environmental pollution problems Crop lands irrigated with untreated waste water and subject to the application of large quantities of pesticides are compounding surface and groundwater pollution problems This may also be adding to the contamination of food supplies Outlying farming areas are also often used as dumping sites for all types of solid wastes This encourages informal pig-raising and the recycling of waste products under unhealthy conditions

It is difficult to quantify the health risks to Lima residents from loss of these areas Nevertheless, we know that landscaped areas and outlying farming areas can minimize the severity of certain adverse

environmental effects and help to improve the cityscape More importantly, we cannot ignore the likelihood that surrounding farmlands are contributing to the contamination of local water and food supplies

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## SECTION XV
## ATMOSPHERIC LEAD POLLUTION

### A Definition of the Problem

Due to its special physical properties (ductility, resistance to corrosion, etc ), lead is widely used for household, industrial, mining, energy and transportation fuel applications It can be found as an anti-knock additive to gasoline, in water pipes, pumps and plumbing fittings, in paints, in some pesticides and fertilizers, in batteries, and in some glazes commonly used in finishing pottery Smelting of lead-containing ores and manufacturing, using and recycling products containing lead can result in significant human exposure to this highly toxic substance In Lima, the majority of lead released into the environment is likely to come from combustion of leaded gasoline in motor vehicles

Exposure to lead occurs through inhalation, ingestion and placental transfer The most important exposure pathway in Lima is most likely inhalation Based on a typical ambient concentration of lead in Lima at 1 5 ug/m$^3$ and an assumed respiration rate of 14 - 20 m$^3$/day, the average amount of lead inhaled per day is calculated at about 20 to 30 ug per day Additional exposure to airborne lead can occur when lead settles onto soil in which children play or when it deposits onto foods as they are grown, transported to markets, or displayed for sale Children who exhibit "pica" behavior, (i e , ingesting dirt, whether intentionally or inadvertently as dirty hands are brought to the mouth) are particularly at risk (EHC3, 1977), especially in areas of heavy vehicular traffic where there is significant deposition of lead onto roadsides Also, mothers with high concentrations of blood lead can affect the health of their unborn children through direct placental transfer

Inhaled or ingested lead enters the bloodstream quickly and accumulates in teeth, bones, and tissues In moderate concentrations lead can produce adverse neurological and hematological effects, such as high blood pressure, and heart disorders in adult and elderly persons Lead is particularly toxic to the central nervous system in children Concentrations higher than 10 ug/dl in the blood can cause neurophysiological disorders, reduced learning capacity (decrements in IQ) (Mage 1992) and alteration of psychomotor behavior in nursing infants (Michaels 1988) Chronic exposure to higher levels of lead can result in anorexia, nausea, vomiting, abdominal pain, paralysis, cerebral diffusion, vision disorders and disorders of the reproductive system In addition, some lead compounds are teratogenic and potentially mutagenic (EPAB2, Michaels, 1988)

### B Overview of the Problem in Lima

In Lima, two-thirds of atmospheric lead pollution is caused by gasoline combustion [1] Table XV-1 provides data from some sites where frequent monitoring has been conducted by DIGESA and CID (SENAMHI) and from other sites where various short term investigations were conducted One site that was monitored multiple times over several years shows declining concentrations over time, with

[1] Cenergia 1995



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concentrations in the peak months declining from 3 56 ug/m$^3$ in 1989 to 1 12 ug/m$^3$ in 1995 At many sites, concentrations exceed the WHO recommended guideline levels of 0 5 - 1 0 ug/m$^3$ Concentrations may be much higher than this in industrial zones, where recent monitoring has shown them as high as 2 44 ug/m$^3$ and 2 61 ug/m$^3$

