The Global Dimensions of Lead Poisoning

An Initial Analysis

Alliance To End Childhood Lead Poisoning

Environmental Defense Fund

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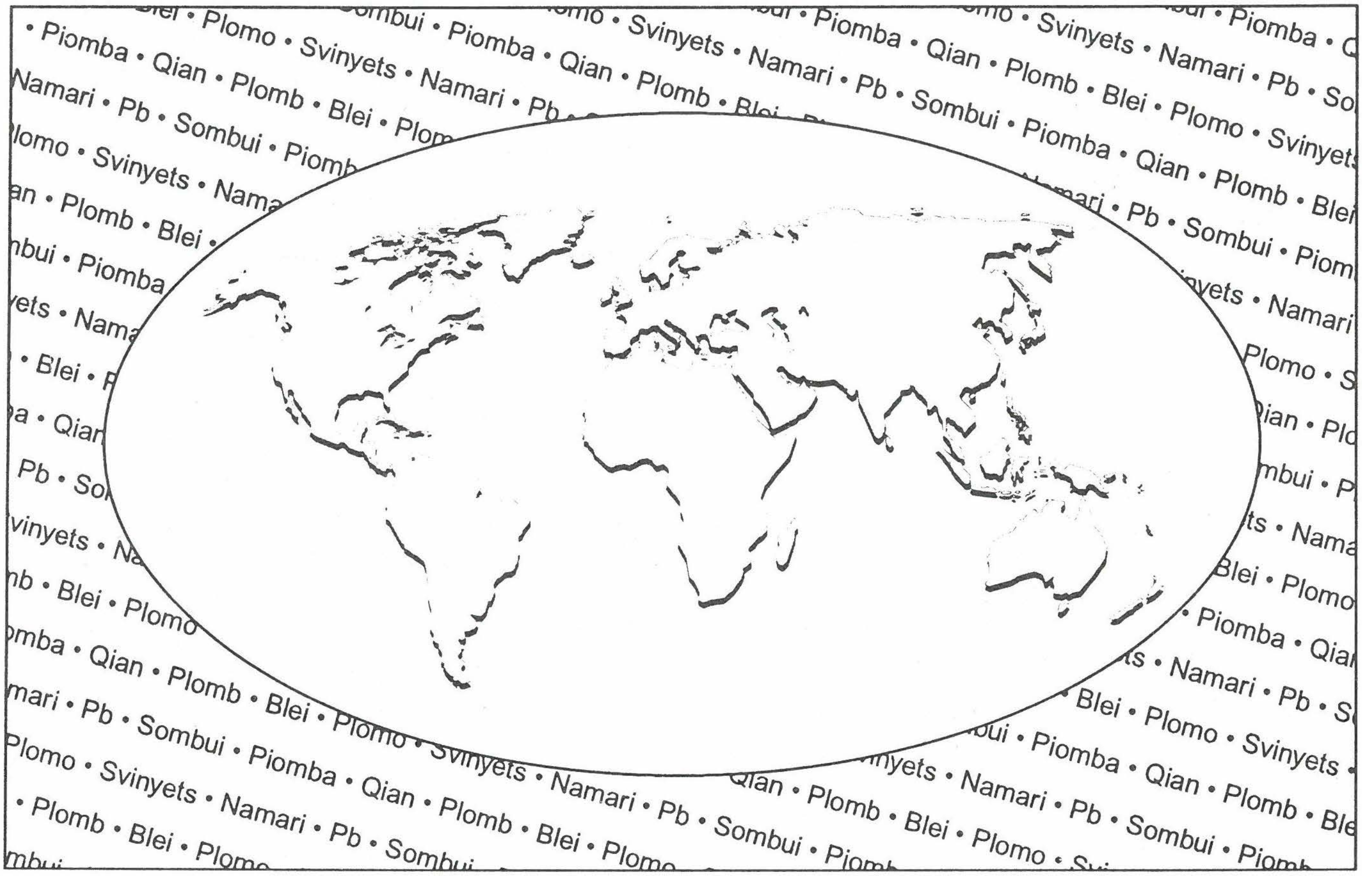

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227 Massachusetts Avenue NE, Suite 200
Washington, DC 20002
Phone: 01-202-543-1147 Fax: 01-202-543-4466

The Alliance is a U.S.-based non-profit public interest organization formed in October 1990 by leaders in pediatrics, public health, low-income housing, environmental protection, education, and children's welfare to focus exclusively on eliminating childhood lead poisoning. The Alliance's mission is to frame the agenda, formulate innovative approaches, and bring critical resources to bear—scientific and technical knowledge, public policy, economic forces, other organizations, and community leaders—to prevent childhood lead poisoning.

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Capital Office
1875 Connecticut Avenue NW, Suite 1016
Washington, DC 20009
Phone: 01-202-387-3500 Fax: 01-202-234-6049

The Environmental Defense Fund (EDF) was founded in 1967 by a group of scientists concerned about the effects of DDT on the environment. From its founding, EDF's accomplishments have been based on the combined efforts of scientists, economists, and attorneys, working for practical, economically sustainable solutions to environmental problems. Since its earliest days, EDF has sought to minimize lead exposure, playing a major role in the successful effort to reduce lead use in U.S. gasoline. Today, EDF's six offices conduct work in a wide variety of program areas, including Water Resources; Energy, Air Quality, and Global Atmosphere; International Issues; Solid Waste Reduction; Toxic Chemicals; and Wildlife and Habitats.

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Table of Contents

About the cover:

An outline of the world's continents is superimposed on field of the word "lead" in many languages. Chinese and Japanese terms are transliterated into the Roman alphabet. "Pb" is the symbol for lead in the periodic table of elements.

Acknowledgments

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Credits

Cover: Artwork design concept by Beatrice Bork; map production by Arnold Bombay.

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1 Executive Summary

Overview

Lead poisoning is an environmental and public health hazard of global proportions. At the same time, lead poisoning is intensely local in nature, as the causes of poisoning vary widely from country to country and from community to community. Strategies to prevent lead poisoning, therefore, depend on concerted efforts at the international, national, and local levels.

Around the world, exposure to excessive levels of lead in the environment, the home, and the workplace impose immense costs, with many millions of adults and children suffering adverse health effects and impaired intellectual development. The data suggest that lead poisoning is a problem that affects virtually every region of the world. Only in those few countries where the use of lead has long been limited, by circumstance or by prudent policy, is lead poisoning relatively insignificant.

Aggressive steps to combat lead poisoning must be taken at many levels. These steps range from raising awareness of the hazards of lead to remediation. Priorities will vary depending on local conditions. The greatest challenge facing most industrialized countries is to clean up lead contamination from inappropriate past uses. The challenge facing many developing countries is to prevent further environmental contamination through source control.

Only in those few countries where the use of lead has long been limited, by circumstance or by prudent policy, is lead poisoning relatively insignificant.

Background on Lead Poisoning

Lead occurs naturally in the earth's crust. When ingested or inhaled, lead is highly toxic to humans. Lead's toxicity has been known for thousands of years; Greek physicians made the first clinical description of lead poisoning in the first century B.C.

At high levels, lead poisoning causes coma, convulsions and death. At low levels—levels far below those that present obvious symptoms—lead poisoning in childhood causes reductions in IQ and attention span, reading and learning disabilities, hyperactivity, impaired growth and hearing loss. These effects are long term and may be irreversible.

Lead poisoning is a disease which responds poorly to the "medical model." For the vast majority of cases, medical treatment is not even an option, as chelation therapy is only appropriate for very high levels of lead poisoning. And while chelation lowers the level of lead circulating in blood, it is not known how effectively treatment can reverse damage that has already occurred. The only solution to lead poisoning is prevention—controlling exposure to lead in the environment before poisoning occurs.

Significance of this Report

Over the past several years, lead poisoning has attracted growing attention in the U.S., with both screening and prevention efforts being expanded. At the same time, however, lead poisoning has not been a subject of concern in most countries, and no comprehensive study has been conducted to characterize the global dimensions of the problem.

This study marks the first comprehensive attempt to collect and analyze existing data on human blood lead levels in conjunction with environmental data on lead outside the U.S. More than 700 published and unpublished studies were collected and reviewed, and more than half the reported data met our criteria for inclusion in this analysis.

Children and adults in virtually every region of the world are being exposed to unsafe levels of lead in the environment.

The data on human blood lead levels, although spotty and incomplete, are reinforced by environmental data and case studies of six countries, as well as illuminated by the well-established relationships between control actions and public health benefits. The contribution of this study is in the realm of public policy, not epidemiology.

The Scope and Nature of Global Lead Poisoning

The picture of the global dimensions of lead poisoning that is sketched by the available data is disturbing. Children and adults in virtually every region of the world are being exposed to unsafe levels of lead in the environment. The principal sources of lead exposure vary, depending on both current and historic patterns of lead use.

This analysis reveals some key patterns in lead exposure globally:

- Both environmental and blood lead levels are likely to be higher in urban areas than in suburban and rural areas (unless an industrial point source is present).

- Populations near a lead-related industry (whether urban or nonurban) are often exposed to unsafe levels of lead in air and soil, and blood lead levels are elevated correspondingly.

- Childhood lead poisoning is typically more severe in developing countries, due to inadequately controlled industrial emissions, unregulated cottage industries, and certain cultural practices, such as use of folk medicines containing lead.

- At the same time, developed countries cannot afford to ignore this problem—average blood lead levels of many studied populations are much higher than levels currently considered acceptable.

The Causes of Lead Poisoning

Worldwide, six sources appear to account for the most significant lead exposures in children and the general public (not necessarily in this order): 1) gasoline additives, 2) food can solder, 3) lead-based paints, 4) ceramic glazes, 5) drinking water systems, and 6) cosmetics and folk remedies.

Other significant exposures result from inadequately controlled industrial emissions from such operations as lead smelters and battery recycling plants, which contaminate environments and people in the surrounding area. Our analysis found that the highest levels of environmental contamination were associated with uncontrolled recycling operations and that the most highly exposed adults are those who work with lead.

Many nations, particularly in the developed world, have taken steps to reduce uses of lead that cause direct human exposure or environmental contamination. Other nations, though, still use leaded gasoline extensively, and few have instituted controls on most other high-exposure lead products. No nation has successfully met the challenge of remediating environmental contamination caused by prior uses and releases of lead.

No nation has successfully met the challenge of remediating environmental contamination caused by prior uses and releases of lead.

The Need for Action is Urgent

This report is intended as a first step toward guiding policy makers and others in developing prevention strategies at the international, regional, and local levels. The need for action on multiple fronts is urgent.

- In most countries, reliable data on the nature and extent of lead exposures are woefully inadequate. Both blood lead screening and environmental monitoring are needed to identify high risk populations and preventable exposures.

- Source controls should be pursued independent of data collection and research, as countries still lacking good data can take preventive steps based on experiences of others. Study after study has linked elevated levels of lead in the environment and humans to leaded gasoline, for example. Restrictions on leaded gasoline, food-can solder, and other lead-containing products must be an immediate priority.

- Prevention also depends on remediating contamination from past uses of lead products. Lead does not degrade. Once in soil or dust it persists indefinitely and can poison generations of children unless properly removed. Similarly, even if lead-based paint is no longer used in homes, old paint eventually deteriorates and contaminates household dust, posing a hazard to children.

- Education of parents and communities helps to minimize exposures to lead in the short term, and can motivate those most affected by lead to play an active role in developing long-term solutions.

- Successful prevention strategies must be launched on the international, national, and local levels, and their success depends on alliances between actors in such fields as housing, environment, and health.

Lead poisoning is a completely preventable disease.

Lead poisoning is a completely preventable disease. Substitutes exist for most products that currently contain lead (other than batteries), and pollution control and remediation technologies are available. Avoiding unnecessary uses of lead and remediating past contamination is entirely consistent with—indeed, arguably a paradigm for—the principles of sustainable development endorsed by most nations of the world during the 1992 United Nations Conference on Environment and Development. If sustainable development is to mean anything, it must include the protection of the intellect of future generations of children.

Scope and Organization of the Report

This report seeks to answer two questions: First, what is the extent and what are the causes of lead poisoning outside of the United States? Second, what strategies at the international, national, and regional levels can be implemented to prevent lead poisoning? The report is designed as a guide to lead poisoning prevention and a call to action for policy makers and advocates.

The most novel component of this report is its compilation and analysis of available human blood-lead data from outside the United States. The results of this analysis can be found in Chapter 5. Chapters 2 and 3 provide background information on lead's toxicity, lead exposure pathways, and global lead production and consumption. Chapter 4 analyzes environmental data from around the world. Chapter 6 presents a detailed analysis of the problem of lead poisoning in six case study countries: Australia, India, Japan, Mexico, Nigeria, and Poland. Finally, Chapter 7 offers international, regional, national, and local policy recommendations for eliminating lead poisoning.

A detailed description of the studies collected and reviewed for this report, as well as discussion of analytical methods can be found in the separate Technical Appendix to this report.

2 Background: The Toxicity of Lead

Lead's toxicity has been known for thousands of years. In 200 B.C., a Greek physician observed that "lead makes the mind give way." Almost two millennia later, Benjamin Franklin bemoaned how little had been done about the hazards of lead, noting in a letter to a friend, "you will observe with concern how long a useful truth may be known, and exist, before it is generally received and practiced upon."

Throughout the 20th century, it has become increasingly apparent that young children are highly susceptible to the harmful effects of lead. The recognition of lead's toxicity at doses that do not cause overt effects has accelerated in recent decades. Prior to about 1970, lead levels below 60 micrograms of lead per deciliter of blood (μg/dl) were not considered to require medical intervention, because overt symptoms such as convulsions generally do not occur until blood lead levels exceed this level. Indeed, one particularly disturbing feature of lead's toxicity is that extremely small amounts can have long-term and measurable effects on children, while at the same time causing no distinctive symptoms. During the 1970's and 1980's, medical authorities in the United States and elsewhere responded to the growing body of evidence on lead toxicity at low dose by repeatedly reducing the blood lead level deemed unacceptable.

The most commonly used measure of lead exposure is blood lead, usually measured in micrograms (millionths of a gram) of lead per deciliter (tenth of a liter), usually expressed μg/dl, of blood. Once lead is absorbed into the bloodstream, some is filtered out and excreted while the rest is stored in the skeleton or other organs. Since lead remains in the blood for only a matter of weeks, blood lead levels indicate very recent or ongoing lead exposure.

Today, a solid scientific consensus exists that exposure to even low levels of lead reduces I.Q., causes reading and learning disabilities, impairs growth, reduces attention span, and causes hyperactivity and other behavioral problems. As noted in a recent report by the U.S. National Academy of Sciences, "The weight of the evidence gathered during the 1980's clearly supports the conclusion that . . . blood lead concentrations in children around 10 μg/dl are associated with disturbances in early physical and mental growth and in later intellectual functioning and academic achievement" (NAS, 1993). These effects persist into adulthood and may be irreversible.

The long term effects of even low levels of lead on children have been well documented.

Prompted by this evidence, in 1991 the U.S. Centers for Disease Control (CDC) lowered the level of concern for lead in the blood of children to 10 μg/dl (U.S. CDC, 1991). Australia adopted the same action level in 1993 for adults as well as children (Australian and New Zealand Environment and Conservation Council, 1993). A level of 10 or 15 μg/dl for children is also being considered by the European Community (OECD, 1993).

Specifying an action level of 10 μg/dl does not necessarily mean that such a level is "safe" or "normal." No clearly defined threshold has been found below which deleterious effects of lead are absent. Nonetheless, higher and more prolonged exposures cause greater harm than do lower or briefer ones. Indeed, the CDC has developed various classes of elevated blood lead levels in children, with more comprehensive and aggresssive responses recommended for higher levels. For example, if a child's lead level is greater than 45 μg/dl, treatment and exposure reduction should start within 48 hours, while levels at or above 70 μg/dl are deemed a medical emergency. Slightly higher levels cause swelling of the brain, known as encephalopathy. Children with levels above 120 μg/dl may die unless immediately treated (lethal doses for adults are significantly higher).

No level of lead in blood is considered "safe" or "normal."

Children's vulnerability to lead results from three factors. First, because the nervous system of children is rapidly developing, it is more susceptible to lead-induced disruption. Second, because of their propensity to explore the world by mouthing their fingers, toys, and other objects, young children ingest far greater quantities of dust and soil than do adults—dust and soil that may be contaminated with lead from deteriorating lead-based paint, fallout from leaded gasoline, or fallout from industrial emissions. Finally, a child's digestive system absorbs much more of the ingested lead than does that of an adult: about 40 to 50 percent, rather than 10 to 15 percent (U.S. CDC, 1991).

While the neurotoxic effects of lead on children are the focus of greatest attention, lead also affects many other organ systems in both children and adults. For example, lead causes anemia by impairing formation of oxygen-carrying hemoglobin molecules beginning at exposures of around 40 μg/dl. In adults, small but significant increases in blood pressure result from exposures as low as 5 μg/dl, with no evidence of a threshold below which lead does not affect blood pressure. Other adverse effects in adults include kidney disease and impaired fertility (NAS, 1993). In addition, lead absorbed during childhood can be released back into the blood during pregnancy, harming the developing fetus as well as the mother (Silbergeld, 1991).

Ideally, neither children nor adults should have any lead in their bodies, since it provides no physiological benefit. But because lead is a relatively abundant metal in the earth's crust, humans throughout evolution have had trace amounts of lead present in their blood. This natural background level, estimated to be 0.016 μg/dl, is minuscule compared to lead exposures following industrial development. Today, even populations in the most remote areas of the Southern Hemisphere have blood lead levels 50 times greater than the natural background level, while the current U.S. level of concern exceeds it by 600 fold (Flegal and Smith, 1992).

While drugs (called chelation therapies) can enhance the body's ability to remove lead from blood and excrete it, these drugs are expensive and have side effects. They may also do little to reverse neurological or other damage already caused by lead. The only reliable "cure" for lead poisoning is prevention—controlling sources of exposure *before* children or adults are poisoned.

3 Lead Production and Use

Lead Exposure Pathways and the "Life Cycle" of Lead

Lead is an element, one of the fundamental building blocks of nature. As such, it does not degrade or lose its toxicity over time once released in the environment. While lead is a naturally occurring component of the earth's crust, it does not become readily bioavailable (i.e., available to living organisms) until it is mined and subsequently used by humans.

Lead can be released into the environment and pose a health hazard to people at any stage of its "life cycle": beginning with mining activities; through smelting and refining (including disposal of associated wastes); during manufacturing of lead-containing products and disposal of manufacturing wastes; when the product is used; and when it is discarded or recycled. The extent to which release or exposure actually occurs for a particular product ranges widely, depending on the type of product and on the kinds of controls on its production and disposal facilities.

Humans are exposed to lead in numerous products and through a myriad of pathways, including air, food, soil, dust, and water.

Humans are exposed to lead in numerous products and through a myriad of pathways, including air, food, soil, dust, and water. The relative importance of these pathways in contributing to an individual's total lead exposure depends on environmental contamination levels as well as his or her behavior patterns, which in turn are influenced by age and other factors. There are no known genetic predispositions to lead toxicity.

