Lead Exposure in Latin America and the Caribbean

Isabelle Romieu,1 Marina Lacasana,1 Rob McConnell,1 and the Lead Research Group of the Pan-American Health Organization*

1Pan American Center for Human Ecology and Health, Division of Health and Environment, Mexico City, Mexico

As a result of the rapid industrialization of Latin America and the Caribbean during the second half of this century, exposure to lead has become an increasingly important problem. To obtain an estimate of the magnitude of lead exposure in the region, we carried out a survey and a literature search on potential sources of lead exposure and on blood lead concentrations. Sixteen out of 18 Latin American and 2 out of 10 Caribbean countries responded to the survey. Lead in gasoline remains a major problem, although the lead content has decreased in many countries in the last few years. The impact of leaded fuel is more important in urban settings, given their high vehicular density. Seventy-five percent of the population of the region lives in urban areas, and children younger than 15 years of age, the most susceptible group, comprise 30% of the population. Other sources of lead exposure identified in the region included industrial emissions, battery recycling, paint, and varnishes, and contaminated food and water. Lead is recognized as a priority problem by national authorities in 72% of the countries that responded to the survey, and in 50% of the countries some legislation exists to regulate the lead content in certain products. However, compliance is low. There is an urgent need for a broad-based coalition between policy makers, industry, workers, unions, health care providers, and the community to take actions to reduce environmental and occupational lead exposures in all the Latin American and Caribbean countries. Key words: Caribbean, Latin America, lead, sources of exposure. Environ Health Perspect 105:398–405 (1997)

Rapid industrial development in Latin America and the Caribbean (LAC) has caused the bioaccumulation of some potentially toxic substances, including lead. Several studies have shown that increased blood lead levels may cause behavioral problems or a decrease in the intelligence quotient. In adults, lead exposure may produce hypertension, among other health problems (1–3).

The main producers of lead in the world are, in decreasing order, Australia, the United States, China, Canada, Kazakhstan, Peru, Mexico, Sweden, the Republic of South Africa, North Korea, and Russia (4). LAC, where Peru and Mexico are the biggest producers, contributes 14% of the world’s lead (5). Lead, in its different forms and compounds, is used in many industrial activities. Precise estimates of the number and types of uses of lead in LAC are not available. However, lead is widely used in batteries, paint, and varnishes, as an anti-knock compound in gasoline, as a cable and pipe covering, and in welding and printing (5–8).

Materials and Methods

To obtain an estimate of the magnitude of lead exposure in LAC, we conducted a survey through the offices of the Pan American Health Organization (PAHO) in each country. Questionnaires were completed by PAHO environmental engineers using available information from governmental and institutional reports. The survey covered the following topics: 1) lead production, export, and import (in tons per year); 2) industrial uses of lead; 3) vehicular and industrial lead emissions into air; 4) other major sources of lead exposure (water, paint, food); 5) studies on lead content in environmental samples; 6) information on results of blood lead concentrations; and 7) data on rules and regulations to control lead pollution. In addition, we reviewed the literature, government reports, and other unpublished documents and collected information from these sources.

The overall response rate to the survey was 64.3%, or 18 of the 28 countries we contacted. However, while Latin American countries had a response rate of 88.8%, the Caribbean countries had a response rate of only 20%. The countries that replied to the survey were Argentina, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, the Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Surinam, Trinidad and Tobago, Uruguay, and Venezuela. Data for Cuba, Ecuador, Jamaica, and Peru were obtained through a review of the literature.

Results

Lead production. Figure 1 shows the principal mines and foundry in the Americas. The most prominent mines in Latin America are found in Peru, Mexico, and Argentina. Primary foundries are located in Peru, Mexico, Brazil, Argentina, and Nicaragua; secondary foundries are located in Mexico, Brazil, Colombia, Venezuela, and Trinidad and Tobago (9). Several countries of LAC, although not among the main lead producers, either produce or import lead for industrial use. These countries include Brazil, Colombia, Bolivia, Venezuela, Ecuador, Honduras, Jamaica, Uruguay, Trinidad and Tobago, Cuba, and the Dominican Republic (Table 1) (10–12).

Lead in gasoline and other industrial uses.

In spite of insufficient data on the main industrial uses of lead in LAC, available information suggests that one of the most important applications of lead is as an anti-knock compound in gasoline (tetraethyl lead). Brazil, Guatemala, and Mexico are the only countries in the region that removed most lead from gasoline. Given that 75% of the population in LAC is urban, the public health impact of leaded gasoline is of major importance. Table 2 shows that, over a period of 14 years, lead in gasoline decreased in Bolivia, Brazil, Chile, Mexico, Guatemala, and Venezuela. In 1994, lead concentrations in gasoline ranged from 1.32 g/l in Surinam to 0.03 g/l in Uruguay. Based on the survey, 46% of the countries have introduced unleaded gasoline. The majority of these countries are in Latin America—Argentina, Bolivia, Brazil, Chile, Colombia, El Salvador, Mexico, Peru, Costa Rica, Guatemala, and Uruguay. The countries of Central America are implementing a gasoline lead control program, and unleaded gasoline is partially used in the two Caribbean countries that answered our survey (the Dominican Republic and Trinidad and Tobago). Eight out of 10 countries did not provide information.