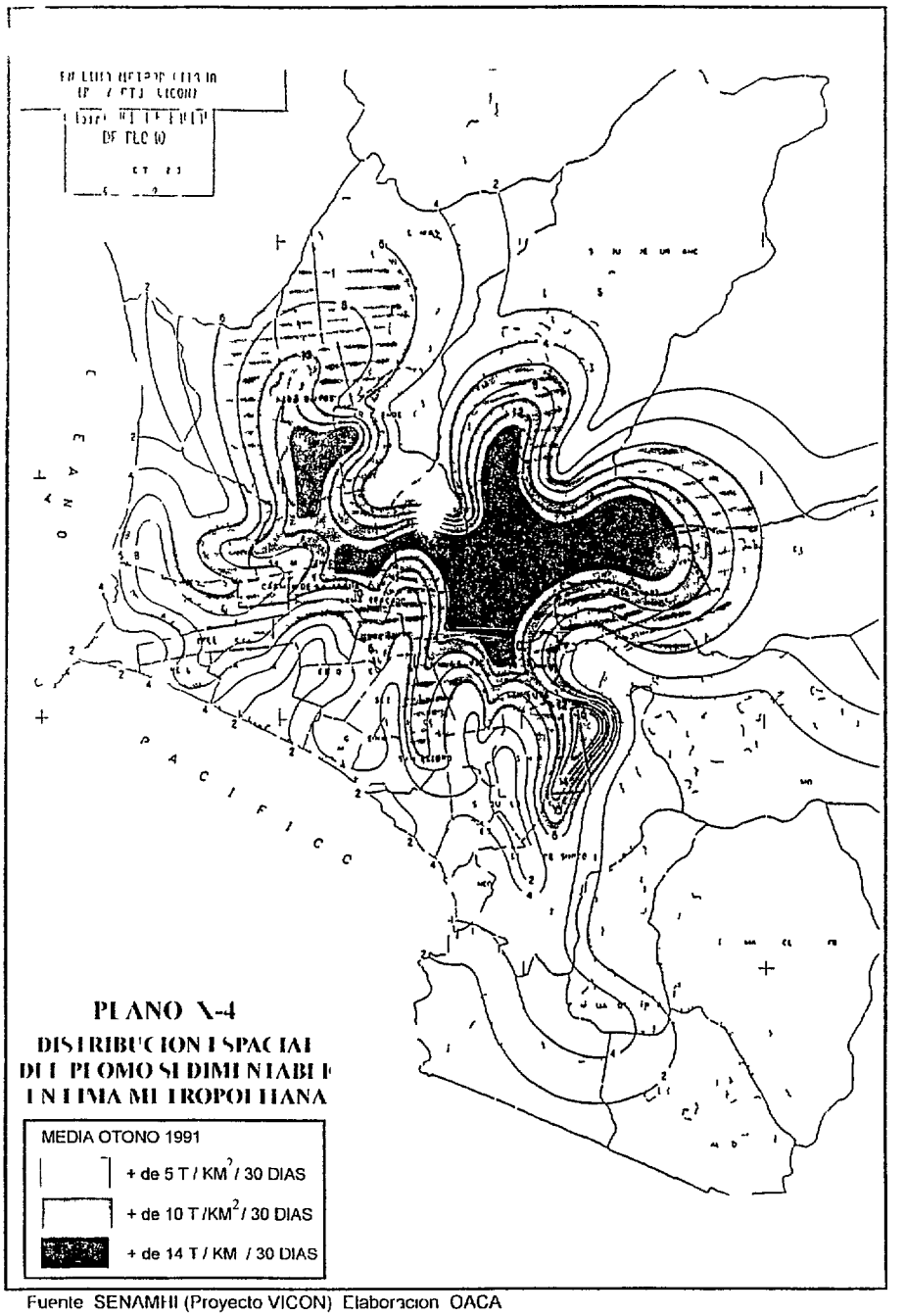
**Table XV-1 Levels of Atmospheric Lead in Metropolitan Lima (ug/m$^3$)**

| Station | Avg Conc | Period | Zone Characteristics |
|---|---|---|---|
| SENAMHI | 2 290 | max month '91( Nov) | Lima Av Salaverry (intense traffic) Intense traffic (45-60 veh/min) |
| | 1 004 | min month '91 (Jun) | |
| CONACO (1) | 2 618 | max month '90 (Feb) | Lima (Central) Intense traffic (50-80 veh/min) Wind 05-1 5 m/s 60-70% HR |
| | 1 453 | min month '90 (Mar) | |
| | 2 609 | max month '93 (Apr) | |
| | 1 118 | min month '93 (Aug) | |
| | 2 183 | avg (Feb-Jun '93) | |
| | 1 118 | max month '95 (Apr) | |
| | 0 017 | min month '95 (Sep) | |
| DIGESA (1) | 0 170 | max month '95 (Mar) | Lima (Lince District) Light traffic (6-10 veh/min) |
| | 0 030 | min month '95 (Apr) | |
| CONACO (1) | 1 683 | annual avg | |
| DIGESA (1) | 0 608 | annual avg | |
| Industrial Zones (2) | 2 080 | max 24 h | Lima |
| | 0 110 | min 24 h | |
| | 2 440 | avg 24 h | Callao |