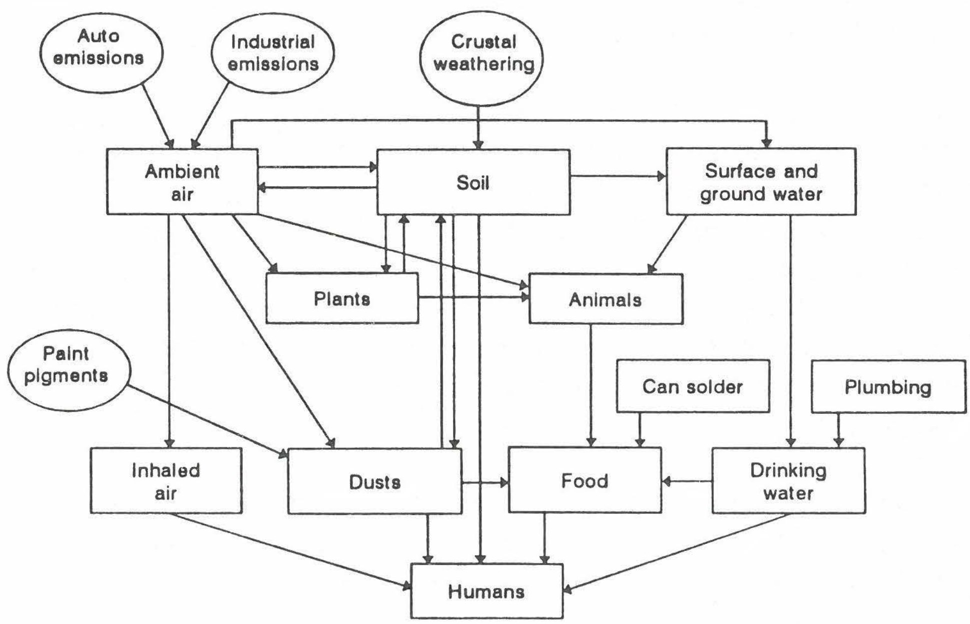
Because of young children's normal hand-to-mouth behavior, dust and soil are the principal exposure pathways for most children. Even an invisible residue of lead dust on objects mouthed by children can present a significant hazard, since daily ingestion of roughly 60 μg of lead—about two-thousandths of an ounce—will cause a child's blood-lead level to rise above 10 $\mu g/dl$ within a few weeks (U.S. Food and Drug Administration, 1993). In addition, some children deliberately eat nonfood items, such as soil and paint chips. This practice, called pica, can be a major source of ingested lead.

Adults who work with lead tend to receive their greatest exposure by inhaling lead fumes or particles. Adults who are not occupationally exposed typically absorb lead primarily from food.

Two factors tend to magnify the intensity of lead exposure among poor populations in both developed and developing nations. First, because lead is absorbed from the stomach more efficiently when the diet lacks essential trace elements (especially iron, calcium, and zinc) as well as when the stomach is empty, poorly nourished people may absorb more of the lead that they ingest. Second, limited water supplies can hamper efforts to wash lead-contaminated dust or fallout off contaminated foodstuffs or out of living spaces. These two factors mean that similar levels of environmental contamination may have more pronounced effects in increasing blood lead levels in disadvantaged populations. In many societies, the poor and disadvantaged also live in areas close to sources of environmental contamination, such as smelters and waste disposal sites. And particularly in developed nations, poor families often live in older, substandard housing which is more likely to contain deteriorating lead based paint and, as a consequence, lead-contaminated dust.

A range of sources can contaminate the various pathways of human exposure, often through intermediate steps (see figure 1). For example, the release of lead to air from vehicles using leaded gasoline or from airborne industrial emissions contributes lead not only directly to air but also—and more importantly—to dust, soil, and food crops when the lead particles fall out. Similarly, the deterioration of lead-based paint releases particles that contaminate dust and soil. Once in soil or dust, lead persists indefinitely unless washed away or remediated. Lead-contaminated soil thus represents an essentially permanent reservoir that can poison children and others for decades or centuries.

Figure 1. Sources and Pathways of Lead from Environment to Humans.



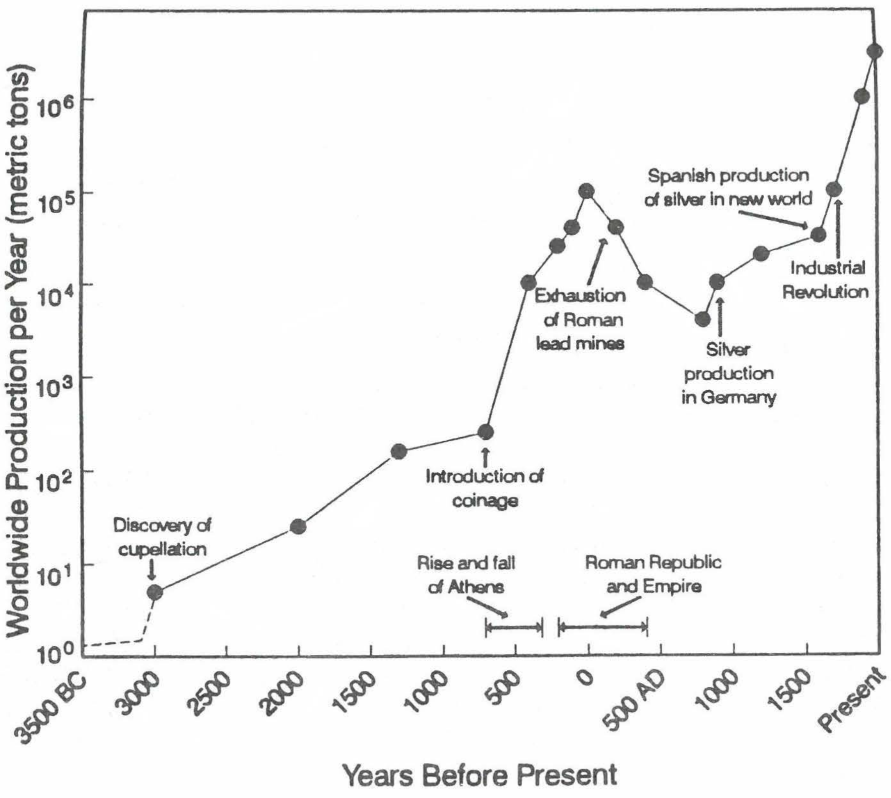
Source: NAS, 1993, reprinted by permission.

Global Lead Production

Despite lead's toxicity, its physical and chemical characteristics—corrosion resistance, malleability, and others—have prompted its use throughout history for a wide variety of products. As new uses for lead have been discovered, and as the global economy has grown, the worldwide use of lead has expanded accordingly.

Significant global lead production began with the discovery of cupellation—a process for separating silver from lead ores—around 3000 B.C. For a brief period, the Roman Empire produced considerable quantities of lead (up to 100,000 metric tons annually). Not until the Industrial Revolution did production consistently exceed that level. (See figure 2; note that the vertical axis of figure 2 is a logarithmic scale using scientific notation, meaning that each increment represents a tenfold increase, i.e., 10^4 is 10,000 while 10^5 is 100,000.)

Figure 2. Historical Record of Industrial Lead Production.



Source: NAS, 1993, by permission.

Despite lead's toxicity, worldwide use of lead has expanded with the global economy and as new uses for lead have been discovered.

At the beginning of the 20th century, annual lead mine production amounted to about 1 million metric tons (ILZSG, 1990). Over the last three decades, both mine production and refined metal production have grown consistently, flattening out in the early 1990's to reflect the global economic slowdown at about 5.5 million metric tons. Throughout this century, secondary smelting (recycling) of lead has become increasingly important and now accounts for almost half of world refined lead production. The chief source of scrap lead for secondary smelters is lead-acid batteries from vehicles and industries. In many instances, secondary smelters are operated by and located adjacent to battery producers.

Today, lead mining and processing operations are found around the globe (see figure 3 on page 10 and Appendix B). About 50 nations mine lead in quantities ranging from a few hundred metric tons to more than half a million metric tons (U.S. Bureau of Mines, 1993b). As has been the case throughout the last three decades, Australia, the United States, and the former Soviet Union are currently the chief producers of ore concentrates (a "concentrate," the form in which lead is generally shipped to the smelter, is a partially processed ore containing 60-70% lead).

Smelters/refineries need not be located close to mines, and in fact the list of top producers of refined metal only partially overlaps that of top ore producers (see table 1). Roughly 20 nations produce only secondary (i.e., recycled) lead, while half a dozen produce refined metal from virgin ore but do no recycling. In a few nations, most notably the United States, production of lead through recycling far outstrips production from ore. The U.S. currently produces 30% of the world's secondary lead (U.S. Bureau of Mines 1993a).

Table 1. Top Lead Producers, 1991 (in metric tons)

Ore Concentrates		Refined Metal	(% primary)
1. Australia	571,000	U.S.	1,229,000 (28%)
2. U.S.	477,000	U.S.S.R.*	630,000 (60%)
3. U.S.S.R.*	400,000	Germany	403,000 (43%)
4. China	380,000	United Kingdom	335,000 (48%)
5. Canada	235,000	China	330,000 (80%)
6. Peru	203,000	Japan	328,000 (67%)
7. Mexico	158,000	France	260,000 (62%)
8. No. Korea	120,000	Australia	240,000 (92%)
9. Yugoslavia	90,000	Mexico	195,000 (82%)
10. Sweden	79,000	Canada	191,000 (52%)

* 1991 data, the most recent available, include the former U.S.S.R. and Yugoslavia as single reporting entities.

Source: U.S. Bureau of Mines, 1993b.

International trading patterns for lead ore and refined lead fluctuate with price and other factors. In general, Europe and Japan are the largest importers of lead, often shipping it from long distances. For example, in 1990, Germany's main sources of supply were Canada, Ireland, and Sweden, while Japan's were Australia, Peru and Canada (U.S. Bureau of Mines, 1991a,b). Overall, Australia, Canada, Mexico, and Peru are the major lead exporters.

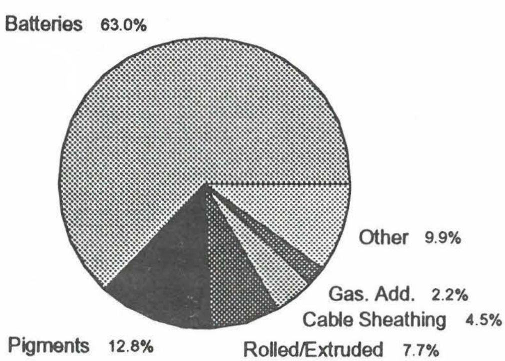
While most recycling occurs in Western Europe, North America and Japan, a growing number of secondary smelters are being established in developing nations to process locally available supplies (e.g., spent batteries) and, in some instances, imported materials.

Global Lead Consumption

Member nations of the Organization for Economic Cooperation and Development (OECD)—essentially, Europe, the U.S., Canada, Australia, New Zealand, and Japan—accounted for 65% of world lead consumption in 1990, off only slightly from 70% in 1970 (OECD, 1993). Relative consumption by the countries of Eastern Europe, Latin America, and Africa has remained fairly constant on a percentage basis. However, their total lead consumption has increased significantly. For example, Africa's change from 1% to 2% of world demand represents a threefold increase in regional lead consumption over two decades. Similarly, lead use in Asia has increased sixfold in the past 20 years.

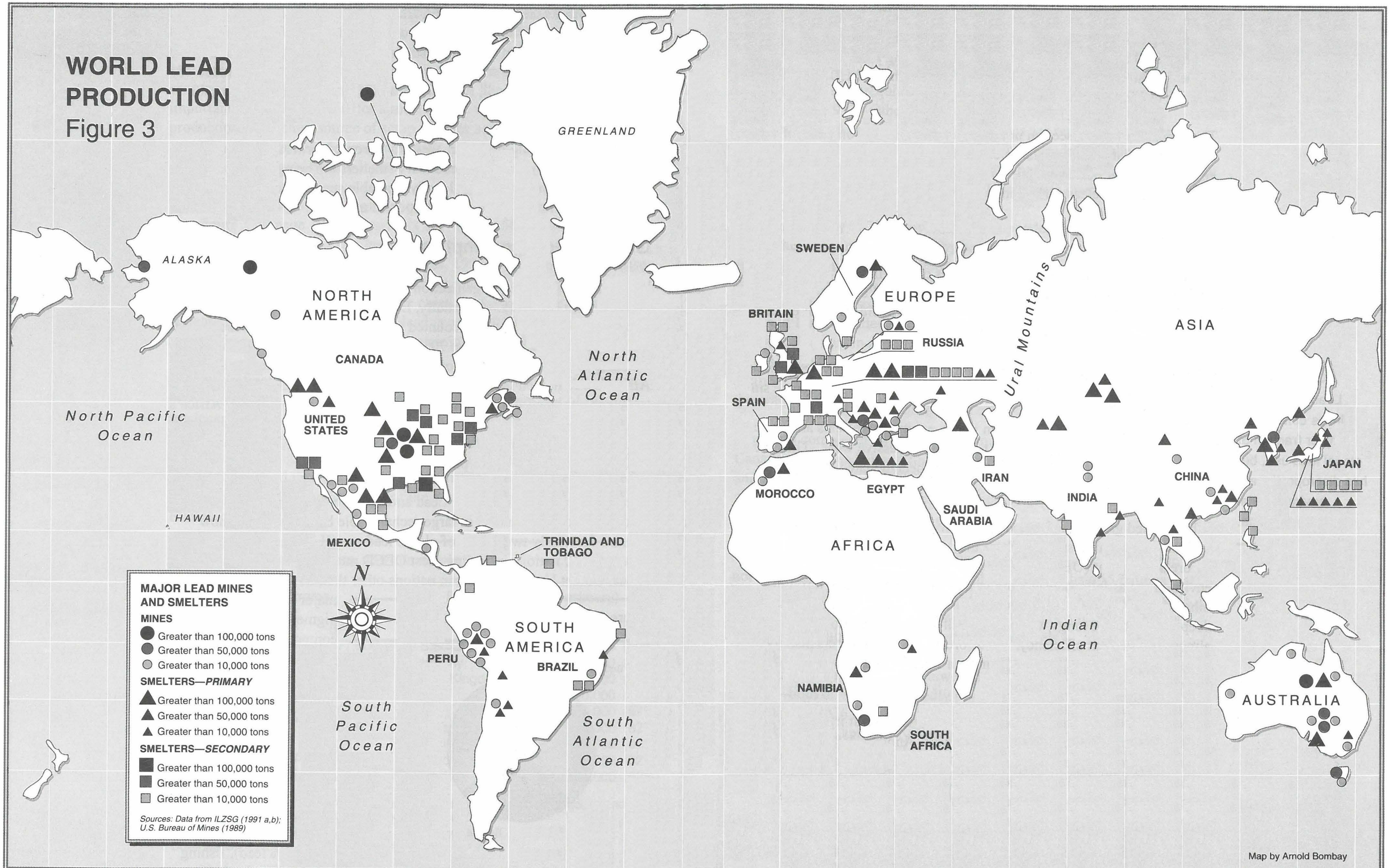
According to the International Lead and Zinc Study Group (ILZSG), the predominant use of lead is in large rechargeable batteries, which now account for nearly two-thirds of global lead use (ILZSG, 1992). (ILZSG data cover 30 nations including most OECD members, but not China, the former Soviet Union, or African nations other than South Africa.) Other major uses of lead include pigments and other compounds, rolled and extruded products, cable sheathing, alloys, shot and ammunition, and gasoline additives (see figure 4).

Figure 4. Principal Uses of Lead



Source: ILZSG, 1992.

Uses of lead not reported as individual categories by ILZSG include radiation shielding, ceramic glazes, crystal (which can contain up to 36% lead), fishing weights, as a heat



WORLD LEAD PRODUCTION
Figure 3
GREENLAND
ALASKA
NORTH AMERICA
CANADA
UNITED STATES
MEXICO
North Pacific Ocean
HAWAII
North Atlantic Ocean
TRINIDAD AND TOBAGO
SOUTH AMERICA
PERU
BRAZIL
South Pacific Ocean
South Atlantic Ocean
SWEDEN
BRITAIN
EUROPE
RUSSIA
SPAIN
Ural Mountains
ASIA
MOROCCO
EGYPT
IRAN
SAUDI ARABIA
INDIA
CHINA
JAPAN
AFRICA
NAMIBIA
SOUTH AFRICA
Indian Ocean
AUSTRALIA
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MAJOR LEAD MINES AND SMELTERS
MINES
Greater than 100,000 tons
Greater than 50,000 tons
Greater than 10,000 tons
SMELTERS—PRIMARY
Greater than 100,000 tons
Greater than 50,000 tons
Greater than 10,000 tons
SMELTERS—SECONDARY
Greater than 100,000 tons
Greater than 50,000 tons
Greater than 10,000 tons
Sources: Data from ILZSG (1991 a,b); U.S. Bureau of Mines (1989)
Map by Arnold Bombay

stabilizer in polyvinyl-chloride plastics, and numerous others. Another potentially important category not separately reported is that of lead-containing pesticides such as lead arsenate, historically used on crops as diverse as tobacco and grapefruit. Lead-containing pesticides have been banned in the U.S., Austria, Belgium, and Germany (OECD, 1993), but data are lacking on other nations.

The remainder of this section provides additional detail on some of the uses of lead that are of special interest due to their volume or their environmental or health significance, and the final portion addresses lead exposures at and releases from industrial facilities.

Gasoline

While lead in gasoline additives constitutes only a minor fraction of global lead use, this use has disproportionate environmental significance. This reflects the fact that the use of leaded gasoline unavoidably and efficiently disperses lead in the human environment.

Lead in gasoline additives constitutes only a minor fraction of global lead use, but has disproportionate environmental significance.

Lead compounds, specifically tetraethyl lead and tetramethyl lead, have been added to gasoline to increase octane and enhance performance since 1923. (Although lead additives were initially developed as octane enhancers, some vehicles—those in which engine valve seats are made of soft metal—allegedly require lead to prevent excessive wear. The extent to which lead is needed for this purpose has been debated [Nriagu, 1990b].)

When leaded gasoline is burned, extremely small particles of lead are emitted into the atmosphere, where they can persist for a few weeks before settling out (OECD, 1993). In addition to contaminating the environment as fallout, lead from gasoline can be absorbed through inhalation. Very small particles of lead can be inhaled and reach the deepest part of the lungs, where they will be absorbed into the blood with almost 100 percent efficiency. Thus, breathing air on streets heavily traveled by lead-fueled vehicles can be a significant source of exposure, as shown in studies of traffic officers.

Only about 10% of lead from auto emissions settles out in the immediate vicinity (within 100 meters) of the roadway. Another 45% settles out within 20 km, 10% between 20 and 200 km, and the remaining 35% is carried on long-range atmospheric transport systems (OECD, 1993). Evidence of this long-range transport are the enhanced levels of lead from gasoline and other sources found in snows in Greenland (Boutron, et al., 1991).

The U.S. and a few other nations began to reduce use of lead additives in gasoline in the early 1970's. At that time, U.S. auto manufacturers were required to place catalytic converters on new cars sold domestically, in order to reduce tailpipe emissions of various pollutants. Because such converters are rendered inoperative by lead, the U.S. Environmental Protection Agency required that lead-free gasoline be made available beginning in 1973. Other nations subsequently imposed similar requirements. As older cars in those nations are replaced by newer converter-equipped vehicles, the market for unleaded gasoline grows (though drivers may "mis-fuel" with leaded gasoline if it is cheaper, since a disabled converter does not prevent the car from operating).

Also in the early 1970's, governments responded to growing concerns about the health effects of lead by beginning to phase down the amount of lead allowed in leaded automotive gasoline. Prior to 1970, the lead content of premium (i.e., high octane) gasoline exceeded 0.78 grams of lead per liter of gasoline (g/l) (Nriagu, 1990b). At present, the allowable levels of lead in leaded gasoline range from a high of 1.12 g/l in the Virgin Islands (Thomas, in press), to a low of 0.026 g/l in Canada and the United States (CONCAWE, 1992). (Because lead is a naturally occurring element, it is present at trace levels even in unleaded gasoline, which is generally defined as containing less than 0.013 g/l of lead [OECD, 1993].

Japan has completed its phaseout and now uses no leaded gasoline, while Canada allows leaded gasoline only in agricultural and marine vehicles and large trucks (CONCAWE, 1992). In the U.S., leaded gasoline now accounts for only a small fraction of total automobile gasoline use and will be fully banned at the end of 1995.

Around the globe, however, some use of leaded gasoline remains the norm, at least for some grades of gasoline. Table 2 lists 55 nations that allow relatively high concentrations of lead in some or all gasoline, i.e., above 0.65 g/l. (Though the list reflects 1991 data, the authors are not aware of any subsequent reductions in these levels.)