The number of automobiles that use unleaded gasoline may be a good indicator of the success of the countries’ programs to control air pollution from lead. According to the survey, Brazil, Guatemala, and Mexico are the

Address correspondence to I. Romieu, Pan American Center for Human Ecology and Health, PAHO/WHO, PO Box 37-473, 06696 Mexico, D.F. Mexico.

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countries using the highest proportion of unleaded gasoline (100, 80, and 46%, respectively). The Dominican Republic, Bolivia, Chile, Colombia, and Argentina follow with 29, 25, 13, 10, and 6% use, respectively. In Peru, the use of unleaded gasoline is minimal (0.2%). El Salvador, Costa Rica, and Honduras did not provide information about the amount of unleaded gasoline used by cars. In most of the previously mentioned countries, regulations have been introduced to control airborne lead levels. However, data reported in the survey (Table 3) suggest that lead concentrations in air have not been routinely monitored except in Brazil, Mexico, Peru, and Venezuela.

Although vehicular lead emissions are considered by 78% of the countries to be a potential health risk, other sources of lead exposure beside vehicular emissions must be considered. While 61% of the countries surveyed consider lead emitted into the air by fixed sources such as foundries, petrochemical products, and mines to be an important health hazard, 67% consider lead-based paint to also be a significant source of lead exposure. Battery recycling is also considered a health hazard. For 50% of the countries—countries like Mexico, Peru, Ecuador, and Honduras, where lead-containing varnishes are used as a glaze for ceramics used in food preparation—contamination of food also constitutes a source of exposure. Finally, for 22% of the countries, water pollution may be considered a problem (Fig. 2).

*Lead in environmental samples.* Data on lead content in environmental samples (Table 4) have been analyzed in the countries Argentina, Brazil, Bolivia, Chile, Colombia, the Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Peru, Trinidad and Tobago, Uruguay, and Venezuela. Analyses were performed in air, sediment, dust, food (fish, shellfish, and vegetables), and water samples (13–21). Some samples contained lead levels that exceeded international standards (22–26). However, the lack of laboratory certification for many of these analyses compromises the validity of the data. Research carried out in Mexico with environmental samples from 200 randomly chosen households in Mexico City revealed that samples that frequently exceeded standards for lead content were lead-glazed ceramics, street dust, and, to a lesser extent, paint. The analysis did not show significant lead concentrations in house dust or residential soil samples (16).

*Blood lead levels in the general population and in occupationally exposed populations.* Several countries have monitored lead in the general population, both in children and adults (27–35). Table 5 presents some of the samples studied, sorted by the sub-

jects' residence age. In general, blood lead concentrations are higher for people who live near fixed sources of lead emissions. In children, average blood lead concentrations varied from 11.5 μg/dl (standard deviation (SD) = 3.7) to 39.0 μg/dl (SD = 5.0).

The proportion of children with blood lead concentrations higher than 10 μg/dl varied from 45 to 100%. It also is worth mentioning that potential exposure to wastes from battery recycling is very high in some populations. Recently (1991), an outbreak of lead poisoning occurred in Trinidad and Tobago in a locality where the soil was contaminated by wastes from battery recycling. Blood lead concentrations in children living in this area varied between 17 and 235 μg/dl, with an average of 72.1 μg/dl (I. Chang-Yen, personal communication).

In urban populations, the average blood lead level ranged between 3.4 μg/dl (SD = 1.6) in Trinidad and Tobago and 28.8 μg/dl in Ecuador. The proportion of children with blood lead concentrations above 10 μg/dl varied from 0 to 100%. For adults, concentrations were similar, although generally slightly higher. In Mexico, unleaded gasoline was introduced in 1991, and a significant decrease in blood lead concentrations has been observed in the population of Mexico City. Today, the proportion of children estimated to have blood lead concentrations exceeding 10 μg/dl ranges between 30 and 50% (36). In adults, this proportion is somewhat higher. The use of lead-glazed ceramics by some groups to cook and store food may partially explain this observation.

For people occupationally exposed to lead, blood levels were higher—between 21.4 and 48.8 μg/dl and within a range of 41–104 μg/dl (37–40). However, data are insufficient to determine the magnitude of lead poisoning in this population.

*Legislation and control measures.* Finally, it is important to determine the government's perspective on the problem of lead exposure and to know if a given country is taking action to prevent or control such exposure. In 72% of the countries that answered the survey, government representatives identified lead as a public health problem. In 50%, existing legislation regulates lead contents in various environments, but enforcement of regulation is low, only 28%. In 44% of the countries, legal instruments exist to control lead exposure, and in 50% of the countries, some control measures have been applied.