(1) Measurements performed by DIGESA
(2) Measurements performed for MITINCI Integrated Coastal Development Company, Peru SA and ICDEVCO Peru 1995 MITINCI
WHO permissible limits = 0 5 - 1 00 ug/m$^3$ annual average

According to SENAMHI, the highest deposition rate of lead occurs in the northeastern section of Lima This in part due to wind patterns and other meteorological factors (see Figure XV-1) We assume that airborne concentrations of lead correlate roughly with deposition rates

**Figure XV-1 Geographic Variation in Lead Deposition in Lima**




Fuente SENAMHI (Proyecto VICON) Elaboracion OACA



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In 1992, WHO/UNEP conducted a comparative analysis of atmospheric lead concentrations in ten large cities throughout the world The data from this study indicate that ambient lead concentrations in Lima were within a similar range as for many of the other cities See Table XV-2

**Table XV-2 Atmospheric Lead Concentration in Selected Cities of the World (Annual Average in ug/m$^3$)**

| City | Concentration | City | Concentration |
|---|---|---|---|
| Bangkok | 0 2 - 0 25 | Bombay | 0 25 - 0 33 |
| Buenos Aires | 0 3 - 3 9 | Calcutta | 0 73 |
| Jakarta | 0 3 - 3 6 | Karachi | 1 0 - 3 0 |
| Manila | 0 3 - 4 4 | Mexico City | 0 5 - 3 5 |
| Sao Paulo | 1 1 - 1 1 | **Lima** | 0 608 - 1 683 |

It should be noted that concentrations in Mexico City have fallen over time From an annual average concentration of 2 75 ug/m$^3$ in 1988, ambient lead concentrations fell to 0 4 ug/m$^3$ in 1995 as a result of the policy introducing "Magma Sin" (lead-free) gasoline and the "Hoy no Circula" program which places all private vehicles out of circulation one day per week These results are similar to findings from cities elsewhere a reduction in the amount of lead consumed in gasoline has resulted clearly and directly in similar reductions in the amount of lead in the atmosphere and in residents' blood

Measurements conducted in Lima by DIGESA indicate that ambient lead concentrations appear to have declined since 1989, even though the number of automobiles in circulation has increased significantly (e g , by 32% between 1993 and 1995) A portion of this apparent reduction in lead emissions is likely attributable to the increasing fraction of the vehicle fleet that is imported and runs on fuels other than leaded gasoline This effect is likely small, though, as the proportion of vehicles using unleaded gasoline, diesel fuel, and liquefied petroleum gas (LPG, used by about 800 vehicles) has grown to only 15 - 20 % of the total in Lima We speculate that a much more important factor in reducing total vehicle lead emissions could be a reduction in the average lead content of the leaded gasoline sold in Lima This is speculation only, however, as we have no information over time on the average lead content of leaded gasoline

## C Impact on Health

We have obtained no studies from Lima specifically or from Peru more generally investigating the impact of ambient lead concentrations on the health of the overall population The limited scientific research available from Lima addresses occupational health problems in foundries or battery recharging operations Thus, we base our assessments of likely health impacts in Lima on extrapolation of research results obtained in other countries

Airborne lead affects human health in a two-step process

1 Some airborne lead is inhaled directly into the lungs Additional airborne lead may be deposited onto soils, food or water and then subsequently ingested A fraction of the lead that is ingested or inhaled is actually absorbed into body tissues The fraction absorbed depends on the mode of exposure, the chemical species of lead, the degree of previous and recent exposure to lead, the age of the subject, nutritional status, diet, and numerous other factors Absorbed lead is transported rapidly through the body in blood, and can then accumulate in many other body tissues An individual's total exposure to lead can be gauged by sampling any of several biological tissues, including blood, urine, semen, hair, teeth, or bone As a matter of convenience in obtaining samples, blood has been the tissue most frequently chosen for examination, and the level of lead in blood is the most commonly used measure of an individual's exposure to lead

2 A large body of international research exists relating health impacts from lead to the level of lead in individuals' blood These relationships project the likely health risks from the total amount of lead (whether deriving initially from air, water, food or other sources) in a person's blood Assessing health impacts specifically from airborne lead is complicated, since because it contributes only a portion of one's total exposure to lead, it will also contribute only a portion of the total risks expected as a function of the level of lead in the blood