Other nations have somewhat lower limits. For example, India and South Africa—both of which reportedly plan to introduce unleaded gasoline in 1995—allow 0.56 and 0.40 g/l respectively (CONCAWE, 1992). Similarly, China apparently uses leaded gasoline extensively, with a lead content up to 0.78 g/l, while Russia allows up to 0.38 g/l; within Russia, the availability of unleaded gasoline is said to be limited outside of Moscow and St. Petersburg (Octel, 1992).

In New Zealand, premium gasoline may contain 0.45 g/l; although premium unleaded is not available, regular grades cannot contain lead (CONCAWE, 1992). Different states within Australia have adopted

Table 2. Highest Allowed Concentrations of Lead in Gasoline (g/l), 1991.

1.12	Virgin Islands
0.845	Dominican Republic
0.84	Aruba, Bahamas, Barbados, Belize, Benin, Burkina, Cape Verde Islands, Central African Republic, Chad, Costa Rica, Cuba, Curacao, Equatorial Guinea, Fiji, Guinea, Guinea-Bissau, Haiti, Honduras, Indonesia, Jamaica, Lebanon, Macao, Maritius, Marshall Islands, Myanmar (Burma), Nauru, New Caledonia, Norfolk Islands, Papua, Paraguay, Peru, Rwanda, Sahara West, Saint Martin, Seychelles, Sierra Leone, Solomon Islands, Somalia, Uganda, Western Samoa, Zimbabwe
Other High Lead Countries:	
	Panama: 0.82, Ivory Coast: 0.8, Libya: 0.8, Madagascar: 0.8, Mali: 0.8, Philippines: 0.8, Angola: 0.77, Liberia: 0.77, Trinidad and Tobago: 0.77, French Guyana: 0.75, Guyana: 0.72, El Salvador: 0.7

Source: Thomas, in press (country names used are those shown in the source cited)

varying lead limits for premium (ranging from 0.3 in Victoria to 0.84 in some regions), though all forbid lead in regular grade gasoline.

Most European nations allow 0.15 g/l in premium gasoline, though some (Germany, Belgium, and Luxembourg) forbid lead in regular grades; other nations (the United Kingdom, Denmark, and the Netherlands) use tax incentives to make unleaded regular cheaper than leaded regular (CONCAWE, 1992). But Portugal allows 0.4 g/l in both premium and regular, and Greece allows 0.4 g/l in regular. Outside of Europe, a handful of other countries have adopted a 0.15 g/l limit for all grades (Singapore, Thailand, Malaysia, Hong Kong, Israel, and Canary Islands) (Octel, 1992).

Even in nations that have already sharply restricted leaded gasoline, corporations continue to supply other markets. For example, in 1991 the U.S.-based Ethyl Corporation estimated that it supplied about one-third of the lead additives sold worldwide, partly through production at a plant in Canada (Ethyl Corp., 1991).

Paint

Because of the durability they provide, lead compounds have been added to paints for hundreds of years. Lead carbonate, or "white lead," was highly popular as a base for oil paints in the 18th and early 19th centuries. White-lead paints often contained up to 50% lead by dry weight.

The toxicity of white lead to workers and children was recognized by the turn of the century, and lead paint was identified as the source of childhood lead poisoning in 1904 in Australia (Gibson, 1904). Nonetheless, lead paints were sold for decades thereafter in many countries (see figure 5).

Children are potentially at risk of exposure wherever lead-based paint has been used.

Today, dust contaminated by lead-based paint is considered the most significant source of moderate and severe lead poisoning in children in the U.S. While the magnitude of the problem may not be as great in most other countries, children are potentially at risk wherever lead-based paint has been used. Whenever leaded paint deteriorates, is disturbed during renovation, or is abraded on surfaces such as floors or window tracks, lead is released into interior dust or exterior soil, where it remains indefinitely unless properly abated.

In response to worker protection concerns, the International Labor Organization developed a treaty in 1921 barring interior use of paints made from white lead and sulfate of lead containing more than 2% lead in the interior of buildings. Most European nations signed the treaty during that decade, and many other countries signed subsequently (see table 3).

Figure 5: PHOTO: Paint advertisement

The dangers of lead-based paint have long been recognized: an 1897 advertisement for paint that is lead-free and non poisonous.

In many countries, lead-based paint has been largely ignored as an important source of lead in children's environments.

While a step in the right direction, the treaty unfortunately led many people to conclude, incorrectly, that lead-based paint posed no further problem. In reality, the treaty was far from comprehensive. It did not apply to exterior paints and addressed only two lead compounds used in paint (excluding, for example, lead chromate). In addition, it allowed up to 2% lead (20,000 parts per million) even in pigments applied to interiors. (By contrast, the current U.S. standard for unleaded paint is 0.06%, or 600 ppm.) Finally, the treaty made no effort to address paint applied before its effective date. Nor is it clear that there was complete compliance with the treaty's terms within signatory nations.

Nonetheless, lead-based paint has been largely ignored outside of the U.S. as an important source of lead in children's environments. There is scant information available on the current or past residential use of lead-based paint in developing countries. And even in developed countries, concern has tended to focus on lead in other environmental media.

But available information suggests this complacency is ill founded. For example, although Belgium signed the treaty in 1926, a 1984 survey found that 52% of homes investigated in Brussels contained at least one surface with lead-based paint (Steenhout, et al, 1984). Recently, a preliminary survey in Paris, France, identified 95 children with blood lead levels above 25 μg/dl and concluded that the principal source of lead exposure was lead paint on walls and door frames. The investigators noted that the prevalence of lead poisoning in France "is certainly underestimated" (Working Group for Child Lead Poisoning, 1989).

Table 3. Signatories to White Paint Treaty

1923	Czechoslovakia, Sweden	1960	Benin, Burkina Faso, Cameroon, Central African Republic, Chad, Congo, Gabon, Ivory Coast, Madagascar, Mali, Senegal, Togo
1924	Austria, Poland, Spain	1961	Mauritania, Niger
1925	Bulgaria, Chile, Romania	1962	Algeria
1926	Belgium, France, Greece	1964	Lao People's Democratic Republic
1928	Cuba, Luxembourg	1966	Iraq
1929	Finland, Norway, Yugoslavia	1969	Democratic Kampuchea
1933	Columbia, Nicaragua, Uruguay, Venezuela	1970	Panama
1936	Argentina	1976	Suriname
1938	Mexico	1978	Comoros, Djibouti
1939	Afghanistan, Netherlands	1988	Malta
1952	Italy		
1953	Viet Nam		
1956	Hungary, Morocco, Tunisia		
1959	Guinea		

Source: United Nations Environment Programme, 1989 (country names used are those shown in the source cited).

During the last few years, a number of OECD nations have tightened controls on residential use of lead-based paints (OECD, 1993). In 1993, for example, France banned the sale of paints containing white lead, while Finland prohibited use of lead carbonates and lead sulfate, except in the restoration of artworks and historic buildings. In Sweden, paint producers agreed as of July 1990 to discontinue the use of lead chromate in paint, and white lead is not used. Japan reports that, under voluntary agreements with industry, no lead-based paints are used on toys or in household paint.

But in these nations and elsewhere, hazards from prior use of lead-based paint will remain an actual or potential threat for decades or even centuries to come. Homes dating from before the 1920's are common throughout Europe, placing a significant number of children at risk.

Finally, it is important to note the lack of restrictions on lead-based paint in nonresidential applications. Such paints are still permitted in most nations for marine, commercial, and industrial purposes. Although nonresidential lead paints are less likely to poison children, worker and environmental exposure remain highly significant. In the U.S., workers repairing or repainting lead-painted steel structures such as bridges and water towers have become severely poisoned (U.S. CDC, 1992). Residential neighborhoods have been contaminated by releases from such work sites.

Plumbing

Lead has been used for pipes and solder in plumbing systems for centuries. So close is the historical linkage between plumbing and lead that the word "plumbing" is derived from the Latin word for lead, plumbum.

Although lead is typically a minor constituent of surface waters and aquifers, drinking water is often contaminated by water distribution systems that contain lead in their pipes, solder, or leaded-brass plumbing fixtures. Water is most likely to absorb lead from plumbing if it is hot, has low mineral content, or is acidic. Infants fed formula made from hot tap water are particularly at risk of lead poisoning from this source.

Drinking water is often contaminated by water distribution systems that contain lead in their pipes, solder, or leaded-brass plumbing fixtures.

Many OECD nations now limit the use of lead-containing materials in drinking water systems, including Finland, Canada, Germany, Ireland, Netherlands, Sweden, Switzerland, the United Kingdom, and the U.S. (OECD, 1993). However, lead water mains, service lines (connectors from the main to the individual buildings), and other plumbing components long ago installed in Europe and the U.S. can continue to present hazards today. To help reduce lead levels in drinking water, many cities have instituted corrosion control measures (i.e., adding chemicals to increase the water's mineral content and pH).

There is little information available on lead in plumbing in developing countries. Much of the developing world lacks plumbing infrastructure, lead-containing or otherwise, with over 1 billion people lacking access to clean and plentiful water (World Bank, 1992). It is not clear whether developing nations are taking steps to avoid the use of lead-containing components as they make investments in their plumbing infrastructure.

Food Can Solder

In addition to its use in plumbing systems, lead solder is used in food cans (and for industrial purposes such as electronics and construction). High levels of lead may leach from lead-soldered cans into food, particularly if the food is acidic (tomatoes, citrus fruits).

High levels of lead may leach from lead-soldered cans into food, particularly if the food is acidic.

International data on use of lead-soldered food cans is sparse. The U.S., which ceased producing such cans in 1991 under a voluntary industry program, has also proposed a ban on imported lead-soldered cans (U.S. Food and Drug Administration, 1993). The industry in Mexico voluntarily stopped manufacturing food cans with lead solder in July 1992. In contrast, food-canning equipment in Eastern Europe and the former U.S.S.R. is generally decades old and thus likely to use lead solder, as is "surplus" equipment sold by developed countries to developing nations.

Ceramic Glazes

Lead is added to many ceramic glazes to promote brilliance and for other properties. In addition to exposure resulting from use of lead-glazed ceramics, exposure also occurs in work places—particularly cottage industry settings—where such glazes are made and applied (see below). Lead glazes, or "greza," have also been used as folk medicines in Latin America.

Leaching of lead from glazes on inappropriately fired ceramics has been recognized as a problem for many years. In 1981, the International Organization for Standardization (ISO) developed standards for leachable levels of lead from ceramicware. The ISO limits—5.0 milligrams per liter for small hollowware, 2.5 mg/l for large hollowware, and 1.7 milligrams per square decimeter for flatware—were promptly adopted by more than a dozen nations (McLaren, 1984) (Lower levels have subsequently been set, at least in the U.S.)

Even in nations that adopted these standards, however, the extent of enforcement is unclear. Mexico, for example, is still struggling to change an artisan tradition established over many generations. In 1991, Mexico instituted a government-funded research group "to study technological alternatives to substitute the use of lead on glazed pottery or to decrease lead solubility without changing the typical characteristics of regional glazed pottery" (OECD, 1993).

Lead exposure from ceramic glazes can be substantial. For example, a 1991 study of a group of 99 housewives in Mexico City concluded that use of lead-glazed ceramics was a principal determinant of their elevated blood lead levels (Avila et al, 1991). Recently, the State of California issued a health alert advising consumers not to prepare food in pottery bean pots imported from Mexico after one such pot was found to leach more than 5,000 ppm lead. Indeed, the beans cooked in the pot contained more than 1,000 ppm lead, enough to qualify as hazardous waste under California law (State of California Department of Health Services, 1992).

Cosmetics and Home Remedies

Use of lead in cosmetics and home remedies is rare in the developed world (except in immigrant populations), but appears to be common throughout the developing world. Some remedies, like empacho in Mexico, are used for stomach ailments. Since one symptom of lead poisoning is stomach pain, use of the remedy may exacerbate the symptom. Cosmetics containing up to 95% lead, like surma in India and tiro in Nigeria, are used on children of both sexes, who are poisoned when they rub their eyes and then put their fingers in their mouths.

Use of lead in cosmetics and home remedies appears to be common throughout the developing world.

A study conducted in the United Arab Emirates (UAE) demonstrates the high toxicity of home remedies containing lead. Infants in the UAE are often given a preparation called Bint Al Zahab (BAZ), which contains 80% lead, for abdominal colic. After short-term use (less than one month), six infants in one study were found to be severely lead poisoned with symptoms of irritability, drowsiness, and convulsions. One infant even showed significant brain atrophy as a result of being given BAZ (Rahman, H. et al, 1986).

Batteries

Around the globe, the principal use of lead for the past several decades has increasingly shifted to lead-acid batteries, primarily for use in automobiles and other vehicles. This shift reflects two independent factors: on the one hand, a fivefold increase in the number of cars in use globally since 1960; and, on the other, restrictions on lead use in some other products, such as gasoline and pigments. Demand for lead in battery manufacturing has increased by 79% over the past 20 years (OECD, 1993) and now accounts for more than 60% of the overall demand for lead. In some nations, the level is even higher (e.g., 80% in the U.S.). Unlike the other products discussed in this section, no substitutes for this use of lead currently exist.

Although batteries present virtually no risk of lead release during their useful life, both production and recycling operations often cause significant contamination.

Once spent, most batteries in industrialized nations are recycled. The recycling rate in some nations, such as Australia, Canada, Germany, Japan, Sweden, the United Kingdom and the U. S., reportedly exceeds 90% (OECD, 1993). But even in nations with generally high recycling rates, the small percentage of non-returns, when multiplied by the large amount of lead in each battery (roughly 8 kilograms), means that a significant amount of lead may end up in municipal landfills or incinerators, or as roadside litter.

Moreover, although batteries present virtually no risk of lead release during their useful life while the battery casing remains intact, both production and recycling operations often cause significant contamination (see figure 6). For example, massive environmental releases and occupational exposures have reportedly occurred at recycling smelters in Brazil and Taiwan (Center for Investigative Reporting, 1990). Such plants may recycle batteries from both their own areas and those exported from developed nations. The U.S.-based Battery Council International reported that 6,800 metric tons of lead were contained in batteries exported from the U.S. for recycling in 1990 (Battery Council International, 1992).

Figure 6: PHOTO: Battery waste

Approximately 3,000 megatons of scrap batteries in Monterey, Mexico, 1989.

Occupational Exposures and Industrial Releases

Just as production and recycling of lead-acid batteries can release lead and cause occupational exposure, so can other industrial operations that process lead or use it in product manufacture. Mining, smelting, refining and manufacturing can release lead into air, water and soil at extraordinarily high levels. In the United States' "Superfund" program for dump site cleanups, lead ranks first on the Priority List of Hazardous Substances found at Superfund sites. Lead earned that dubious distinction when ranked against all other contaminants in terms of its frequent presence at cleanup sites, its toxicity, and the potential for human exposure (U.S. Agency for Toxic Substances and Disease Registry, 1991).

Work place exposures to lead are often extreme, with workers receiving doses well above those experienced by the general population. The most heavily lead-exposed adults are almost exclusively found to be those who work with lead, particularly in the absence of adequate ventilation and other controls. Moreover, exposed workers may carry lead particles home on their clothing, shoes, or hair, putting family members in jeopardy.

The use of lead in the small-scale, often home-based operations known as cottage industries is of special concern. Such industries include making or applying leaded glazes to ceramics, producing jewelry from lead-containing silver, and recycling spent lead-acid batteries. Common in the developing world, cottage industries are especially dangerous because they almost never have adequate ventilation or controls on worker exposure or lead release. Poisonings can affect not only workers but whole families and sometimes even entire neighborhoods.

In Jamaica, for example, backyard lead smelting is a common practice in some areas. Soil lead levels in some backyard smelting sites are extraordinarily high, ranging up to 30% (300,000 ppm) in the topmost soil. Since backyards are shared by more than one household, multiple families are exposed to the hazard. Mean blood lead levels of young children living near smelter sites were almost three times higher than those of children from a nearby community with no backyard smelting activities (Matte, 1991).

4 Environmental Contamination Patterns

Although some exposure to lead results from direct contact with lead-containing products, human exposure more frequently occurs via environmental media such as air, water, and soil. This section describes the limited information now available on lead levels in environmental media, and attempts, where possible, to link particular sources and media. (See chapter 5 for a discussion of human blood lead data.) A fuller discussion of methods and sources is found in the separate Technical Appendix to this report.

Methods

To assess global lead contamination patterns, we compiled and analyzed a database of lead measurements in air, water, soil, and dust. To compile the database, we first identified through a literature search more than 500 potentially relevant articles, most published since 1967. We then obtained as many of the articles as possible (some could not be retrieved) and reviewed them. In addition, we sent letters to more than 200 national environmental agencies around the world and received approximately 50 responses.

Data from both sources were entered into a computerized database using standardized units of measure and place names. Some studies had to be omitted because they lacked appropriate information on these or other key variables. A considerable number of studies turned out to contain data on plants and animals rather than environmental media; because of the lack of comparability of data on various species and subspecies, we did not include biota in our analyses. Despite repeated efforts to locate data on nations outside of Europe and North America, we found such information to be relatively sparse. The final database includes nearly 600 measurements of lead in air, water, soil and dust from approximately 215 studies. Except where otherwise noted, figures presented in this chapter are derived from our analyses of this database on environmental media.

Many of the studies reported city- or area-wide averages for data collected from multiple sites having similar characteristics. Because most studies did not report their raw data, we performed our analyses on these averages. Although comparisons among averages must be drawn with considerable caution, they can provide some indication of overall patterns.

For air and soil, we first divided studies into categories based on the investigators' characterization of the study sites as urban, suburban, rural, or near an industrial point source. We present the reported averages within these categories as points on a scatter-plot graph, from which we have also calculated medians for each category (the median value of a set of numbers is that above which half the data points fall and below which the other half fall). For sites for which data from more than one year were available, only the most recent was used in the scatter-plot. Data on drinking water were too limited to allow this approach. Because only limited conclusions can be thus derived, we also discuss a number of specific studies within the database as examples.

A number of caveats must be noted. First and foremost, the lack of standard methodologies for collecting and reporting environmental samples means that rigorous quantitative analyses of existing environmental data cannot be carried out. Although the studies reviewed in this section generally suggest which pathways of environmental contamination are likely to be of greatest significance in most areas, direct comparisons of different studies are often not possible, as their results depend on methods of sample collection and analysis used by different investigators. Additionally, many studies fail to identify all possible contributing sources of lead.

Air lead measurements, for example, are influenced by many factors, including height at which the sample was collected, method of filtering the air for the sample, flow rate of air in collecting the sample, even the time period over which the sample is averaged (e.g., an eight-hour sample may or may not include a rush hour). Similarly, a critical variable for soil samples is the depth at which the sample was collected, since lead content typically decreases with depth. For measurements of lead in dust, whether the sample was collected by wiping or by vacuum can influence the results. Water lead levels are typically higher in first-draw samples, (i.e., those collected after the water has sat in the pipes overnight).

Despite these limitations, some generalizations can be drawn about patterns of lead contamination in air, soil, dust, and water.