Medical and epidemiological research has linked human exposure to lead to a wide range of serious adverse health effects involving mental development, blood chemistry, the kidneys, and the nervous, reproductive and cardiovascular systems Adverse effects have been documented among infants, children and adult men and women Researchers have linked these adverse health effects to ever-lower levels of lead In both developing and developed countries, the levels of lead to which large fractions of the population are exposed are now believed to result in significant health problems There is essentially no margin of safety between the level of lead exposure for the general population in large cities of developing countries, including Lima, and the level at which adverse human health effects are observed Adverse impacts from lead have been noted at levels as low as about 10 ug/dl of blood lead Table XV-3 summarizes some of the research findings

**Table XV-3 Health Effects at Various Levels of Blood Lead**

| Reference | Scientific Basis | Blood Lead Levels | Group at Risk | Effect on Health |
|---|---|---|---|---|
| EHC 3 77 | Experimental | 10 - 50 ug/dl | Adults elderly | Hematological effects (high blood pressure), leading to increased likelihood of cardiovascular illnesses (e g , heart attack, stroke) |
| EHC 3 77 | Transversal | 40 ug/dl | children | Subtle damage to nervous system |
| EHC 3 77 | Transversal longitudinal | 70 ug/dl | population | Kidney problems |
| EHC 3 77 | Transversal longitudinal | 80 ug/m$^3$ | population | Encephalitis |
| Mage 92 | Cohort | 25 ug/m$^3$ | children | Lowered IQ, motor coordination problems |
| Mage 92 | Cohort | fetus 8 - 14 ug/dl | fetus | Reduced gestation period, low birth weight and resulting increased frequency of developmental problems and infant mortality |

Limited information available regarding the levels of blood lead in residents of Lima suggest that much of the population is exposed at levels putting them at risk of these adverse health impacts We are aware of three studies in Lima evaluating the levels of blood lead

- Flores and Marquez (1995) analyzed the blood of 30 persons living near a metal processing plant in east Lima The average blood lead concentration found throughout the sample was 46 25 ug/dl for adults (range from minimum to maximum of 21 42 to 70 77 ug/dl) and 49 5 ug/dl for children (range from 30 28 to 68 7 ug/dl) The main source of pollution in the study area is the metallurgical industry and the second largest source is the intense vehicular traffic

- Jacoby, Cueto and Pollet conducted a limited exploratory study of 40 children in the San Juan de Lurigancho district (east Lima health sub-region) revealing that with atmospheric lead concentrations between 1 5 and 2 ug/m$^3$, children showed an average of 11 7 ug/dl of blood lead (standard deviation of 3 7 ug/dl) This study estimated that between 25% and 35% of children in Lima could have blood lead concentrations higher than 10 ug/dl

- A small study by UNEP in 1987 - 1988 as part of a world-wide investigation found that blood lead concentrations in adults in Lima averaged 9 6 ug/dl This was apparently lower than in other major cities (see Table XV-4), but still left roughly half of the population with levels exceeding the 10 ug/dl level of concern

**Table XV-4 Average Adult Blood Lead Concentrations for Major Cities (1987-1988)**

| City | PbB in Adults (ug/dl blood) |
|---|---|
| **Lima** | **9 6** |
| Cairo | 29 7 |
| Mexico City | 22 5 |
| Brussels | 15 0 |
| Calcutta | 10 7 |
| Jerusalem | 8 2 |
| Ahmedabad | 13 8 |
| Baltimore | 7 5 |
| Zagreb | 9 2 |
| Bangalore | 17 9 |

Each of these studies has important shortcomings in providing a current picture of blood lead levels in Lima -- these studies are either small scale and/or not representative of the city's general population and/or sufficiently old so as to miss the impact of Lima's tremendous growth in the last 10 years The three studies suggest that blood lead levels in Lima today are sufficiently high to cause major adverse health impacts, but a more definitive study would be very valuable

## D Risk Characterization and Calculation

To estimate the health risks in Lima resulting from airborne lead, we apply a set of dose-response functions developed by Ostro (1994) drawn from his review of the literature Ostro's relationships have been applied in risk analyses for other cities, including Cairo, Jakarta and several cities in the U S Because of numerous uncertainties in the underlying health studies and likely differences between Lima and the sites where the studies were conducted, the figures resulting from applying these dose-response relationships to Lima should be viewed as rough, order-of-magnitude estimates only Ostro's dose-response relationships are as follows

*For each 1 ug/m$^3$ increase in atmospheric lead concentration*

- *There will be 7 260 additional cases of hypertension (defined as diastolic blood pressure exceeding 90 mm Hg) per 100 000 adult males,*
- *The increased blood pressure among adult males will result in 34 additional cases of coronary heart disease and 35 additional cases of premature mortality per year per 100 000 adult males,*
- *Each child exposed throughout childhood on average will lose 975 IQ points*