Findings

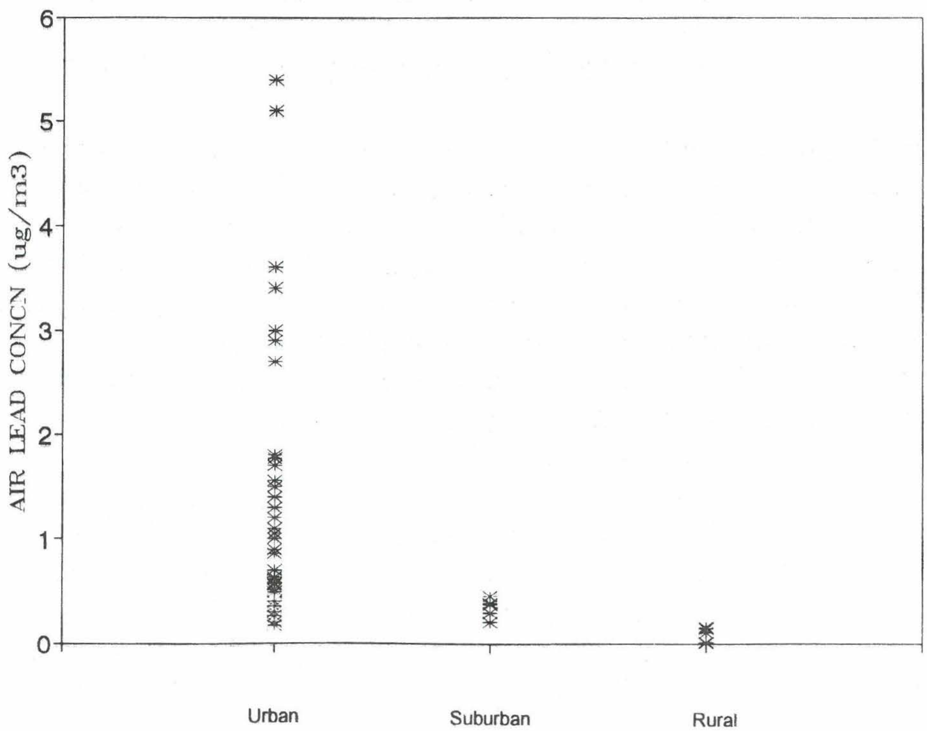
1. Lead in Air

Local concentrations of lead in air vary dramatically, as do existing standards for permissible levels. Standards for ambient air in non-occupational settings range from 1.5 $\mu g/m^3$ (micrograms per cubic meter) in the U.S. and some parts of Australia, to 4.0 $\mu g/m^3$ in South Africa (OECD, 1993). Even the most stringent of these standards may not be adequately protective in light of current knowledge on lead's low-dose toxicity. As an expert panel reviewing U.S. air standards recently noted, a standard of 1.5 $\mu g/m3$ provides "relatively little, if any, margin of safety." The panel urged that "greater consideration be given to air lead values below 1.0 $\mu g/m^3$" (U.S. Environmental Protection Agency, 1990). Unfortunately, the database on global air lead levels is, as one expert recently noted, "far from being satisfactory" (Pacyna, 1993). Working from the limited data available, one researcher estimated that the total worldwide atmospheric emissions of lead from anthropogenic sources—including mining, refining, energy production, manufacturing, commercial uses, and waste incineration—totaled 332,000 metric tons as of 1983. The lion's share (248,000 tons) came from use of gasoline additives (Nriagu, 1990a). Although global use of leaded-gasoline additives has subsequently fallen significantly, annual releases of lead to air remain substantial.

a. Urban and Nonurban Air Lead Levels

The analysis prepared for this report indicates that air lead levels are generally highest in cities and lowest in those rural areas without a local source such as a smelter (see figure 7). Although considerable caution must be used in combining limited data from disparate sources, it is noteworthy that, of the studies included in the scatter plot, the median air lead level for urban sites exceeds the median suburban level by threefold. In turn, the suburban median exceeds the rural median by another factor of three.

Figure 7. Air lead concentrations by site type.



Median Values

Urban:	1.075 $\mu g/m^3$
Suburban:	0.33 $\mu g/m^3$
Rural:	0.1 $\mu g/m^3$

Air lead levels vary significantly by region. In developing nations, urban levels of 1.5 to 3 $\mu g/m^3$ are not uncommon. In most European and North American cities, by contrast, lead levels typically range from 0.2 to 0.8 $\mu g/m^3$; in rural areas of those continents, levels are usually in the range of 0.05 to 0.3 $\mu g/m^3$ (OECD, 1993).

A further analysis of urban data shows that lead levels in cities are not always uniform. In particular, ambient air levels near roads with heavy traffic tend to be higher than roads with lighter traffic, other factors—such as the level of lead in gasoline—being equal. At the same time, areas with similar gasoline lead levels and traffic patterns may have dissimilar air lead readings, due to climatic and geographic factors. Such factors profoundly influence air movement and can either exacerbate contaminant levels (by retarding dispersal of stagnant air) or alleviate them (by rapidly clearing emissions away).

Figure 8 shows data from a number of studies conducted in various cities on air-lead concentrations and the local traffic density. Different investigators reported their data in dissimilar ways; some indicated number of vehicles per day, others characterized the locations as high or low traffic density or described characteristics that reflect traffic density. Although these disparities mean that the data cannot be aggregated, they demonstrate that higher traffic levels are associated with higher air lead levels within each study.

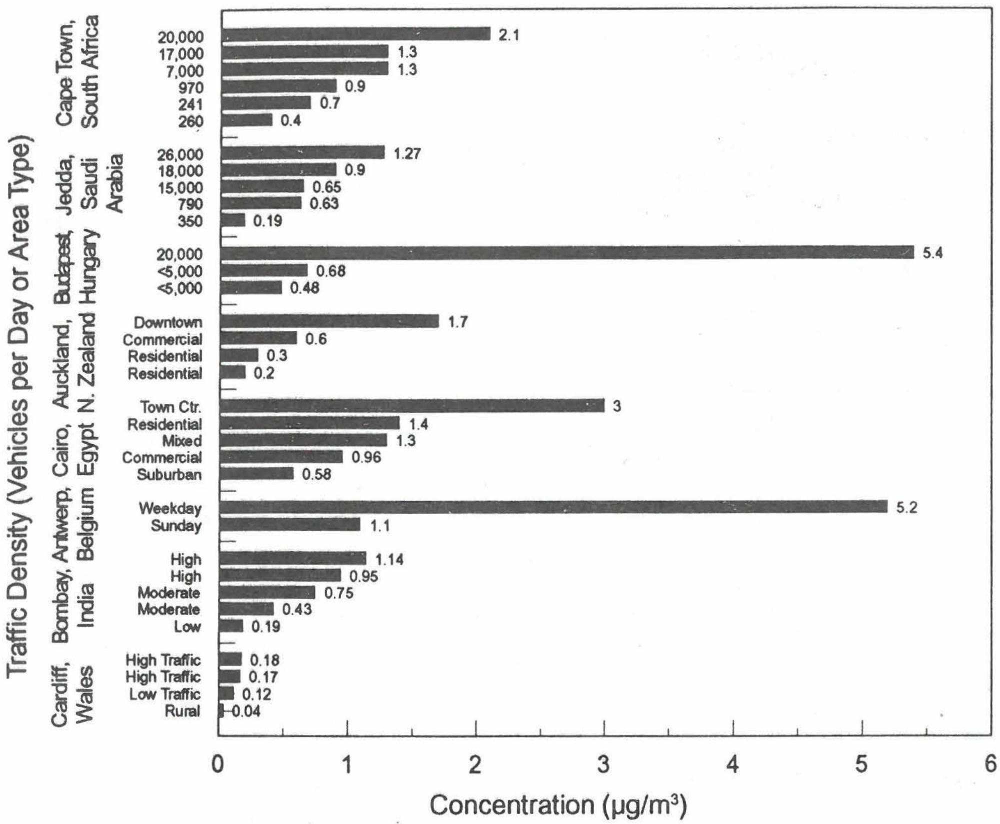
Similarly, figure 9 presents the results of studies conducted at the same sites during lead phasedowns. Not surprisingly, reducing the amount of lead in gasoline results in lower ambient air lead levels at each site.

b. Industrial and Occupational Air Lead Levels

Another important influence on ambient air lead levels is the presence of an industrial point source. Air lead levels near smelters are frequently higher even than those in dense urban traffic zones. Levels of 20 $\mu g/m^3$ have been reported in the vicinity of smelters in the Netherlands (Zielhais, 1979) and the former Yugoslavia (Popovac et al, 1980), and levels up to an astonishing 145 $\mu g/m^3$ were recorded near a Zambian smelter (Nwankwo and Elinder, 1979). Lead-using industries can also produce substantial elevations, such as the 2.7 to 6.5 $\mu g/m^3$ reported near a brass plant in an industrial area of India (Tripathi, 1986).

The significant role played by point sources in elevating nearby ambient air lead levels is reflected in the dramatic air-lead reductions that occur when pollution control devices are installed. For example, air lead concentrations in a Yugoslavian smelter town ranged from 21.3 to 29.2 $\mu g/m^3$ in 1980. After pollution controls were installed, the level fell to

Figure 8: Lead air concentration and traffic density



Note: Gas lead levels all 0.4 g/l except 0.5 g/l for Bombay.
All measurements outdoors except for Cardiff.

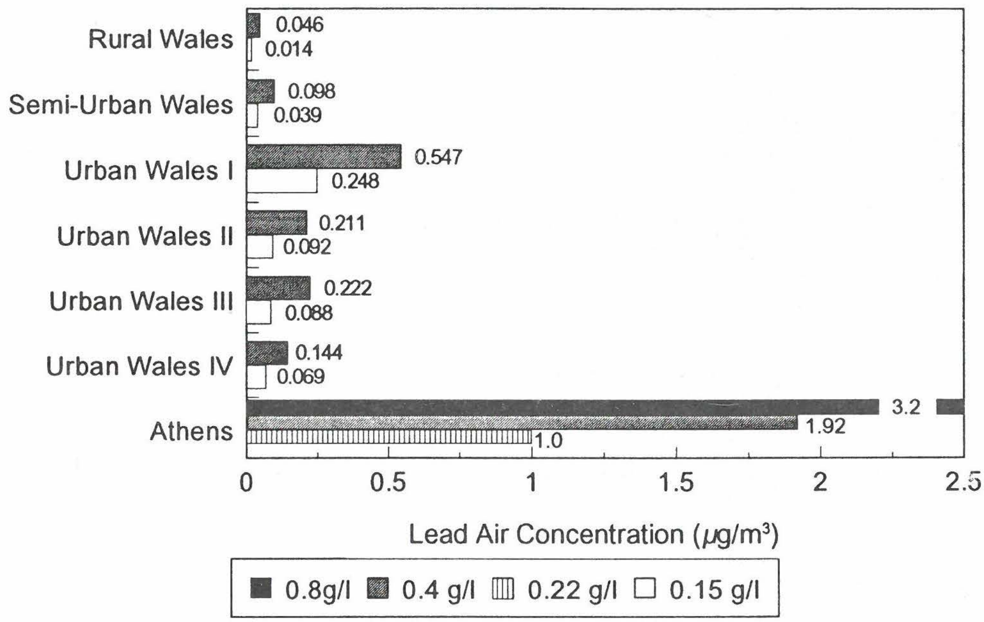
Sources: Cape Town: Von Schirnding, 1991; Jeddah: Abulfaraj, 1988; Auckland: Graham, 1984; Cairo: Ali, 1988; Antwerp: Janssens, 1975; Budapest: Farkas, 1989; Bombay: Tripathi, 1984; Cardiff: Elwood, 1984.

12.8 $\mu g/m^3$ (OECD, 1993). (Even after this reduction, however, remaining emissions were still far from acceptable.)

Air lead measurements typically decrease with distance from an industrial source, just as they decrease with distance from a heavily traveled roadway. Measurements made in the 1970's near a smelter in Brussels revealed that within one kilometer of the smelter, air lead ranged from 2.7 to 4 $\mu g/m^3$, compared to 0.5 to 1 $\mu g/m^3$ just 2.5 kilometers away. At rural control sites, levels were 0.2 to 0.3 $\mu g/m^3$ (Roels et al, 1980).

Virtually everywhere, ambient air levels are dwarfed by those found in the work sites of certain industries. As with ambient air, nations have established a range of standards for lead in air in the work place, from 50

Figure 9: Lead air concentration and lead gasoline levels



Sources: Chartsias, 1986; Page, 1988.

µg/m³ in the U.S. and several other nations to 200 µg/m³ in Peru, Thailand and Morocco (ILZSG, 1991c). Even the most stringent of these standards does not appear to be adequately protective, and noncompliance is widespread. Extraordinarily high levels of lead in air—up to 10,000 µg/m³—have been recorded in some smelters (both primary and secondary) and in battery plants.

2. Lead in Soil and Dust

Few nations have defined allowable standards for lead in soil. The U.S. Superfund program for cleanup of waste sites has set an interim guideline of 500 to 1000 ppm lead in soil at sites that may be used for residential purposes. The United Kingdom limits lead in domestic soil to 500 ppm and in recreational soils to 2,000 ppm. Canada restricts lead in agricultural soil to 375 ppm, in residential soil to 500 ppm and at commercial sites to 1,000 ppm (OECD, 1993).

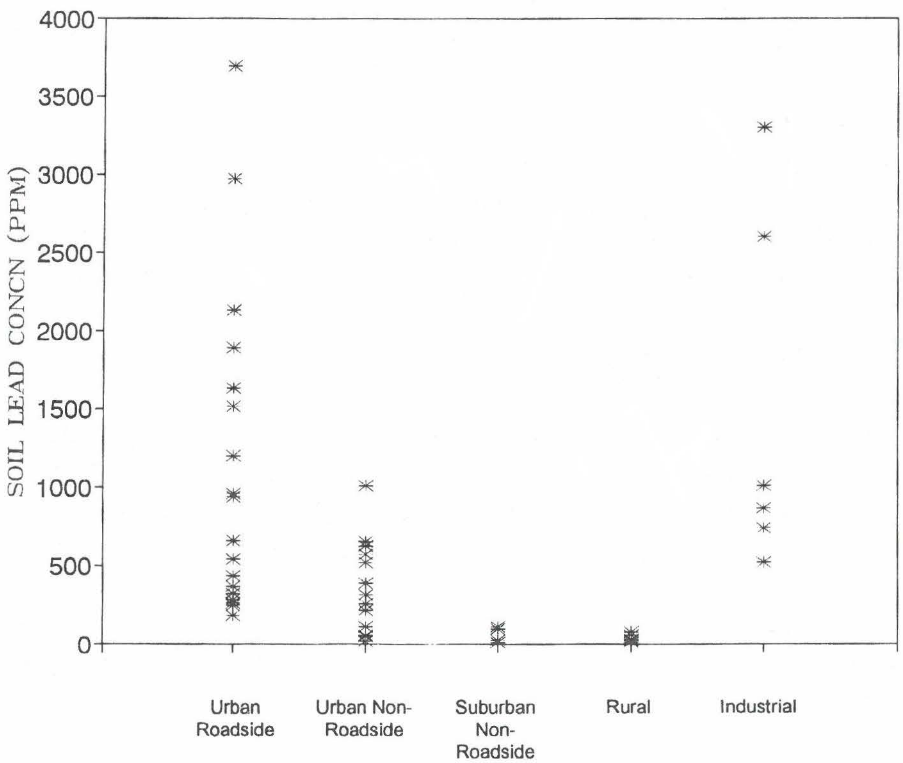
The extent to which any of these levels reflects a rigorous analysis of health hazards from lead in soil is unclear. The U.S. Environmental

Protection Agency is required to define a dangerous level of lead in bare residential soil in 1994. Similarly, the agency is required to define a "dangerous" level of lead in indoor surface dust, a task apparently not undertaken elsewhere to date.

Available data, though sparse, indicate that leaded gasoline and industrial facilities (including mines and cottage industries) are both significant contributors of lead to soil. In addition, U.S. data strongly suggest that deteriorating lead-based exterior paint is a major source of lead in soil (U.S. Department of Housing and Urban Development, 1989).

Data compiled for this report indicate that soil lead levels, as with air lead levels, are typically highest in urban areas, lower in suburban areas, and lowest in rural areas. (This correlation is not surprising since air-borne lead particles settle out onto soil.) Figure 10 shows soil lead concentrations in five categories of areas: urban roadsides; urban, suburban and rural gardens, parks, and yards; and industrial areas. Again, as with air lead data, aggregated figures must be interpreted with caution, but some differences are clear. For studies included in the scatter plot, the median level for urban roadside soils is 2.6 times higher than that for other urban soils, while suburban gardens and similar sites are some sixfold lower than those in urban areas. Rural gardens are even lower, by a factor of two. The highest median level is found in industrial areas.

Figure 10. Soil lead concentrations by site type.



Median Values

Urban, roadside	800 ppm
Urban, other	313 ppm
Suburban	59 ppm
Rural	27 ppm
Industrial areas	936 ppm

Again, vehicles that burn leaded gasoline are a chief source for widespread elevated lead levels in roadside and urban soil and dust. Studies of soil lead concentrations by distance from a road consistently show the highest levels closest to the road, ranging from several hundred ppm within a few meters of the road to 10 to 100 ppm 50 meters from the road, decreasing roughly exponentially (Agrawal, 1986; Collins, 1984; Ndiokwere, 1984).

The effects of vehicle traffic and industrial emissions can be seen on indoor dust as well as exterior soil. In Toronto, for example, a study found that house dust near smelters had higher lead readings than house dust from control areas though both were high: 2,000 ppm near the smelter, 850 ppm for the controls (Roberts et al, 1974).

One dramatic difference between air and soil lead contamination patterns is the degree to which they reflect historical factors. While most lead particles settle out of air within a month, soil-lead levels, once elevated, may persist for decades or even centuries.

Vehicles that burn leaded gasoline are a chief source for widespread elevated lead levels in roadside and urban soil and dust.

Studies in communities located near former lead mines reveal the persistence of lead contamination. For example, the Leadhills area in southwestern Scotland has been the site of intermittent lead mining for some 700 years, most recently about 1850 to 1910 (Rowan et al, 1993). The area, through which flows the Glengonnar Water, contains numerous old mine shafts and smelter sites. Samples collected in 1992 in the local floodplain average over 33,000 ppm of lead, with a high of more than 75,000 ppm. Metals initially released during mining and smelting in the nineteenth century now represent the major pollution source to this river system.

Similarly, garden soil in the United Kingdom near a mine closed in the 1950's contained up to 7,000 ppm lead when measured in the 1980's (Davies et al, 1984). Elsewhere in Great Britain, garden soil in Derbyshire mining villages has average lead readings of 5,600 ppm.

3. Lead in Water

Lead levels in water sources (e.g., lakes, rivers, and aquifers) are only occasionally elevated to levels of concern for human exposure. Most developed nations regulate lead discharges, with varying levels of intensity, as part of programs to control the discharge of pollutants from industry into waterways. Limits often vary depending on the nature of the waterway as well as the type of industry, and reportedly range from 0.008 mg/l (milligrams per liter) in Australian estuaries to 5.0 mg/l in the United Kingdom (OECD, 1993).

Background levels of lead in water are normally well below 10 parts per billion (ppb) (OECD, 1993). The considerable amount of reported data on lead levels in surface waters and bottom sediments consistently indicates that lead levels are higher near industrial sources than elsewhere. For example, in one stretch of coastal water along the Canary Islands with a single sewage discharge, lead concentrations averaged 1.9 ppb, while a section with four major industrial outputs averaged lead concentrations of 5.2 ppb, and as high as 62 ppb (Diaz, 1990). Similarly, background lead levels in a river in southern India were measured at about 0.6 ppb upstream from an industrial area, and at 12 ppb in the vicinity of the industrial development (Borkar et al, 1984). Most surface water measurements outside cities or polluted areas range from 0.2 to 5 ppb (e.g., in northern Israel [Sandler et al, 1988], Kenya's Lake Nakuru [Greichus et al, 1978], and Ibadan, Nigeria [Mombeshora et al, 1983]).

Water nonetheless forms an important source of human lead exposure in many areas because, as noted earlier, lead has long been used in plumbing systems and can leach into the water (particularly if the water is corrosive). Most developed nations have set standards for allowable lead levels in drinking water (OECD, 1993). The majority of European nations have adopted 50 ppb; in 1991, the U.S. repealed its prior 50 ppb standard and established an action level of 15 ppb in first-draw water that has stood in pipes overnight. If more than 10% of the homes tested in a community exceed the 15 ppb level, the water supplier must undertake a program to reduce the corrosiveness of the water. The EPA estimates that if first-draw water does not exceed 15 ppb, average water levels will be about 5 ppb, so the U.S. standard may be viewed as more stringent in some regards than that of most other developed nations.

Surprisingly few studies were found on lead in drinking water outside the U.S., and virtually all of those data come from other developed nations. Only one study was located from a developing nation; it reported unusually high lead levels (up to 350 ppb) in well water in Pilani, India (Kaphalia et al, 1983).

Most studies of lead in drinking water have focused on lead plumbing. The influence of lead plumbing components on tap-water lead levels is reflected in a British study of almost 3,000 households (Pocock, 1980). Investigators found water lead levels above 100 ppb in 79% of houses with lead storage tanks and 23% of homes with lead household pipes and/or supply lines. In contrast, only 1% of homes without lead pipes had levels above 100 ppb. Furthermore, no houses with lead storage tanks had lead concentrations below 10 ppb.

Where leaded components are present, corrosive water greatly compounds the problem, as demonstrated in a study of water flowing through lead pipes in Leige, Belgium (Sartor and Rondia, 1981). There, investigators found that where the water was naturally non-corrosive or was treated to reduce its corrosiveness, the maximum water lead level was 300 ppb; when the water was soft, and thus highly corrosive, the maximum level was 2050 ppb. Although both levels were unacceptably high, the latter represents a sevenfold enrichment in lead content.

While corrosion-control programs can reduce lead leaching rates, such systems must be monitored and treatments sustained indefinitely. And, as the studies cited above demonstrate, even use of such measures may not be adequate to reduce lead concentrates in drinking water to acceptable levels where leaded components are present in the water distribution system.

Summary

This chapter presents the results of an analysis of lead levels in environmental media. (By definition, human exposures due to products that cause direct exposure during use were not addressed.) Though available data are far from complete, they indicate the following patterns of environmental contamination:

- Lead levels in both air and soil are generally higher in urban areas and near industrial sources than in other areas.

- In urban areas, air and soil levels are associated with use of leaded gasoline. Lead concentrations in both air and soil increase with traffic density and proximity to roads, as well as with higher lead concentrations in gasoline.

- While data on lead in water are particularly limited, it appears that human exposure results primarily from leaching of lead from leaded plumbing components, rather than contamination of source waters (i.e., lakes, rivers, and aquifers).

5 Blood Lead Levels in Children & Adults

Environmental contamination patterns give a good indication of the sources of exposure that put populations at risk. However, measurement of blood lead levels is the most accurate method of determining actual current exposure in individuals and populations. Throughout the world, many populations have been studied to identify individuals and groups with high and low exposure levels. In some cases, attempts have been made to explain differences in blood lead levels found by relating them to specific sources or levels of lead in the environment. Many of these blood lead studies have been published in scientific journals and government documents and reports.

Methods

What follows is a brief description of the methods used in this study to analyze data on lead in blood. A more detailed description of methods can be found in the separate Technical Appendix to this report.

The purpose of this analysis was to assemble and analyze existing data on human blood lead levels around the world. We attempted to compile all studies containing blood lead data that had been conducted on populations outside the United States since 1967. A literature search (primarily using the U.S. National Institutes of Health Medline database, augmented by written requests for published and unpublished data) identified more than 500 potentially relevant studies from more than 60 countries. Unfortunately, the majority of these studies could not be included in this report because of technical failings (most often because critical information such as sample size was omitted), or because tissues other than blood were tested. Of the over 500 studies we reviewed, 188 studies from 40 different countries met our criteria to be included in this report. The data from these studies were entered into a computerized database. Figures presented in this chapter are derived from our analyses of this database on human blood-lead levels.

It should be emphasized that the available blood lead studies come from disparate populations, used different methodologies, and were prompted by different motivations. Moreover, for most countries, there are insufficient data to provide a comprehensive picture of lead exposure and risk for that country's population as a whole. Only in rare cases were the collected studies designed to represent the general population.

In most cases researchers have tended to concentrate on identifying populations believed to be exposed to excessive amounts of lead from specific sources in the environment. In fact, 90 percent of the studies which we reviewed were carried out on populations exposed to a known or suspected source of lead. For this reason, excessive lead exposure tends to be overemphasized in these studies, while the range of exposure in the general population remains largely unknown.

The 188 studies reviewed and analyzed here reported blood lead levels as a population average, or "mean." Average blood lead levels can be misleading because they can be influenced by excessively high or low blood lead levels in some individuals. For these reasons, the results of this analysis cannot be extrapolated to represent the general population of the countries studied. This analysis does, however, offer snapshot views of the magnitude of lead toxicity in exposed populations in many regions of the world.

Every study included in our database presented at least one average blood lead level for the population studied. Most studies also divided the overall population into subgroups (by age, sex, or some other category) and reported an average blood lead level for each. Thus, there are a total of 1,240 average blood lead levels derived from the 188 studies surveyed in this report. The size of each population sampled varies considerably, as does the range of population average blood lead levels.

To make our analysis as useful as possible to policy makers we have summarized the data by reporting the percentage of population blood lead averages above designated thresholds for different demographic groups. Reporting the data in the context of designated thresholds helps to focus attention on populations at risk of exposure, as well as providing a reference point for comparison between groups.

Any blood lead level above the designated threshold is recognized as a cause for concern on the basis of scientific research associating such lead levels with adverse health effects (though, as noted in Chapter 1, such levels cannot be regarded as "safe" or "normal"). For children, the threshold we used is 10 μg/dl, the level of concern set by the U.S. Centers for Disease Control and Prevention (U.S. CDC). Because fetuses are vulnerable to lead's toxicity and because lead moves across the placenta freely, we used the same threshold of concern (10 μg/dl) for pregnant women and women of childbearing age. For other adults the threshold used for this study is 25 μg/dl, because many researchers believe that adverse effects begin to occur in adults at least at this level (if not lower levels) (Silbergeld, et al, 1991).

Readers should take careful note that almost all of the values reported in this chapter take the form of *percentage of population averages* that exceed the levels of concern, not the percentage of individuals studied who exceed the level of concern. Thus, for example, figure 12 indicates that of all the studies of urban children ages 0 to 2 years included in our database, 91% of those studies reported population average blood lead levels greater than 10 μg/dl.

Findings

1. Global Distribution of Studies

One of our clearest findings is the continuing lack of critical information on human lead exposures worldwide. The overwhelming majority of studies have been done in the developed nations. Indeed, of the roughly 1,200 populations included in our database, only 15 percent are from developing countries.

The overwhelming majority of studies have been carried out in developed nations: only 15% of those we identified were from developing countries.

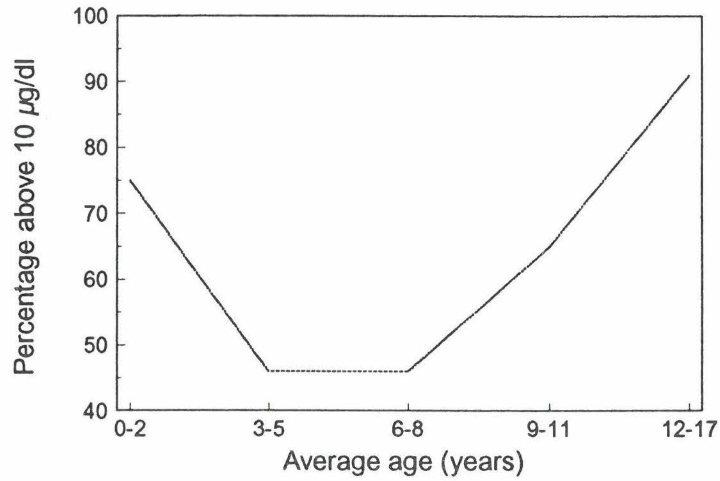
It is obvious at the outset that much more screening needs to be done on lead toxicity (especially in children) in the developing world. Researchers are only beginning to respond to this need. The number of studies on children in developing countries conducted from 1985 to the present is three-and-a-half times the number of studies conducted in the previous two decades—an encouraging trend, but still far from adequate. There are no studies in developing countries that adequately characterize lead exposure for populations on a representative basis.

2. Age

We first examined how blood lead levels varied by age, since young children are considered to be at highest risk for both exposure and toxicity. Average blood lead levels for the populations of children studied varied by age in a distinctive 'J'- shaped pattern (see figure 11). Average blood lead levels were higher among 0 to 2 year olds, with 75% of the populations studied having averages greater than 10 μg/dl. Studied populations of children between the ages of 3 and 8 had, on average, slightly lower levels, with 46% of the studies having population averages above the threshold of 10 μg/dl. The population averages then rise again in adolescence.

The generally accepted explanation for this pattern is that the normal hand-to-mouth behavior of young children puts them at risk of lead exposure when soil and house dust are contaminated with lead. As children get older, they display less hand-to-mouth activity, and average blood lead levels drop. It is not clear why blood lead averages in the studied populations rise again in adolescence—the explanation may well reflect the bias of researchers to study exposed populations, which could include adolescents in the workplace, particularly in developing countries.

Figure 11. Percentage of Average Blood Lead Levels above 10 $\mu g/dl$ in Studied Populations of Children, by Age.



3. Urban v. Nonurban Children

For many reasons, urban populations are more at risk for lead exposure than are nonurban populations. Exposure to industry, wastes, and automobiles fueled with leaded gasoline have all been found to be correlated with population density in many countries. Children identified as being exposed to specific industrial sources of lead were excluded from the analysis of urban versus nonurban populations.

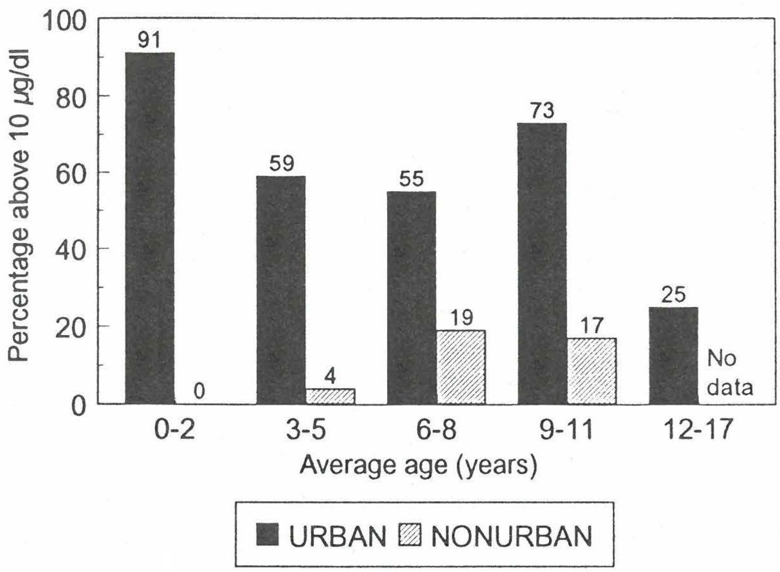
At every age level, populations of urban children were much more likely to have average blood levels exceeding the designated threshold than populations of nonurban children.

At every age level (except ages 12 to 17, where the data did not permit comparison), populations of urban children studied had much higher average blood lead levels than nonurban children (nonurban includes towns, suburbs, and rural areas) (see figure 12). Among 0 to 2 year olds, for example, 91% of urban populations studied had average blood lead levels greater than the 10 $\mu g/dl$ threshold; although we identified only two studies of nonurban children in this age range, neither reported population averages greater than the threshold. The imbalance of studies on nonurban children probably reflects the bias toward studying children where exposure was anticipated.

Average blood lead levels in studied populations of children living in towns and suburbs were relatively low, suggesting that in most cases these children have lower exposure to lead in the absence of "hot spots" of environmental lead, such as a smelter. There was slightly more variability in average population blood lead levels in children studied from rural areas. Low traffic density and few industrial sources probably contributed to some of the lowest population averages reported. But rural areas also had some of the highest reported population averages, suggesting pockets of unchecked industrial exposure. The peak in blood lead averages in populations of young children (0 to 2 years) was not found in children from rural areas, suggesting that hand-to-mouth behavior does not expose children to lead when environmental lead levels are low.

We could not compare urban and nonurban population average blood lead levels between developed and developing countries, since only three age-specific samples from nonurban regions of the developing world were identified. However, in urban areas of developing countries, the percentage of average blood lead levels in populations of children under the age of 8 found to have blood lead levels above 10 $\mu g/dl$ was much higher than in developed countries.

Figure 12. Percentage of Average Blood Lead Levels above 10 $\mu g/dl$ in Studied Populations of Children in Urban and Nonurban Areas



4. Children in Developing v. Developed Countries

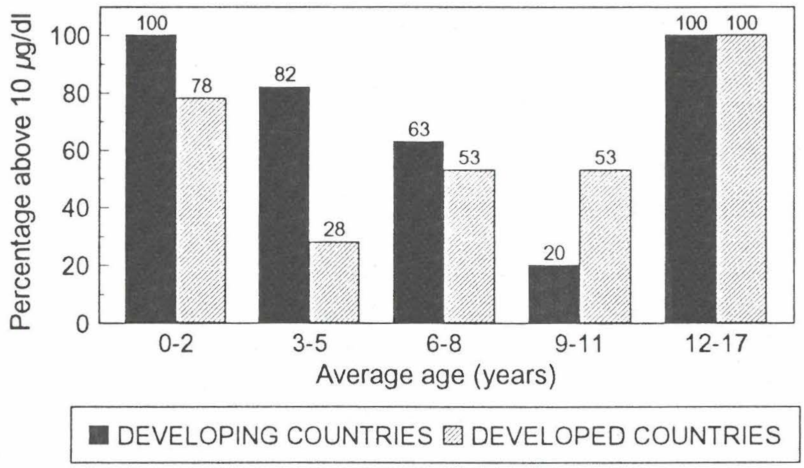
Populations of children in developing countries were much more likely to have average blood lead levels above the threshold than studied populations of children in developed countries. This was true for populations of children exposed to identified occupational and industrial sources of lead as well as in populations of children without exposure to specific point sources.

Children Not Exposed to Industrial or Occupational Sources of Lead. This category includes children with no known or recognized exposure to lead, as well as children with suspected exposures to non-industrial sources (i.e., automobile emissions, lead-based paint, plumbing, cosmetics, home remedies, and ceramicware).

Among populations of children in developing countries with no identified industrial source in the vicinity or occupational lead exposure, 100% of those 0 to 2 years old and 82% of those 3 to 5 years old had average blood lead levels greater than 10 μg/dl (see figure 13). This is compared to 78% and 28%, respectively, of average blood lead levels in populations of children not exposed to occupational and industrial sources of lead from developed countries in the same age ranges.

Whether or not they were exposed to industrial or occupations sources of lead, populations of children in developing countries were much more likely to have average blood levels exceeding the designated threshold than populations of children in developed countries.

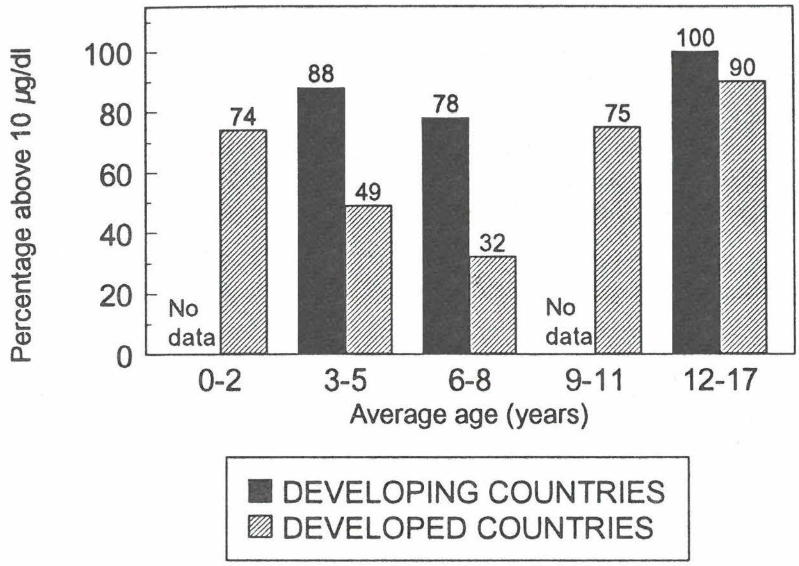
Figure 13. Percentage of Average Blood Lead Levels above 10 μg/dl in Studied Populations of Children Not Exposed to Occupational and Industrial Sources of Lead



Children Exposed to Industrial or Occupational Sources of Lead. In both developed and developing countries, populations of children regularly exposed to occupational and industrial sources of lead (through proximity of residence or school) generally have even higher average blood lead levels than populations of children not exposed to these sources. However, since populations of children not exposed to occupational and industrial sources of lead also had high percentages of average blood lead levels above the designated threshold of 10 μg/dl, the difference seen here between the two populations is not dramatic.

There are no data available from developing countries for children near lead industries in the 0 to 2 age range. Population averages are available only for older children, and those are quite alarming. In populations of children ages 3 to 8 (the ages at which blood lead levels are typically lowest in nonindustrially exposed children), the great majority of average blood lead levels were elevated: 88% of blood lead averages of studied

Figure 14. Percentage of Average Blood Lead Levels above 10 $\mu g/dl$ in Studied Populations of Children <u>Exposed</u> to Occupational and Industrial Sources of Lead



populations of 3 to 5 year olds and 78% of blood lead averages of studied populations of 6 to 8 year olds were greater than 10 $\mu g/dl$.

In developed countries, the percentages were lower, with 49% of studied population averages of 3 to 5 year olds and 32% of population averages of 6 to 8 year olds above 10 $\mu g/dl$. Population average blood lead levels reached up to 62 $\mu g/dl$ in developing countries and 50.9 $\mu g/dl$ in children from developed countries living near industrial sources.

These data indicate that living near lead smelters and other lead-using industries can pose serious risks to children worldwide. Although significant percentages of populations of children in both developing and developed countries are highly exposed, the problem seems to be worse in developing countries, where environmental and occupational health and safety regulation and enforcement is often lax.

5. Correlations With Soil and Dust Lead Levels

Not surprisingly, soil and dust lead levels correlate with average blood lead levels in children. Among studied populations of children exposed to the lowest levels of soil and dust lead (less than 45 ppm), half had average blood lead levels below the 10 $\mu g/dl$ threshold (the sample averages ranged from 7.0 to 22.6 $\mu g/dl$). All the population averages of children exposed to the middle level of soil and dust lead (46 to 375 ppm) were above the threshold (averages ranged from 11.7 to 21.0 $\mu g/dl$), as were all

> ***Brazilian Smelter Poisons Area Children Through Multiple Routes***
>
> Children living within 900 meters of a lead smelter in Santo Amaro, Brazil were found to have an average blood lead level of 59 μg/dl. Children living within 300 meters of the smelter chimney were found to have an average blood lead level of 87 μg/dl (a level considered a medical emergency in the U.S.) The problem of exposure was compounded by the company's practice of giving old smokestack filters to workers, who used them as blankets and carpets. Smelter waste containing between 10,000 and 30,000 ppm lead was also given to workers to use as filler in yards and gardens (Silvany-Neto, et al, 1989).

population averages for children exposed to the highest levels of lead in soil and dust (376 to 88,000 ppm); averages for these populations of children ranged from 12 to 110 μg/dl. Populations studied were from both developed and developing countries (India, Italy, Jamaica, the Netherlands, and the United Kingdom).

6. Adult Workers

Most of the studies of blood lead levels among adults were designed to measure occupational exposure, as opposed to general population exposure. Typically, men outnumber women in these studies by more than two to one. Furthermore, more than three times as many studies of workers were carried out in developed countries than in developing countries.

Workers in developing countries were at an even higher risk of having population average blood levels above the designated threshold than workers in developed countries.

For both sexes, average population blood lead levels in workers were higher in developing countries than in developed countries. Population averages in workers from the developing countries were more than twice as likely to exceed the 25 μg/dl adult threshold (62%) than in developed countries (29%).

Workers in developing countries may be at increased risk of having elevated blood lead levels because regulations for worker protection in developing countries lag behind those in the developed world. In addition, corporations headquartered in developed countries often operate lead-related industries in developing countries, thus avoiding expensive worker protection regulations such as protective clothing, medical monitoring, and leave with pay for workers with elevated blood lead levels (LaDou, 1991).

7. Families of Exposed Workers

Occupational exposures to lead can also affect workers' families (MacDiarmid and Weaver, 1993). Among studies of children living in the same house as a lead-industry employee, 58% of the average population blood lead levels were above 10 μg/dl. These children were also more likely to live near a lead-related industry, so the exposure may occur via both the parent and releases from the industry itself.