These health effects for which dose-response functions have been developed represent only those health impacts from lead for which quantitative relationships are known with some degree of confidence Lead is believed to cause many sorts of health effects in addition to these analyzed by Ostro (e g,

hypertension and coronary illnesses among women as well as men, developmental problems in fetuses and increased infant mortality)

Ostro combines several intermediate steps in developing these dose-response functions A first step is to develop a slope factor relating the change in blood lead concentration to changes in the concentration of lead in ambient air Ostro estimates a blood lead to air lead slope of 2 0 for adults (e g , for a 1 ug/m$^3$ increase in the concentration of lead in air, the concentration of lead in the blood of adults breathing that air will increase by 2 0 ug/dl) and 3 9 for children A second step for adults is to estimate the relationship between changes in blood lead and blood pressure Third, for adults, Ostro develops a relationship between blood pressure and the likelihood of adverse health outcomes such as coronary heart disease and premature mortality For children, Ostro develops a statistical relationship directly between blood lead levels and loss of mental capacity (IQ)

Because of the limited extent to which airborne lead has been monitored in Lima, there is significant uncertainty about the concentrations to which the bulk of the city's population is typically exposed We have chosen to reflect this uncertainty by developing lower and upper estimates based on the most recent average lead concentrations observed at the two sites where DIGESA has conducted longer-term monitoring These concentrations are 0 608 ug/m$^3$ and 1 683 ug/m$^3$ This concentration range was also chosen by WHO to describe typical lead concentrations in Lima in their study of lead in cities throughout the world

To estimate the health risks from airborne lead in Lima, we therefore apply Ostro's dose-response functions to the assumed minimum and maximum typical concentrations of 0 608 ug/m$^3$ and 1 683 ug/m$^3$ The risk calculations and results are shown in Table XV-5

In sum, the resulting estimates of risks in Lima caused by airborne lead include

- 44,000 - 122,000 additional cases of high blood pressure among adult males,
- 212 - 588 premature deaths per year among adult males,
- 206 - 571 cases of coronary disease per year among adult males, and
- 0 59 - 1 64 IQ points lost on average for each child

**Table XV-5 Health Risks from Airborne Lead in Metropolitan Lima**

| Dose-Response Functions* Effects from 1 ug/m$^3$ change in Pb concentration | Exposed Population | Estimated Risks+ | |
|---|---|---|---|
| | | Assuming Pb at 1 683 ug/m$^3$ | Assuming Pb at 0 608 ug/m$^3$ |
| 7,260 cases of hypertension per 100,000 adult males | 998,000 (males over age 35) | 121,941 cases hypertension | 44,052 cases hypertension |
| 35 cases of premature death/yr per 100,000 adult males | 998,000 | 588 premature deaths/yr | 212 premature deaths/yr |
| 34 cases of coronary disease/yr per 100,000 adults | 998,000 | 571 cases coronary disease/yr | 206 cases coronary disease/yr |
| Reduction of 0 975 IQ points for each child | 2,099,000 (population under age 15) | 1 64 IQ points lost for average child | 0 59 IQ points lost for average child |

* Analytical method developed by Ostro (1994)
+ 2 scenarios correspond to the annual max and min figures provided by DIGESA

## E Conclusions and Discussion

Although these numerical risk estimates are quite uncertain, it appears that airborne lead causes substantial damages to the health of Lima's population The effect of lead on the mental development of children is of particular concern The number of premature deaths attributable to airborne lead is of a similar order of magnitude as the numbers of premature deaths caused by particulate matter and by sulfur dioxide, making lead one of the several most important air pollutants The number of premature deaths and the number of coronary illnesses should not be regarded as separate and distinct health impacts It is probably that most of the premature deaths attributable to lead are from coronary illnesses, while many of the coronary illnesses result in premature deaths

The estimates of IQ reductions in children attributable to lead are perhaps the most reliable of all these estimates, as they are based on a very large amount of research relating lead and retarded mental development The negative impact of lead on children's IQ in Lima may be even larger than these estimates if one takes into account the levels of malnutrition and anemia present in Lima