Spouses of lead-exposed workers are also at higher risk of having elevated blood lead levels. In addition to coming into contact with the lead-exposed worker, spouses often wash lead-contaminated work clothing. All the studies that measured the blood lead levels of adult family members reported population averages greater than 10 μg/dl, although none were above the adult threshold of 25 μg/dl. However, particularly when the spouse is a pregnant woman or a woman of childbearing age, average blood lead levels above 10 μg/dl are of concern.

8. Women of Reproductive Age

The developing central nervous system in fetuses as well as young children is vulnerable to lead poisoning. Among populations of women of reproductive age selected without regard to exposure, more than half had average blood lead levels greater than 10 μg/dl. This indicates that if these women were pregnant, their infants would be at risk of being born with elevated blood lead levels.

9. Global Differences in Lead Exposures

Outside the U.S., the vast majority of blood lead studies have been conducted in adult and child populations in Western Europe. Among adult populations, average blood lead levels were least likely to exceed the level of concern in Western Europe and most likely to exceed 25 μg/dl in Africa (where the fewest number of studies were carried out). Adult populations in the Middle East and Latin America were also likely to exceed the level of concern. Among populations of children, the potential for lead poisoning worldwide appears alarmingly high. The only region with more than half of the population averages below 10 μg/dl was North America (i.e., Canada, since this report excludes the U.S. and categorizes Mexico as Latin America) (see figure 15).

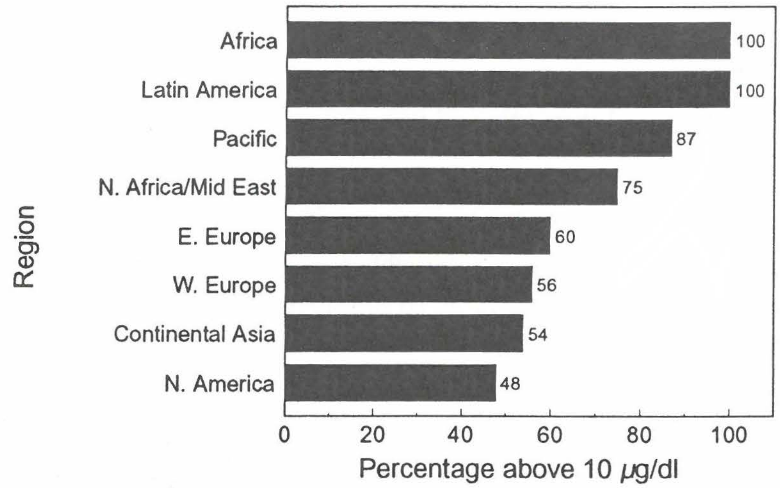
Among populations of children, the potential for lead poisoning worldwide appears alarmingly high.

It must be emphasized that many of these studies have been conducted in populations suspected to be at risk for lead poisoning, and these results cannot be generalized to all children. However, the high percentage of blood lead averages above 10 μg/dl in all regions of the world is troubling.

Summary

Adequate data on blood lead levels in humans do not exist, especially for children. In addition, there are no country-representative studies (outside

Figure 15. Percentage of Average Blood Lead Levels above 10 μg/dl in Studied Populations of Children, by Region.



of the U.S.) characterizing the scope and severity of lead poisoning in the general population.

The studies that have been carried out indicate that:

- Although researchers concentrated their work on populations with known or suspected exposure to lead, the fact that these populations exist in every region of the world and in many countries suggests that lead poisoning deserves global attention.

- A higher percentage of populations of children studied in urban areas had average blood lead levels above 10 μg/dl than populations of studied nonurban children.

- A higher percentage of studied populations of children residing in developing countries had average blood lead levels greater than 10 μg/dl than studied populations of children in developed countries.

- This analysis of existing data serves as a preliminary step to guide policymakers, but much more blood lead screening and research needs to be carried out, especially in developing countries.

6 Case Studies: Lead in Six Nations

Introduction

This chapter analyzes in detail the nature of lead uses and the scope of lead poisoning in six case-study countries: Australia, India, Japan, Mexico, Nigeria, and Poland. Although the countries are located in different regions of the world, they are not intended to be representative. Rather, these particular countries were chosen to illustrate varying degrees of the lead poisoning problem and sources of lead exposure in countries at various stages of development, with different cultural practices, and with different approaches to controlling exposures.

These case studies illustrate the similarities and differences in the manifestation of the lead problem among countries. For example, large populations in both Australia and Mexico have significant potential for exposure to lead from the continued use of leaded gasoline. However, other sources of lead in the environment of the two countries differ. Deteriorating lead-based paint is a serious concern in Australia, while a major concern in Mexico is the use and manufacture of lead-glazed ceramics.

The case studies demonstrate that countries around the world are at different stages in confronting and responding to lead poisoning and will be required to adopt strategies specific to their needs. For example, as developed countries continue to restrict the use of lead in consumer products, they face the problem of cleaning up past lead contamination. In contrast, many developing countries need to regulate current lead use as well as clean up contamination. Still other countries need to put regulations in place now to avoid the mistakes of developed countries. Finally, every country, if it has not already done so, needs to screen for lead poisoning in its population to determine the extent of the problem and locate the sources of significant lead exposure .

The case studies demonstrate that countries around the world are at different stages in confronting and responding to lead poisoning and will be required to adopt strategies specific to their needs.

Each of the following case-study sections, with slight variation, is organized in the following manner: economic/political overview, lead uses and exposure, and nonoccupational blood lead data.

1. Case Study: Australia

Australia is a high-income, industrialized country with a very diverse topography and a large percentage of the population living in urban areas (total population was estimated to be 17.5 million in 1992). Six states and two territories make up Australia's commonwealth; each has its own government with significant control over its own environmental policies.

In June 1993 the National Health and Medical Research Council (NHMRC) issued revised guidelines, Lead in Blood in Australians. The new guidelines seek to achieve a blood lead level at or below 10 μg/dl for all Australians, particularly children under the age of 4 years old (ANZECC, 1993).

Historically, the Commonwealth Government of Australia has made recommendations for permissible amounts of lead in air, drinking water, and food, but the state governments have developed and enforced their own standards. In 1992, however, the Commonwealth Environmental Protection Agency (CEPA) was founded to establish enforceable environmental standards for the entire country. In July 1993, the Commonwealth Minister of the Environment convened representatives of states, industry, communities, and nongovernmental organizations at the Roundtable Conference on Lead in Petrol to address the new NHMRC guidelines.

In 1993, the Australian government issued revised guidelines, stating a goal of achieving a blood lead level at or below 10 μg/dl for all Australians.

The Roundtable committee decided that CEPA would coordinate the efforts of all of these groups and focus on a national education campaign. CEPA also chairs a Commonwealth interdepartmental committee to coordinate the efforts of Commonwealth agencies. Finally, CEPA has established the Lead Abatement Taskforce, with a focus on technical and policy issues. The Minister of the Environment is considering convening another Roundtable to address other sources of lead in the environment (ANZECC, 1993).

Among Australia's state governments, New South Wales has been one of the most proactive on lead issues. The state's Environmental Protection Authority and its Health Department issued a joint report on lead in 1993 that identifies sources of lead in New South Wales and proposes management strategies to control identified sources. The report focuses on plans to institute an interdepartmental task force with working groups to implement effective lead reduction strategies for gasoline, paint, food, air, soil, dust, and water. Working groups will include representatives from relevant state agencies, the local government, industry, and the community.

Australia's environmental lead pollution comes in large part from widespread historic use of leaded gasoline. According to the Australian Bureau of Statistics, approximately 90% of the lead in urban air is from vehicle emissions. Currently, Australia has no national standard for lead in gasoline; state limits range from 0.3 g/l to 0.84 g/l (CONCAWE, 1992). Since 1986, however, national law has required that all new domestic and imported cars run on unleaded gasoline and use of leaded gasoline is declining sharply. Still, as recently as 1990, Australian vehicles emitted an estimated 4,000 tons of lead into the environment (Thomas and Spiro, in press).

Deteriorating lead-based paint is another source of lead contamination in many areas of Australia. The New South Wales government, for example, has attributed all recent cases of acute lead poisoning in Sydney to lead-based paint disturbed during home renovations. Restrictions on lead-based paint have been in place since the 1960s, and major Australian companies no longer make white lead-based paint for the domestic market (OECD, 1993). But, Australia's allowable level for lead in domestic paint remains relatively high—0.25% by weight in contrast to 0.06% in the U.S. (NSW, 1993). Also, previously applied leaded paint still remains in a large proportion of the housing stock.

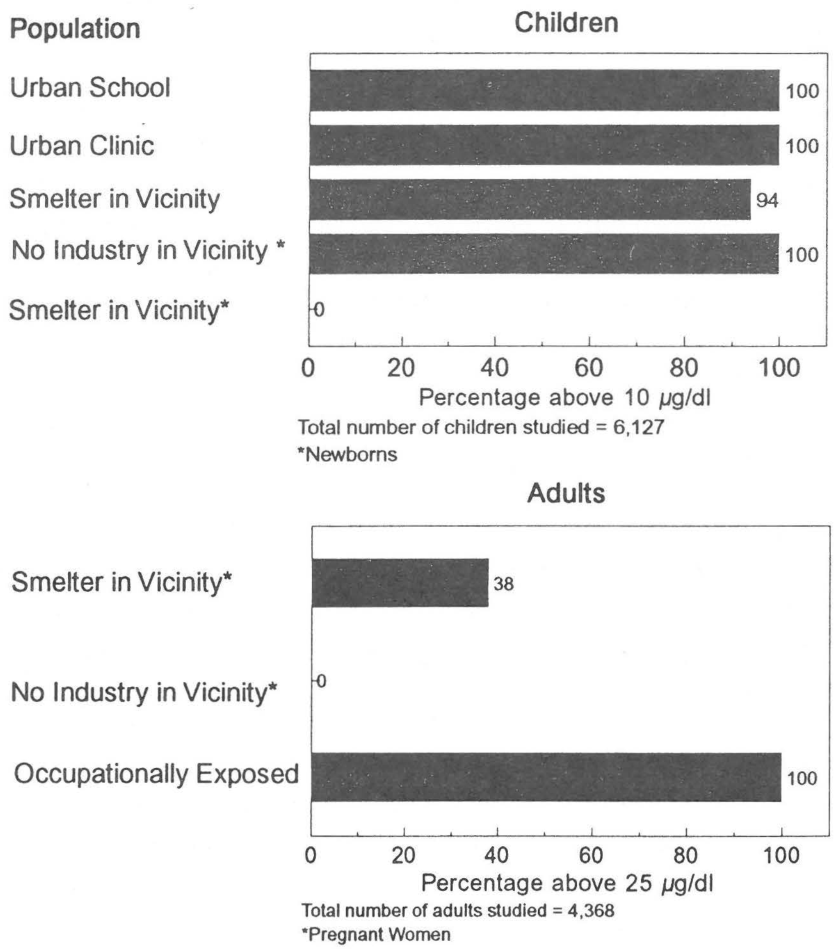
In addition to leaded gasoline and paint, Australia's lead industries contribute significantly to environmental lead contamination. Australia is one of the foremost lead mining and exporting countries in the world. There are 15 lead mines, four primary smelters, and two secondary smelters scattered throughout the country. The world's largest operating lead mine is located in Broken Hill, New South Wales. Exposed ore and tailing dams have resulted in high soil lead levels in the surrounding area. The New South Wales Government is devising plans, including revegetation of mine spoils, to deal with the environmental degradation (NSW, 1993).

The New South Wales government has attributed all recent cases of acute lead poisoning in Sydney to lead-based paint disturbed during home renovations.

A few hundred miles away in South Australia is the Port Pirie smelter and refinery complex, which processes ore from Broken Hill. The complex operated from 1889 to the mid-1970s without emission controls. The first pollution control strategy to be implemented consisted of building a tall stack that only distributed the lead over a wider area. Although more effective cleanup measures are now being taken, the amount of historical lead in the surrounding environment is abundant, thus putting the Port Pirie community of roughly 17,000 at risk.

Australia has some environmental and biological data on lead poisoning available. Many health studies have been conducted among the people of Port Pirie, and these indicate reason for concern, including soil lead levels above 1,000 ppm near the smelter and 38% of population average blood lead levels among pregnant women above 10 μg/dl (Baghurst, et al, 1987). According to the data presented in figure 16, newborns born to these women were much more likely to have an average blood lead level above 10 μg/dl than newborns in nonindustrial areas.

Figure 16. Percentage of Average Blood Lead Levels above Designated Threshold in Studied Populations of Australian Children and Adults



2. Case Study: India

India is a large, heavily populated (890 million, 1992 estimate) country making strides toward industrialization. The economy of India is mixed, with both the public and private sector playing a large role. The central government has primary control over most mineral and manufacturing industries.

In environmental policy, as in other areas, the central government has highest authority but the state governments have considerable autonomy. The national Department of the Environment's responsibilities include assessing the environmental impact of development projects, monitoring and regulating pollution, and conservation. National agencies are responsible for setting standards, overseeing research, and coordinating state efforts. With respect to air and water pollution, state agencies have responsibility for developing pollution control programs and inspecting industries.

While few environmental and health regulations in India specifically address lead, lead levels in the environment and human exposures to lead have been relatively well studied. These studies indicate that lead poisoning is endemic in both children and adults. Auto emissions, surma (a cosmetic containing lead), cookware, poorly regulated workplaces, and unchecked industrial emissions all contribute to the problem. Among the significant industrial point sources of lead emissions in India are three primary lead smelters, nine secondary lead smelters, and seven lead refineries (ILSZG, 1991a,b).

While the majority of countries around the world have reduced the amount of lead in gasoline, in India the lead content has remained high and unleaded gasoline will not be available to consumers until 1995.

While the majority of countries around the world have reduced the amount of lead in gasoline, in India the lead content has remained high, containing up to 0.56 g/l (Thomas and Spiro, in press), and unleaded gasoline will not be available to consumers until 1995. As a result, urban areas with heavy traffic have very high reported lead levels in air, soil, and water as well as in people. For example, average air lead levels of 1 $\mu g/m^3$ or higher are not uncommon in Bombay (by comparison, air lead levels in European and North American cities are in the range of 0.2-0.8 $\mu g/m^3$, OECD, 1993).

Investigations of blood lead levels in various cities have revealed high lead exposures across the country. A 1991 study of more than 300 Bombay children reported an average blood lead level of 11.3 $\mu g/dl$ (Khandekar, 1991). In 1982, teachers from three cities in India were included in an international study of blood lead levels. Their median blood lead levels ranged from 11.8 to 18.3 $\mu g/dl$ (Vahter, ed., 1982). These blood lead levels are believed to represent fairly well the blood lead levels of average nonoccupationally exposed adults in urban areas of India.

Most of the occupational studies on adults in India have focused on workers involved in cottage (home-based) industries, which often cause substantial exposures to both adults and children.

For example, workers in the jewelry industry commonly work out of homes, where they extract silver by heating impure metals that contain lead. Often laboring in poorly ventilated rooms, workers are exposed to high air concentrations of lead, and their blood lead levels are almost invariably high. Only two studies on these populations were identified, but both reported average levels well above 25 μg/dl—in fact, the lower of the two population averages reported was 51.3 μg/dl. Spouses and children are also at risk from the fumes and piles of waste stocked nearby. Another cottage industry, papier maché manufacturing, also threatens workers, who use paints that contain white lead acetate as their main ingredient (Kaul and Kaul, 1986).

A serious source of lead poisoning in children, not unique to India, is the use of a powder containing lead sulfide as a cosmetic or, occasionally, as a medicine. In India the material is called surma or kohl, and its use dates back 1,500 years. Once thought to preserve eyesight, surma is now used as an eye makeup for women and children of both sexes. Children are particularly at risk of exposure because they find the powder irritating, rub their eyes and then put their fingers in their mouths. Surma has only recently been recognized as a potential source of lead poisoning in children and most research thus far consists of case studies of exposed children as opposed to population surveys.

Figure 17. Percentage of Average Blood Lead Levels above Designated Threshold in Studied Populations of Indian Children and Adults

3. Case Study: Japan

This small, densely populated (estimated at 123 million in 1992) archipelago has been a leader in dealing with lead contamination. It was one of the first of the OECD member countries to reduce lead in gasoline, in part because of reports in 1970 of widespread lead contamination in Tokyo. Although it was later discovered that the reports had been exaggerated, the Japanese Government had already taken steps to begin the gradual elimination of leaded gasoline. (At that time, a survey of traffic police officers reported average blood lead levels ranging from 17.5 to 19.1 μg/dl). By the early 1980s, just 1 to 2% of gasoline contained lead. Today, no leaded gasoline is produced or used in Japan.

Japan was one of the first countries to reduce lead in gasoline. Today no leaded gasoline is produced or used in Japan.

In many cases, Japan, a constitutional monarchy with a parliamentary government, relies on largely successful voluntary agreements between government and manufacturers to regulate the use of lead. For example, lead paint production is limited by such an agreement. Toys have been free of lead paint since 1960 and household paints free of lead since 1980 (although house paint of any kind has never been widely used in Japan).

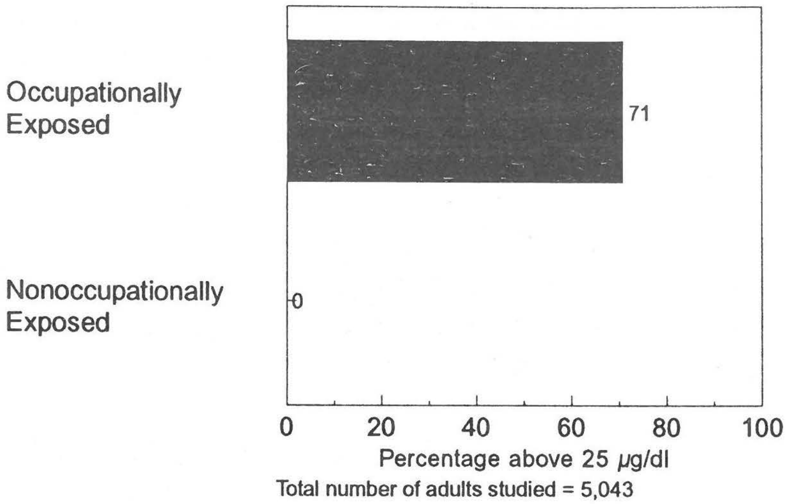
Japan has reasonably strong environmental regulations, overseen by the Environmental Agency. Among other standards, there are restrictions on emissions to air and water from industrial sources, as well as waste management controls. Also, 41 cities and metropolitan regions have pollution control programs.

About three quarters of all the lead used in Japan is for the manufacture of batteries (probably for cars). Pigments and chemicals consume an additional 15% of the lead used in the country.

There appear to be no recent studies on blood lead levels in Japanese children, but limited studies have been done on adults. Consistent with Japan's proactive stance on lead contamination, the data reveal that adults not exposed either occupationally or to a local industrial source have low blood lead levels. For example, a 1982 international study of 200 teachers in Tokyo (a group without any specific exposure to lead), found a median blood lead level of 6.3 μg/dl, with none higher than 7 μg/dl (Vahter, ed., 1982). Blood lead levels in rural areas are even lower—a survey of 2,026 adult farmers in 1985 reported an average blood lead level of 3.8 μg/dl (Watanabe, et al, 1985).

Some surveys carried out in the early and mid-1980s uncovered occupations in which exposure to lead was elevated. These studies found high blood lead levels in tire manufacturers (averages ranged from 14.5 to 53.9 μg/dl in a sample of 294), and newspaper workers exposed to leaded type (average of 43.1 μg/dl in a sample of 353). Although not as high as blood lead levels in occupationally exposed populations elsewhere in the world, the levels are high enough to suggest that problems may persist in certain occupational settings in Japan.

Figure 18. Percentage of Average Blood Lead Levels above Designated Threshold in Studied Populations of Japanese Adults



4. Case Study: Mexico

Mexico is a rapidly industrializing country with the world's largest city, Mexico City, as its capital. Mexico's total population of 81 million (1990 estimate) has wide disparities in living standards with the rural and urban poor having limited access to modern medicine. The economy is diversified, with significant employment in agriculture, manufacturing, trade, mining, and tourism. Mexico is also one of the largest primary lead producers in the world.