Another important factor in describing the risks associated with airborne lead is spatial variation According to SENAMHI, the areas of highest lead concentrations are the north and northeast sections of Lima and Lima-Cercado In addition to the adverse meteorological conditions which tend to concentrate pollutants in these areas, these areas also have the highest population density, the greatest number of manufacturing plants, intense vehicular traffic, and an inordinate lack of green space The greatest population of children is concentrated in the peripheral shanty towns of these areas North Lima alone accounts for 25% of the total school age population of Lima High lead concentrations may in part explain why the incidence of heart disease in north and east Lima is so high

Among the segments of the population at greatest risk from lead are malnourished (anemic) children, individuals with parasitic illnesses, pregnant women, the elderly, and individuals with cardiovascular diseases

Note that these risk estimates cover only the health effects from lead that can be quantified with reasonable confidence Lead is believed to affect additional segments of the population beyond those that have been analyzed here (e g , older women as well as men), and it also causes additional sorts of health effects beyond those analyzed here (e g , low birth weight and developmental problems for new-borns) In this sense, the total health risks posed by airborne lead in Lima are likely to be greater than the estimates developed here

An interesting question that is quite relevant in developing strategies for abating lead problems in Lima involves the relative importance of the different sources contributing to the population's total exposure to lead What fraction of blood lead, for example, derives from the air and what fractions derive from food, drinking water, soils, etc ? To answer this question fully we would need information which we do not have on the lead content of drinking water at the tap, on lead in the various foodstuffs that make up a typical diet, and on lead in soils With our current data, we can answer this question only with regard to the contribution of airborne lead to total lead exposure

Using Ostro's slope factors relating blood lead concentration to the concentration of lead in the air (2 0 for adults and 3 9 for children), we can make the following calculations

- For the members of Lima's population that are exposed to the typical airborne lead concentrations of 0 608 - 1 683 ug/m$^3$, we can expect blood lead concentrations due to airborne lead of 1 2 - 3 4 ug/dl for adults, and 2 4 - 6 6 ug/dl for children In comparison, average total blood lead levels, reflecting contributions from all sources, might be 9 6 ug/dl for adults (UNEP, 1988) and perhaps 11 7 ug/dl for children (San Juan de Lurigancho, from Jacoby, Cueto and Pollet) It appears that airborne lead might be responsible for only about 15 - 60 % of total blood lead Other sources of lead are clearly important also

- The Flores and Marquez (1995) data afford some perspective on the contribution of airborne lead in an industrial area in contrast to throughout the city as a whole Flores and Marquez found an average blood lead concentration of 46 25 ug/dl in their study zone near a metal processing plant If we assume an airborne lead concentration of 2 44 ug/m$^3$ in this area (the highest monitored airborne lead concentration found in any industrial area in Lima), then only approximately 5 ug/dl of the 46 25 ug/dl total blood lead -- about 11 % would be due to lead in the air

These suggestions that airborne lead is responsible for only a minority of total lead exposure in Lima are consistent with typical findings elsewhere, where food or occasionally drinking water are the predominant sources of lead Note, though, that this conclusion about the relative importance of air compared with other exposure pathways to lead refer to the pathways by which individuals are ultimately affected by lead, and not necessarily to the means by which lead initially enters the environment Food may be a more important exposure pathway, but, as discussed earlier and in the food contamination section, there are a variety of ways that lead may get into the food consumed by Lima residents,

including air deposition, pollution of waters from which seafood is harvested, etc Further studies are needed to better understand the movement of lead among different environmental media in Lima With the completion of such studies, one can assess which sources releasing lead to the environment must be addressed in order to reduce the population's exposure to lead

## APPENDIX A
## OVERVIEW OF APPROACH TO RISK ANALYSIS

In the papers on each environmental problem, we use a variety of different approaches for estimating the health effects that each problem causes among the population of Metropolitan Lima This short paper describes the risk analysis procedures that we use In general, we use methods that have been developed by the U S Environmental Protection Agency (EPA), both in terms of overall approach and in terms of the specific cause-effect relationships thought to exist for specific environmental pollutants

### Dose-Response Assessment

Dose-response assessment involves estimating quantitatively the connection between the amount of exposure to a substance and the likelihood of the health effect of concern occurring Dose-response assessment may be performed separately for multiple different health effects that may be caused by a single substance One study may examine the potency with which a substance causes cancer, another study may examine the different degree to which it may cause toxic effects on the liver There are two general approaches to dose-response assessment depending on whether the health effects under investigation involve threshold relationships or not