Although Mexican environmental laws are strong in writing, enforcement has historically been weak. However, under the Salinas administration, which has been in office since 1988, spending on environmental protection has been steadily increasing. Mexico also took part in the OECD's first project on the study of lead. Under this project, the government developed four strategies to reduce the problem of lead contamination to: establish lead regulations; reduce the concentration of lead in gasoline; create a relationship between the government and industry for the reduction of lead in consumer products; and educate the public on the measures taken to reduce lead exposure.

Progress has already been made in implementing these strategies, especially in reducing the amount of lead in gasoline. Between 1980 and 1992, lead levels of gasoline were reduced by 88%, to an average of 0.2 g/l. Lead-free gasoline was introduced in 1990, and as of 1993 all new cars must run on lead-free gasoline (automobile manufacturers voluntarily phased in this requirement two years earlier). The government has also reduced the price of lead-free gasoline to encourage its use. At the same time, the lead content of leaded gasoline has been reduced from 0.21 g/l in 1990 to 0.09 g/l in 1992 (Driscoll, et al, 1992). This limit is among the lowest allowable level of lead in gasoline in the developing world.

Other regulations include a 1988 requirement to limit the amount of lead in drinking water to 50 ppb (the level allowed in U.S. drinking water until revised standards took effect in 1991), and limits on the amount of allowable lead in paint, food, drinks, medicines, and cosmetics (consumer products containing lead must have warning labels). The Mexican Government is currently working to reduce the allowable limit of lead in air in occupational settings from 150 $\mu g/m^3$ to 50 $\mu g/m^3$. There is no Mexican law or regulation setting the maximum blood lead level for children or adults.

In spite of the current efforts of the Mexican government to reduce lead in the environment, lead pollution and lead poisoning continue to be major problems throughout Mexico due to historical reliance on leaded gasoline, the pervasiveness of lead industries (primary and secondary smelters and battery manufacturing industries can be found throughout Mexico, often with little pollution control), and the presence of lead in many consumer products.

In any discussion of the Mexican environment, Mexico City deserves special mention. More than 20% of Mexico's population lives in this metropolitan area, and roughly 50% of the country's industry and manufacturing is located in the city, often with little separation between residential and industrial areas. It has been estimated that 30% of all lead emitted in Mexico is emitted in and around Mexico City (Albert and Badillo, 1991). In addition, the unique topography and frequent temperature inversions readily trap air pollutants—including lead—over the city. As recently as 1991, unleaded gasoline accounted for only 7.2% of gasoline sales in Mexico City.

Despite the current efforts of the Mexican government, lead pollution and lead poisoning continue to be significant problems due to the historical reliance on leaded gasoline, the pervasiveness of industry, and the presence of lead in many consumer products.

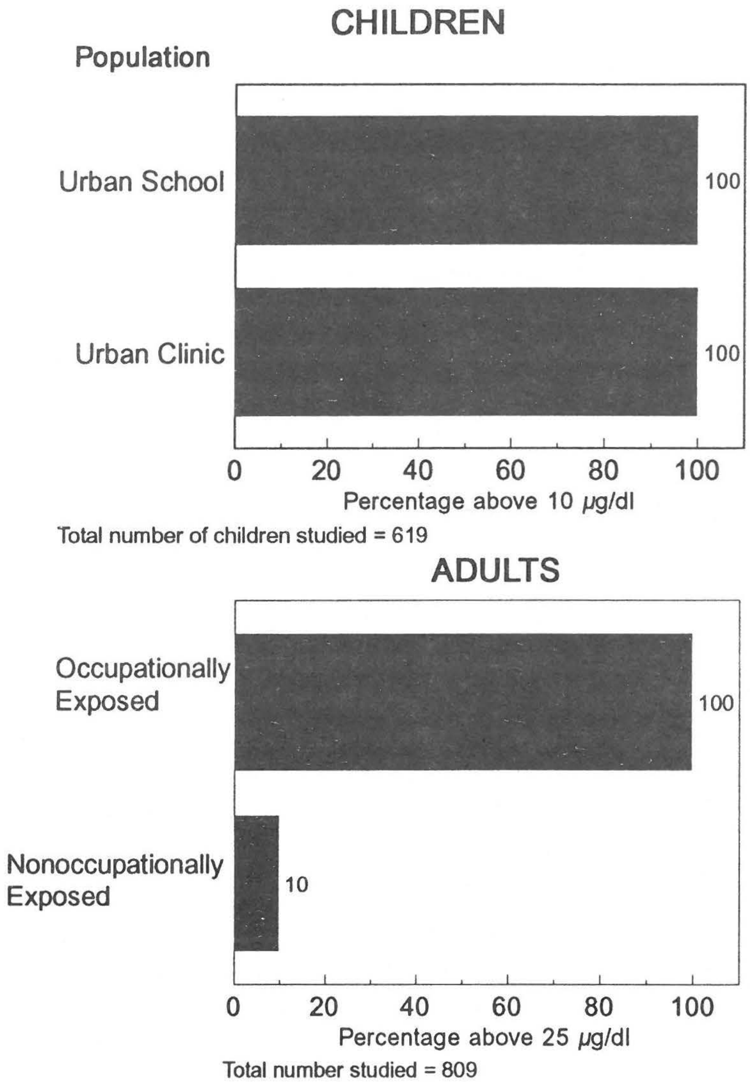
A major source of occupational and consumer exposure to lead is the ceramics industry. Mexico is one of the world's principal producers of earthenware pottery, typically lead glazed. Populations of adults working in pottery factories with leaded glazes have been reported to have average blood lead levels ranging from 50.9 to 84.2 μg/dl.

An additional hazard of the industry is that it is often carried out in homes as a cottage industry. Inefficient kilns are kept on patios, where children can come in contact with powdered glaze mixes or with dripping leaded glaze before it is fired. The inefficient kilns that expose workers and their families to lead also fail to seal the leaded glazes properly, resulting in exposure of consumers. In many areas of Mexico, the exclusive use of ceramicware for cooking, storing, and serving food exposes populations to high levels of lead, because hot and acidic foods are most likely to leach lead from the glazes. In fact, a study conducted in 1991 found that the major determinant of an elevated blood lead level was the use of lead-glazed ceramicware for cooking and storing food (Avila, et al, 1991).

Other sources of lead in the diet include lead-soldered cans, which the government is beginning to phase out, and folk remedies for stomach ailments known as "empacho," which may contain 75 to 95% lead powder.

There have been surprisingly few studies on lead in the general population of Mexico. Blood lead levels reported in the studies that have been conducted are alarmingly high, in both directly exposed and "unexposed" populations. In 1980, when the lead content in gasoline was still quite high, a sample of 85 Mexico City teachers had a median blood lead level of 24.1 μg/dl. These teachers presumably had no particular exposure to lead other than that in the air.

Figure 19. Percentage of Average Blood Lead Levels above Designated Thresholds in Studied Populations of Mexican Children and Adults



5. Case Study: Nigeria

The most populous country in Africa (nearly 90 million people), Nigeria also has one of the continent's largest economies. However, like many other developing countries, Nigeria has been able to devote limited attention to its environmental problems.

Laws to protect the environment are still relatively undeveloped in Nigeria, although the country's Environmental Protection Agency, established in 1988, has broad responsibilities and enforcement powers. The lack of strong environmental regulations and the lax enforcement of existing ones have contributed to an increasing amount of environmental pollution.

Available environmental information suggests that Nigeria's cities and towns have high levels of lead contamination.

Available environmental information suggests that Nigeria's cities and towns have high levels of lead contamination. An important contributor to lead pollution in the country is emissions from vehicles running on leaded gasoline, since premium gasoline contains 0.66 g/l of lead (Octel, 1991).

Lead emissions are rising as more vehicles using leaded gasoline crowd Nigeria's urban streets. Despite lower average traffic densities in Nigeria than in many developed countries, the concentration of lead in roadside dust about equals that of the most polluted areas of developed countries (Nriagu, 1992). In addition, lead-contaminated dust from Nigeria's many unpaved roads is kicked up by traffic and eventually settles in nearby neighborhoods. Winds from the Sahara increase the dispersion of lead dust, which settles across the country (Beavington and Cawse, 1979).

Although Nigeria is not a major lead mining country, there are numerous small mines and smelters that largely operate with outdated equipment and without environmental controls. When pollution control equipment breaks down, repairs are rarely made (Nriagu, 1992). Nigeria's rivers and coastal waters have been polluted with untreated industrial wastes high in lead. Over time, lead has gradually accumulated in the sediment at the bottom of these rivers and streams and has slowly contaminated marine life. This poses a serious threat to the people of Nigeria who rely on fish for 20 to 40% of their total protein intake (Nriagu, 1992). Another source of lead contamination is cooking salts collected by many villagers from springs often polluted with lead from nearby mines (Dim, et al, 1991).

Many Nigerians use a cosmetic called tiro (similar to the surma used in India), containing up to 85% lead sulfide. It is used around the eyes, by both sexes of all ages, even on children as young as 4 months. Children may ingest tiro by putting their hands in their mouths after they have rubbed their eyes.

Studies of blood lead levels of Nigerian children and adults are unavailable, but based on studies of environmental contamination, one investigator estimated in 1992 that between 10 and 30% of children in African urban areas suffered from lead poisoning (he did not specify at what blood lead level he considered children to be poisoned) (Nriagu, 1992).

No Blood Lead Data Available for Nigeria

6. Case Study: Poland

Poland has been undergoing a rapid and drastic transformation during the past few years, from a centrally planned economy under Communist rule to a mixed economy with a parliamentary democracy. It will take much longer to clean up the legacy of pollution left behind primarily by the widespread development of environmentally unregulated industry in one of Europe's largest and most populous countries.

Although various environmental laws have been enacted in Poland since 1949, enforcement has been lax. In December 1991 new legislation placed responsibility for environmental protection on the national Ministry of Environmental Protection, Natural Resources, and Forestry; the 49 provincial governments, and the National Park directorship.

The Ministry creates, implements, and finances environmental policy, with the regional governments overseeing compliance. Regional governments also participate in carrying out environmental impact assessments, setting projects, issuing licenses, and assessing penalties for environmental violations. The basic legal philosophy regarding environmental protection in Poland has been one of "polluter pays," but fines and penalties have been small and offer little disincentive to pollute.

Currently, few laws specifically regulate lead. However, the government is now engaged in the extensive revision of its environmental laws. Ultimately, Poland's goal is to move toward European standards of environmental protection so that it can join the European Community (EC).

Poland's goal is to move toward European standards of environmental protection so that it can join the European Community.

Because control measures are less expensive for particulates, lead, and other heavy metals, Poland plans to regulate them before dealing with sulfur dioxide and nitrogen oxide emissions. The EC standard of lead in air, which the Polish Government hopes to achieve, is an annual average concentration of 2 $\mu g/m^3$.

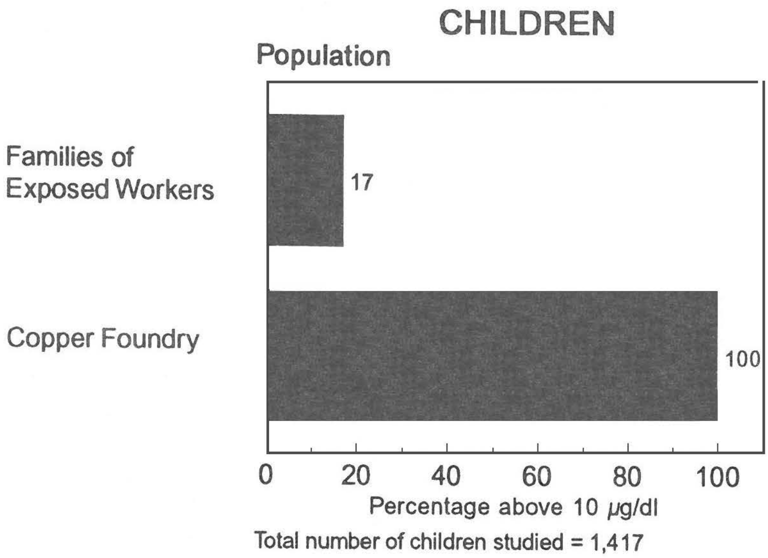
The National Environmental Policy, approved by the Parliament in May 1991, includes a "program to limit the harmful effects of motorization on the environment," which indicates a commitment to reduce the amount of lead in gasoline. Indeed, unleaded gasoline has been introduced in Poland, and the use of leaded gasoline will eventually be phased out. In addition, new vehicles must meet EC emission standards, necessitating the use of catalytic converters, which are rendered inoperable by leaded gasoline.

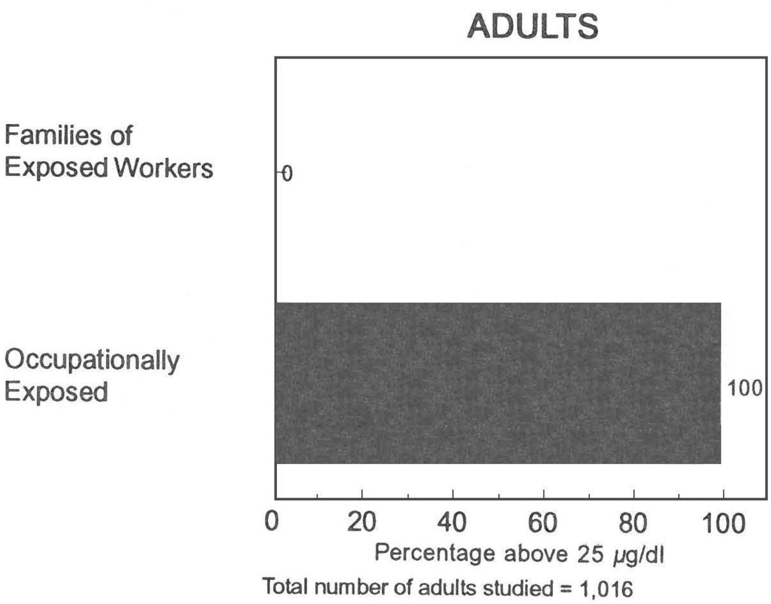
However, it will take time before the effects of these programs can be seen. Poland has five million passenger cars, which on average travel approximately 7,000 kilometers a year (WRI, 1992). While traffic density is much lower than in most industrialized countries, Poland's gasoline currently has lead concentrations, ranging from 0.3 to 0.56 g/l and averaging about 0.4 g/l (Thomas and Spiro, in press). Only about 1% of the gasoline sold in the country is unleaded. As a result, as much as 40% of the lead emitted in Poland comes from motor vehicles (WRI, 1992).

Nationwide, Polish mines produce 60,000 metric tons of lead a year (U.S. Bureau of Mines, 1993b). The southern and southwestern part of Poland is a heavily industrialized region known as Upper Silesia, which with neighboring regions in Germany and the Czech Republic makes up the greatest concentration of industry in Eastern Europe. Upper Silesia is Poland's principal lead-producing region, containing mines and primary and secondary smelters. Some soil lead levels recorded in Upper Silesia are the highest ever reported in the world (WRI, 1992). A study of soil lead from Katowice, in the heart of Upper Silesia, revealed a broad range of levels, from 82 ppm to 19,750 ppm.

A study of the families of workers in different cities illustrates the effect of working and living near lead-related industries. In two cities with lead-related industry, Zukowice and Grodziec, population average blood lead levels in adults ranged from 7.9 to 15.8 μg/dl, and average levels in populations of children ranged from 10 to 17 μg/dl. But in four cities without industries that produce heavy metals, none of the average blood lead levels in either adults or children was above 7 μg/dl. Finally, four studies of direct occupational exposure in 776 workers found very high blood lead levels, with averages ranging from 10.5 to 96.8 μg/dl.

Figure 20. Percentage of Average Blood Lead Levels above Designated Thresholds in Studied Populations of Polish Children and Adults





7 Policy Recommendations

Our survey and analysis of the world literature on environmental lead contamination and human lead exposure suggests that lead poisoning affects virtually every area of the world. Patterns of lead use, both historical and ongoing, vary from country to country and community to community but produce significant exposures for many groups of children and adults. Lead poisoning is a significant problem in both developed and developing countries. Only in those few countries where the use of lead has long been limited, by circumstance or prudent policy, is lead poisoning relatively insignificant.

For the most part, awareness of the nature and extent of lead poisoning hazards is very low. Many populations being poisoned are not being identified or treated and few steps are being taken to control sources of exposure. At the same time, the relationships between various uses of lead and the resulting environmental and human exposures are well documented, so that necessary steps to reduce human exposure are clear. This report therefore proposes recommendations for action on several levels, which can and should be carried out simultaneously.

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Assess the Problem

There is a critical need for better information on the nature and extent of lead exposures in many countries. No nation other than the U.S. has adequate population-wide data available from which to draw solid inferences on national prevalence rates or develop strategies to assess and control sources of exposure. However, the lack of country-specific environmental and human contamination data is not sufficient reason to delay strategies to reduce human exposure by controlling sources of lead, such as leaded gasoline.

Documentation of environmental contamination and lead poisoning prevalence rates is important to target appropriate medical treatment to individuals who are lead poisoned and to identify high risk groups not previously recognized. Such documentation is also critical for prevention by focusing source control efforts on priority sources, particularly for those countries where resources are severely limited, and by mobilizing both policy makers and the public to support prevention measures.

- National governments should develop programs to screen populations for elevated blood lead levels and monitor occupational exposure to lead.

- National governments should undertake environmental monitoring to identify serious sources of exposure and contamination patterns in air, soil, dust, and drinking water.

- National governments should review data derived from blood lead screening, occupational health and safety monitoring, environmental monitoring, and industrial permitting to determine the lead poisoning prevalence rates in the population, as well as geographic "hot spots" of high environmental lead levels.

- Intergovernmental organizations should establish and maintain an international registry of human exposure and environmental monitoring data, periodically publish reports on the data, and make it available to governmental and nongovernmental organizations.

- Intergovernmental organizations should develop and institute a standard method for collecting and reporting human exposure and environmental monitoring data, in order to enhance the comparability and usefulness of such data. Consideration should be given to identifying sources of human exposure to lead in the design of the reporting form.

Set Priorities for Prevention

The data presented in this report indicate an urgent need for action to control and eliminate lead hazards in many nations. The steps necessary to prevent lead poisoning are generally clear. Prevention requires controlling the sources of lead exposure rather than belated reaction to cases of poisoning.

Prevention requires controlling the sources of lead exposure rather than belated reaction to cases of poisoning.

Controlling exposures from the multitude of lead sources requires strategies that address both ongoing and past uses of lead. Limiting exposure from ongoing uses of lead requires product restrictions, materials substitution, and process controls on lead mining and processing, and on product manufacturing, disposal, and recycling. Accelerating the development and transfer of cleaner technologies and preventing the transfer of older, more polluting technologies can also greatly reduce continuing exposures to workers, their families, the surrounding environment, and local residents. Limiting exposure from past uses of lead requires remediation of existing reservoirs of lead in the human environment. No nation has yet fully resolved the remedial problems associated with lead-based paint, contaminated soil, or leaded water-distribution systems.

Lead hazard control strategies must be linked to the sources of lead—for both historic and current uses of lead. Thus, intervention usually requires a source-specific approach.

Gasoline

Lead additives to gasoline contaminate the environment and harm human health. Countries that have imposed phase-downs in leaded gasoline use have seen direct reductions in environmental exposures and significant public health benefits. For nations that have not yet banned leaded gasoline, considerable additional benefits can be gained by phasing out this highly dispersive use of lead. In addition, because lead emissions from vehicles contribute to transboundary pollution via atmospheric transport, concerted and harmonized international action is necessary to ensure health benefits for all.

- National governments should phase out leaded gasoline for domestic use and for export. In the interim, government policy should institute taxes or other mechanisms to ensure pricing incentives that discourage the use of leaded gasoline.

- Intergovernmental organizations should encourage the adoption of national and multinational phase-outs of leaded gasoline.