#### Threshold Effects

One major approach to dose-response assessment examines threshold effects This approach applies primarily to systemic toxicants and non-carcinogenic health effects Dose-response assessment for substances exhibiting threshold responses involves calculating what has traditionally been known as an Acceptable Daily Intake (ADI) value The ADI for a chemical is the daily dose below which significant risk of adverse effects is not expected More recently, the Agency has preferred to use a new term, the Reference Dose, or RfD, to avoid the connotation of acceptability

Briefly, EPA's approach for calculating an RfD involves taking an appropriate lifetime-adjusted No Observed Effect Level (NOEL), No Observed Adverse Effect Level (NOAEL), Lowest Observed Effect Level (LOEL), or Lowest Observed Adverse Effect Level (LOAEL) -- derived from either laboratory animal and/or human epidemiology data -- and dividing it by the appropriate uncertainty (safety) factors Safety factors are intended to establish an RfD sufficiently far below an experimentally devised LOAEL that adverse effects are extremely unlikely to be observed for a dose at the RfD level The more uncertainty there is in translating the experimental conditions under which the LOAEL was observed to conditions of human exposure, the greater the safety factors will be Typical safety factors used include

- A factor to protect sensitive individuals from an effect observed among average individuals
- A factor to provide for extrapolation from animals to humans

- One or more factors to reflect uncertainty in the experimental setting, such as low sample sizes, short term studies, etc

Non-Threshold Effects

For non-threshold effects, an attempt is made to extrapolate response data from doses in the experimental range to response estimates in the dose ranges typical of most environmental exposures Typically, the dosage to which animals have been subjected in experiments are much higher than those to which humans are exposed in the environment The greatest number of such dose-response extrapolations have been performed in the field of carcinogen risk assessment In general, EPA considers the risk of cancer to be linearly related to dose At this time, the Agency does not consider any level of exposure to carcinogens as de minimus, or safe The Agency also provides guidance on such issues as choice of extrapolation model, how to consider benign tumors, adjustment of dosage from animals to humans, etc

The slope of the carcinogenic dose-response function in the low dose range is estimated for each chemical through use of a linearized multi-stage model Using this model, a cancer potency factor (symbolized as $Q_1$*) is derived that can be used in quantitative risk assessment The product of $Q_1$* and the dose of the chemical yields an estimate of the lifetime cancer risk to an individual receiving that dose level for a lifetime $Q_1$* is expressed in terms of risk-per-dose, and thus has units of (mg/kg/day)-1 The linearized multi-stage model gives a plausible upper-bound estimate to the slope of the dose-response curve in the low dose range In essence, this means that risk estimates using EPA's $Q_1$*s are not likely to be lower than true risks EPA notes that a procedure does not yet exist for making the "most likely" or "best" estimates of risk within the range of uncertainty defined by the upper and lower limit estimates

**Risk Characterization**

The final step in the risk assessment process is risk characterization This step essentially involves putting together in a useful way the information developed in the three previous steps For non-carcinogens, this step often involves comparing the dose estimates (from the exposure assessment step) to the Reference Dose (from the dose-response evaluation step) to estimate the relationship of dose to the threshold level If the level is not exceeded, we can generally presume there is little likelihood of health effects occurring We typically cannot, however, say what the statistical likelihood is that the effect will occur, only that the likelihood is higher as the Hazard Index (ratio between actual dose and RfD) increases beyond one For a few chemicals, an epidemiologically derived dose-response relationship may be available that allows quantification of a risk estimate

For carcinogens, risk can be estimated by multiplying the actual human dose by the risk per unit dose projected from the dose-response modeling

$$\text{Risk} = \text{Dose} \times Q_1^*$$

Risk may be calculated for both the maximally exposed individual as well as for the aggregate population as a whole



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**Variations in Risk Assessment Approach**

For the contaminants of concern in this project, we attempt to identify the potential adverse health effects that may be associated with chronic exposure to them We rely primarily on EPA's determinations to estimate the effects of each contaminant We treat carcinogenic and non-carcinogenic compounds differently

For known and suspected carcinogens, we rely on the EPA's estimates of potency ($Q_1$*) The EPA uses a linearized multi-stage model with zero as the threshold The $Q_1$* value, which is the plausible upper-bound on the low-dose portion of the curve, is used as the slope of the dose-response curve for carcinogens For non-carcinogens, we rely on EPA's Reference Dose (RfD) as the threshold value The RfD and $Q_1$* values have been scientifically peer-reviewed and are widely accepted, although other groups concerned with environmental health occasionally have reached different conclusions For some chemicals, EPA's health effects information is updated frequently and is summarized in the Integrated Risk Information System (IRIS)

Consistent with EPA's final risk assessment guideline for Chemical Mixtures, we will assume additivity of cancer estimates in cases where exposure occurs simultaneously to multiple contaminants Unless data are available, we do not consider synergistic or antagonistic interactions between contaminants

Risk estimates are not additive across multiple contaminants for non-carcinogenic health effects, however An RfD applies for a single health effect for a single pollutant, theoretically, if exposure to two different chemicals resulted in the same health effect at the same rate of exposure, the effects could be additive However, for most of the chemicals examined here, the health effects upon which the RfDs were calculated represent a range of effects to a number of different target organs Therefore, if exposure occurs to two different chemicals, each at one-half of their respective RfDs, we cannot add the exposure to say that total exposure equals the RfD Exposure to a single chemical across multiple exposure routes should be added, however

In several instances in this project, we follow risk assessment procedures different from the general approaches we have outlined for carcinogenic and non-carcinogenic substances These variations include

- For some non-carcinogenic health effects and some substances, epidemiological studies have established a relationship between the incidence of an adverse health effect and the ambient concentration of the substance (An example is the relationship between airborne particulate matter and various measures of morbidity) In such cases, we use the epidemiological relationship and ambient data in preference to simply comparing the ambient data to the RfD

- For some pollutants, we have no data on dose-response relationships and/or no ambient data (e g microbiological contaminants) In these cases, we attempt to obtain data on

the actual incidence of the health effect of concern (e g , number of disease cases) and speculate about the fraction of such cases are attributable to environmental causes

- Note that the risk assessment methods for exposure to lead employ a methodology that differs from the approach used for other contaminants For a variety of reasons, lead exposure and health effects must be treated independently Three important factors account for this special treatment First, lead health effects are based on non-linear dose-response information Secondly, because of the nature of the epidemiological data for lead, diseases are disaggregated into those affecting sub-populations of men, women, and children Finally, the dose-response information available is based not directly on an environmental exposure, but rather on a blood lead level Lead health effects are related to a concentration of lead in the bloodstream, expressed as mean blood level or PbB This is in contrast to other contaminants, which have health effects expressed in terms of concentrations in air or amount of contaminant ingested The health calculations in this report are based on the elevation in blood lead level that results from exposure to lead from various environmental sources

**Differing Degrees of Conservatism in Health Effects Information**

We use the EPA's dose-response information for pollutants In compiling this information EPA has generally attempted to avoid underestimating the health effects of a chemical For chemicals with more uncertainty about their health effects, EPA typically adopts a larger margin of safety For chemicals whose effects are well understood (e g , from extensive epidemiological studies of effects on humans), EPA is likely to provide a relatively small margin of safety EPA's health effects database thus does not provide "best guesses" about the potency of each chemical Instead, it provides potency estimates that are likely not lower than the true potencies Different degrees of conservatism are inherent in this database, with substantial implications for interpreting our risk calculations Nearly all of our risk calculations for this project fall into one of the following four categories

- **Cancer risk estimates** If we use estimates based on limited animal studies, our estimate of cancer incidence resulting from pollutants is likely to *substantially overestimate* the true number of resulting cancer cases For example, the number of cancers from trihalomethanes in drinking water is unlikely to be as high as the number we estimate using EPA's cancer potency factors, it is more likely to be perhaps 1/10 or 1/100 of that amount The same is true, to a lesser extent, of cancer risk estimates for pollutants based on evidence from studies of humans

- **Estimates of non-cancer effects based on epidemiological studies of humans** These provide *best estimates* and are not expected to be biased either high or low They are derived generally by estimating a relationship between the level of concentration and the incidence of a health effect in the human population exposed to the pollutant, with no conservatism intentionally built into the process The potency estimates for air pollutants and lead are of this sort

- **Estimates of non-cancer effects based on reported health statistics** Typically, reported health statistics should be adjusted by to account for possible under or over reporting They may be further adjusted by apportioning the estimated cases of a disease among environmental and other causes There is substantial uncertainty in making such adjustments, but unless an adjustment is intentionally made in a conservative or non-conservative manner, these are *best estimates*

- **Estimates of the number of individuals exposed to a pollutant at levels exceeding the RfD for the pollutant** When exposure only modestly exceeds the RfD (perhaps 1 to 10 times the RfD), the number of people exposed will *greatly exceed* the number of people likely to suffer the health effect When exposure is much higher than the RfD, the number of people suffering the health effect will approach the number of people exposed

In comparing projected health effects for different environmental problems, the numerical bias of each method must be kept in mind

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