- International lending organizations should ensure that investments in refineries are restricted to production of unleaded gasoline and that investments in automobile factories are restricted to those that produce cars that operate on unleaded gasoline.

- Vehicle manufacturers and national governments should accelerate the technological shift to producing vehicles that operate on unleaded fuel.

Countries that have imposed phase-downs in leaded gasoline use have seen direct reductions in environmental exposures and significant public health benefits.

Point Sources

The data surveyed indicate that populations living near point sources, such as smelters and industries involving lead, face a significant risk of lead poisoning. Worldwide, there are many hundreds of primary and secondary lead smelters, battery plants, and other industrial facilities emitting significant amounts of lead. In addition, small-scale, cottage-type industries, particularly in developing countries, often entail manufacturing or other activities in the home environment, sometimes with the involvement of family members. Of special concern are uncontrolled recycling operations that recover lead (and other metals) from discarded products, such as batteries.

- National governments should adopt and enforce regulations to control lead in air emissions and effluents from industrial sources.

- National governments should adopt and enforce strict regulations to protect the health and safety of workers and their families, including workplace air lead level monitoring, blood lead screening, use of safer technologies and protective clothing, and education programs for workers and surrounding populations. These regulations should apply to both domestic companies and multinational corporations. Where appropriate, national governments should undertake education campaigns on the hazards of polluting cottage industries.

- National governments should adopt programs to encourage capture and appropriate recycling of used lead-acid batteries.

- Intergovernmental organizations should set standards for product safety and industrial emissions as well as standards for occupational health and safety; they should also review international standards and recommendations for occupational lead poisoning for consistency with current knowledge of toxicity and exposure routes.

- International lending agencies should recognize the benefits of clean technologies and make technology transfer a priority.

- International corporations should publicly make and fulfill commitments to avoid transferring outdated polluting technologies and operations to developing countries.

Paint

While the hazards associated with lead-based paint have been recognized since the turn of the century, lead paints are still in use in many countries, and old lead-based paint is still found in the residences of millions of children, particularly in the developed world. Some countries reduced the allowable content of lead in paint in the 1920s, and may face a smaller reservoir of lead-based paint in housing. However, preliminary data on children in these countries, combined with the continued availability of lead-based paints, indicate that hazards from lead-based paint may be underestimated in many countries.

The hazards from lead-based paint may be underestimated in many countries.

- National governments should immediately ban the use of lead-based paint, especially in residential structures and buildings used by children, such as child care areas, schools, or similar public structures, as substitutes are readily available.

- National governments should identify housing and day-care centers with likely lead-based paint hazards (i.e., those containing deteriorated lead-based paint or lead-based paint on surfaces likely to generate dust or be mouthed by children). Subsidies to abate serious hazards should be provided, along with educational materials describing hazard reduction steps. Property owners should avoid aggravating lead-based paint hazards during remodeling and renovation, and, as resources permit, conduct hazard abatement.

- National governments should ensure the safety of workers and protect the environment from severe contamination that often occurs during the repainting or repair of lead-painted steel structures.

- Intergovernmental organizations should develop and promulgate harmonized, stringent standards for the allowable use of lead in paint. Such standards should not exceed trace amounts of lead for residential paint.

- International development and lending agencies should ensure that all construction loans prohibit the use of lead-based paint and that potential hazards posed by prior use of lead-based paint are considered in housing assistance and renovation programs.

Food can solder

The use of leaded solder in food cans, which can contaminate the contents, is unnecessary in light of the availability of lead-free solder and alternative canning techniques.

- National governments should ban use of leaded solder for domestically and imported canned food. Pending the ban, all lead-soldered cans should be required to carry warning labels.

- Intergovernmental organizations should adopt harmonized international prohibitions on lead solder in food cans.

- International lending agencies should restrict investments in canning plants to facilities that use unleaded solder.

Ceramic dish glazes

Cooking, storing, and serving food in improperly fired ceramicware with lead glazes can cause high lead exposures in children and adults.

- National governments should develop and enforce stringent limitations on leachable levels of lead in glazes and other materials applied to dishes for human use, and assist with changing the process of ceramic production through education, technology adaptation, and targeted investments.

- National governments should institute education campaigns to convince consumers to discontinue use of unsafe lead-glazed ceramicware.

Medicines, Cosmetics, and Other Products

Certain traditional products, including cosmetics and home remedies, are also associated with cases of severe lead poisoning.

- National governments should discourage or restrict sale and use of such products, working in concert with cultural and religious leaders. For example, use of lead-containing medicines and cosmetics—such as empacho in Mexico, surma in Kuwait, and kohl in India—should be discontinued as soon as possible.

Drinking Water Systems

Drinking water is a potential source of lead exposure wherever leaded plumbing fixtures, pipes, or solder have been used. Infants are at special risk from lead-contaminated drinking water if they consume large quantities of formula or other beverages made with water. Because lead in drinking water typically causes widespread exposure, the health benefits of control actions can be significant.

- National governments should require use of non-leaded materials for water mains, service-line connectors, and solders, and require that all water-contact surfaces in plumbing fittings be lead-free, as water systems are installed, expanded, and upgraded.

- National governments should identify drinking water systems contaminated with lead and institute corrosion-control efforts to reduce lead levels in water.

- International lending agencies should ensure that all loans for drinking water supply systems specify lead-free materials.

There is a need for coordinated and integrated action at all levels: in the local community, by national governments, and through regional and international organizations.

Develop Integrated Programs and Coordinate International Efforts

Lead poisoning is at one and the same time an international problem and an intensely local one. The international elements of the problem include the stream of lead-containing products in commerce, the potential transboundary movement of lead in air and water, and the global toxic materials and hazardous waste trade. The localized nature of the problem is characterized by variations in and proximity to primary sources of lead exposure. As a result, there is a need for coordinated and integrated action at all levels: in the local community, by national governments, and through regional and international organizations. Nongovernmental organizations also have an important role to play, both in influencing international organizations and in implementing prevention efforts.

Program Coordination

An effective prevention program requires that data collection be linked with hazard control efforts, in order for control actions to be targeted to those areas, populations, or circumstances that face the greatest risk. In addition, all agencies working on prevention must coordinate their efforts. At the horizontal level, all relevant agencies—health, environment, planning, housing—need to work together to coordinate interdisciplinary prevention activities. Programs should also interact vertically, working with national, regional, international organizations, and community groups to develop and utilize common resources, such as databases and training resources. An active outreach program that uses the resources and experience of the community and gives community members a stake in the outcome of prevention efforts is also critical to success.

Although not a substitute for source controls and remediation, education efforts are important in raising awareness of the hazards of lead and can provide important prevention benefits. Education efforts should be proactive, not passive. In the first instance, such efforts should be directed at raising awareness of the nature and causes of lead poisoning, combined with disseminating knowledge of prevention strategies and what the targeted audience can do to prevent lead exposures. Educational efforts must be appropriate to the audience addressed, and include sensitivity to cultural factors.

An effective prevention program requires that data collection be linked with hazard control efforts, in order for control actions to be targeted to those areas, populations, or circumstances that face the greatest risk.

Cooperative International Solutions

In June, 1992, the largest official international meeting ever held—the United Nations Conference on Environment and Development (UNCED)—was convened in Rio de Janeiro, Brazil. This meeting was attended by over 100 heads of government, as well as senior government officials. Hundreds of nongovernmental organizations participated in preparatory meetings for UNCED and held a parallel conference of their own. The action plan endorsed at UNCED, known as Agenda 21, provides a "road map" to sustainable development for governments, businesses, international organizations, nongovernmental organizations, and private citizens.

Developing cooperative international solutions to childhood lead poisoning is critical to the advancement of the post-Rio order. There is a need, first of all, for an optimism-engendering success story to demonstrate effective international cooperation on a basic environment and health issue—and lead appears the most promising candidate. Preventing childhood lead poisoning, in addition, is a critical element of "sustainable development." There is nothing more basic to sustainable

Czechoslovakia	*Secondary:* Pribram
France	*Primary:* Noyelles-Godault, Pas-de-Calais *Secondary:* Escuadoeuvres, Nord • Villefranche, Rhoone • Bourg Fidele, Rocroi • Toulouse, Haute-Garonne • Bazoches-les-Gallerandes, Loiret • Brenoville
Germany	*Primary:* Binsfeldhammer • Duisberg • Hamburg • Nordenham *Secondary:* Rhineland-Palatinate • Bavaria • North Rhine-Westphalia • Lower Saxony • Muldenhutten
Greece	*Primary:* Lavrion, Attikis *Mines:* Olynthus, Chalkidiki
Honduras	*Mines:* Santa Barbara
India	*Primary:* Vishakhapatam • Chanderiya *Secondary:* Thane, Maharashtra • Parganas, West Bengal *Mines:* Rajasthan
Iran	*Secondary:* Sorb Abad, Nr. Tehran *Mines:* Zanjan
Ireland	*Secondary:* County Dublin *Mines:* County Meath
Italy	*Primary:* Porto Vesme • San Gavino *Secondary:* Arcola, La Spezoa • Paderno Dugnano, Milano • Maclodio, Brescia • Brugherio, Milano
Japan	*Primary:* Hachinohe, Aomori • Hosokura, Miyagi • Kamioka, Gifu • Kosaka, Akita • Noashima, Kagawa • Takehara, Hiroshima • Saganoseki, Oita • Harima, Hyogo • Chigirishima, Hiroshima *Secondary:* Ichikawa-shi, Chiba Pref. • Yawata-shi, Kyoto Pref. • Amagasaki-shi, Hyogo Pref. • Kariya-shi, Aichi Pref.
Korea, Democratic People's Republic of	*Primary:* Munpyong, Kwangwong Province *Mines:* Tanchon
Korea, Republic of	*Primary:* Onsan, Kyoung Nam Province
Malaysia	*Secondary:* Selayang Industrial Estate, Selayang

development than the protection of the children of the world—the intellectual, social, and economic resources of the future.

- Lead poisoning prevention efforts should be actively incorporated into actions under Agenda 21.

- The United Nations Commission on Sustainable Development should designate lead poisoning prevention as one of its top priorities for its forthcoming round of activities and, in addition, should require that lead poisoning prevention efforts be included in national sustainable development plans.

Nothing is more basic to sustainable development than the protection of the children of the world—the intellectual, social, and economic resources of the future.

- The Basel Convention on the Transboundary Movement of Hazardous Wastes and their Disposal should be effectively implemented as a model of continuing international cooperation. The Convention should be used as the basis for strict regulation of the transboundary transportation and disposal of lead waste and its eventual elimination through waste minimization strategies.

- Intergovernmental organizations should encourage nations to set standards at stringent levels of protection and to adopt common monitoring requirements. As the European Community has begun to promote and require Member States to adopt regulations, other regional groups should also work to develop lead policies and regulations in their member states.

- Intergovernmental organizations should encourage nations to screen blood lead levels, provide education materials on the hazards and causes of lead poisoning, and establish protective action levels.

- An international action plan should be developed to clearly define the role and responsibility of each international and regional organization that can contribute to preventing lead poisoning. Appendix A provides a list of the many international and regional organizations that have important roles to play.

Appendix A

International Organizations with a Role in Lead Poisoning Prevention

- United Nations Environment Programme (UNEP)
- United Nations Development Program (UNDP)
- World Health Organization (WHO)
- International Labor Organization (ILO)
- The World Bank and Other Regional Development Banks
- United Nations Economic Commission for Europe (UNECE)
- The Council of Europe
- Organization of Economic Cooperation and Development (OECD)
- European Community
- Organization of American States
- Pan-American Health Organization (PAHO)
- United Nations Children's Fund (UNICEF)
- United Nations Industrial Development Organization (UNIDO)
- Food and Agricultural Organization (FAO)
- Association of South East Asian Nations (ASEAN)

Appendix B Lead Production Locations

Primary and Secondary Lead Smelters, Refineries, and Mines Worldwide

Sources: ILZSG, 1991a, 1991b; U.S. Bureau of Mines, 1989

Argentina

Primary: Palpala, Jujuy • Lastenia, Tucuman
Mines: Humhuaca, Jujuy

Australia

Primary: Port Pirie, South Australia • Cockle Creek, New South Wales • Mount Isa, Queensland
Mines: Hellyer, Tazmania • Cadjebut • Taralga, New South Wales • Broken Hill, New South Wales • Mount Isa, Queensland • Northern Territory • Thalanga, Queensland • Cobar, New South Wales • Roseberry, Tazmania

Austria

Primary: Gailitz
Secondary: Arnoldstein

Belgium

Primary: Hoboken, Antwerp
Secondary: Beerse • Brussels

Bolivia

Primary: Karachipampa, Potosi

Brazil

Primary: Santa Amaro • Panelas
Secondary: Sao Bernardo do Campo • Recife, PE • Jancarei, SP
Mines: Paracatu

Bulgaria

Primary: Kardjali • Plovdiv
Mines: Madan

Canada

Primary: Belledune, New Brunswick • Trail, British Columbia
Secondary: Ville St. Catherine, Quebec • Toronto, Ontario • Mississauga, Ontario
Mines: New Brunswick • Little Cornwallis Island, Northwest Territory • Yukon Territory • Watson Lake, Yukon • Nova Scotia

China

Primary: Zhuzhou, Hunan • Shengyang, Liaoning • Shaoguan, Guangdong • Kunming, Yunnan • Baiyin, Gansu • Shuikoushan, Hunan
Mines: Guangdong • Hunan • Quinghai

Colombia

Secondary: Cali, Valle

Czechoslovakia	*Secondary:* Pribram
France	*Primary:* Noyelles-Godault, Pas-de-Calais *Secondary:* Escuadoeuvres, Nord • Villefranche, Rhoone • Bourg Fidele, Rocroi • Toulouse, Haute-Garonne • Bazoches-les-Gallerandes, Loiret • Brenoville
Germany	*Primary:* Binsfeldhammer • Duisberg • Hamburg • Nordenham *Secondary:* Rhineland-Palatinate • Bavaria • North Rhine-Westphalia • Lower Saxony • Muldenhutten
Greece	*Primary:* Lavrion, Attikis *Mines:* Olynthus, Chalkidiki
Honduras	*Mines:* Santa Barbara
India	*Primary:* Vishakhapatam • Chanderiya *Secondary:* Thane, Maharashtra • Parganas, West Bengal *Mines:* Rajasthan
Iran	*Secondary:* Sorb Abad, Nr. Tehran *Mines:* Zanjan
Ireland	*Secondary:* County Dublin *Mines:* County Meath
Italy	*Primary:* Porto Vesme • San Gavino *Secondary:* Arcola, La Spezoa • Paderno Dugnano, Milano • Maclodio, Brescia • Brugherio, Milano
Japan	*Primary:* Hachinohe, Aomori • Hosokura, Miyagi • Kamioka, Gifu • Kosaka, Akita • Noashima, Kagawa • Takehara, Hiroshima • Saganoseki, Oita • Harima, Hyogo • Chigirishima, Hiroshima *Secondary:* Ichikawa-shi, Chiba Pref. • Yawata-shi, Kyoto Pref. • Amagasaki-shi, Hyogo Pref. • Kariya-shi, Aichi Pref.
Korea, Democratic People's Republic of	*Primary:* Munpyong, Kwangwong Province *Mines:* Tanchon
Korea, Republic of	*Primary:* Onsan, Kyoung Nam Province
Malaysia	*Secondary:* Selayang Industrial Estate, Selayang

Primary: Chihuahua, Avalos • Monterrey • Torreon *Secondary:* Tiaxcala • Tijuana • Monterrey • Cienega de Flores *Mines:* Zacatecas • Chihuahua, Avalos	**Mexico**
Primary: Oued el-Heimer, Oujda *Mines:* Douar, Hajjar • Er Rachidia	**Morocco**
Primary: Namtu	**Myanmar**
Primary: Tsumeb *Mines:* Aus • Tsumeb	**Namibia**
Secondary: Arnhem • Delft	**Netherlands**
Primary: La Oroya • Fundeconsa *Mines:* Cerro de Pasco • Lima • Huanuco	**Peru**
Secondary: Marilao, Bulacan, Luzon	**Philippines**
Primary: Miasteczko *Secondary:* Piekary, Slaskie • Katowice • Miasteczko Slaskie *Mines:* Bukowko • Trzebinia	**Poland**
Primary: Copsa-Mica *Secondary:* Maramures	**Romania**
Primary: Germiston, Transvaal *Mines:* Namaqualand, North Cape	**South Africa**
Primary: Cartegena, Murcia *Secondary:* Medina del Campo, Vallodolid • San Esteban de Gozmar, Sorie *Mines:* Sevilla • Linares	**Spain**
Primary: Ronnskar *Secondary:* Landskrona *Mines:* Garpenberg • Laisvall	**Sweden**
Secondary: Taipei • Tah Liau, Kaohsiung	**Taiwan, China**

Thailand	*Primary:* Lat Ya, Karnchanaburi *Secondary:* Tambon Koonkaew, Amphur Nakonchaisri, Nakhonphatum *Mines:* Karnchanaburi
Trinidad & Tobago	*Secondary:* O'Meara Industrial Estate, Arima
Turkey	*Secondary:* Kartal, Istanbul *Mines:* Keyseri
Union of Soviet Socialist Republics	*Primary:* Chimkentsk, Kazakhstan • Glubokoye, Kazakhstan • Leninogorsk, Kazakhstan • Ordzhonikidze, North Caucasus • Oust Kamenogorsk, Kazakhstan • Konstaninovka, Ukraine • Tetuikha, Far East • Karlyuk *Secondary:* Details not available. *Mines:* Akhtale region, Arminian SSR • Alma Ata Oblast, Kazakhstan • Chimkent Oblast, Kazakhstan • Dzhezkazgan Oblast, Kazakhstan • Karaganda Oblast, Kazakhstan • East Kazakhstan Oblast, Kazakhstan • Semipalatinsk Oblast, Kazakhstan • Taldy-Kurgan Oblast, Kazakhstan • Chita Oblast, Soviet Far East • Khabarovsk Kray, Soviet Far East • Primoskiy Kray, Soviet Far East • Degtyarsk, Urals • Gay, Urals • Karabash, Urals • Kirovgrad, Urals • Krasnourals'k, Urals • Dal'negorsk, Urals • Sibay, Urals • Aktyuz, Kirgiz SSR • Berdunskiy, Kirgiz SSR • Sumsar, Kirgiz SSR • Kvaisi, Georgian SSR • Madneuli, Georgian SSR • Verkhniy Fiaagdon, North Ossetian ASSR • Mizurskiy, North Ossetian ASSR • Svintosovyy Rudnik, Turkmen SSR • Almalyk, Uzbek SSR • West Siberia
United Kingdom	*Primary:* Northfleet, Kent • Avonmouth *Secondary:* Darley Dale, Derbyshire • Wakefield • Northfleet, Kent • Newcastle upon Tyne • Glasgow • Woodville, Staffs
United States of America	*Primary:* East Helena, Montana • Glover, Missouri • Omaha, Nebraska • Boss, Missouri • Herculaneum, Missouri *Secondary:* Ponchtoula, Louisiana • Lyons Stations, Pennsylvania • Reading, Pennsylvania • Muncie, Indiana • Altoona, Pennsylvania • College Grove, Tennessee • Eagan, Minnesota • Tampa, Florida • Leeds, Alabama • Cleveland, Ohio • Columbus, Georgia • Frisco, Texas • Los Angeles, California • Memphis, Tennessee • Beach Grove, Indiana • East Syracuse, New York • Rossville, Tennessee • Indianapolis, Indiana • City of Industry, California • Walkill, New York • Troy, Alabama • Baton Rouge, Louisiana • Forest City, Missouri *Mines:* Missouri • Kotzebue, Alaska • Admiralty Island, Alaska • Idaho
Venezuela	*Secondary:* Guacara, Estado Carabobo
Yugoslavia	*Primary:* Titov Veles • Titova, Mitrovica • Kosovska, Mitrovica *Mines:* Pristina, Kosovo • Macedonia • Srebrenica
Zambia	*Primary:* Kabwe *Mines:* Kabwe

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