**Discussion**

The information in this survey must be interpreted with some caution because of the lack of complete data from many coun-

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Figure 1. Geographic distribution of major lead mines and smelters across the Americas. From Rapine and Florin (9); reprinted with permission.


| Country          | Production 1984 | Production 1985 | Production 1987 | Production 1988 | Production 1992 | Production 1993 | Production 1994 | Production 1995 | NS |
|------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|----|
| Argentina        | -               | -               | -               | 32              | -               | -               | -               | 29.4            | -  |
| Export           | -               | -               | -               | 20              | -               | -               | -               | 0.2             | -  |
| Import           | -               | -               | -               | 0.4             | -               | -               | -               | 0.11            | NS |
| Bahamas          | -               | -               | -               | -               | -               | -               | -               | 18              | NS |
| Bolivia          | -               | -               | -               | 12.5            | 18.0            | -               | -               | -               | NS |
| Export           | -               | -               | -               | 9.9             | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | 15              | -               | -               | -               | -               | NS |
| Brazil           | -               | -               | -               | 14.3            | 7.5             | -               | -               | 24              | -  |
| Export           | -               | -               | -               | 2×10³           | -               | -               | -               | 0               | -  |
| Import           | -               | -               | -               | 79.9            | -               | -               | -               | 46.3            | -  |
| Canada           | -               | -               | -               | -               | -               | -               | -               | 342.5           | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Colombia         | -               | -               | -               | 31×10³          | 0.4             | 0.41            | -               | -               | -  |
| Export           | -               | -               | -               | 1.9             | 0.3             | 0.2             | -               | -               | -  |
| Import           | -               | -               | -               | 32              | 9.3             | 2.2             | -               | -               | -  |
| Cuba             | -               | -               | -               | 1.3             | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | 0.28            | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Dominican Republic | -             | -               | -               | 1.0             | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Ecuador          | -               | -               | -               | 0.2             | 0.2             | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Guadalupe        | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | 12×10³          | -               | -               | -               | -               | NS |
| Guatemala        | -               | -               | -               | 0.1             | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | 0.23            | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Honduras         | -               | -               | 21.2            | 11.2            | 0.8             | -               | -               | 0.25            | -  |
| Export           | 18.1            | -               | -               | -               | -               | -               | -               | -               | -  |
| Import           | 0.45            | -               | -               | -               | -               | -               | -               | 0.45            | -  |
| Jamaica          | -               | -               | 36×10³          | -               | -               | -               | -               | -               | NS |
| Export           | -               | -               | 3.4             | -               | -               | -               | -               | -               | NS |
| Martinique       | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Mexico           | -               | -               | -               | 171.3           | 174.0           | 153.5           | -               | -               | -  |
| Export           | -               | -               | -               | 136.5           | 120.0           | 15.9            | -               | -               | -  |
| Import           | -               | -               | -               | 2.9             | 3.9             | 0.2             | -               | -               | -  |
| Peru             | -               | -               | -               | 202.6           | 193.2           | -               | -               | 202             | -  |
| Export           | -               | -               | -               | 121             | -               | -               | -               | 188             | -  |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Surinam          | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Trinidad and Tobago | -              | -               | 1.6             | -               | -               | -               | -               | -               | 0.2 |
| United States    | -               | -               | -               | 0.44            | -               | -               | -               | 0.2             | -  |
| Import           | -               | -               | -               | 2.0             | -               | -               | -               | -               | NS |
| Uruguay          | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | 2.1             | -               | -               | -               | -               | NS |
| Venezuela        | -               | -               | -               | 18              | -               | -               | -               | -               | NS |
| Export           | -               | -               | -               | -               | -               | -               | -               | -               | NS |
| Import           | -               | -               | -               | -               | -               | -               | -               | -               | NS |

NS, not specified. Data from U.S. Department of the Interior (10,11) and Consejo de Recursos Minerales (12).
tries. In addition, there are few laboratories in LAC certified for blood and environmental lead measurements, which limits the evaluation of lead exposure in the region and the assessment of control programs. Nevertheless, the results presented suggest that lead poisoning is a significant problem in this region. Most of the governments are aware of this problem, but actions to confront it are limited. Based on this survey, 13 countries have at least begun to introduce unleaded gasoline; however, the use of unleaded gasoline is still very limited.

Lead poisoning is a preventable disease. During the 1994 Summit of the Presidents of the Americas, it was agreed that lead should be phased out of gasoline as an important step toward the prevention of lead intoxication. The results of this survey and literature search emphasize the need to implement the agreement of the summit in LAC. In most of the countries, some part of the population presents average blood lead concentrations that exceed the 10 μg/dl recommended by the Centers for Disease Control and Prevention (2). It is also important to note that toxic effects in children and adults have been observed at even lower concentrations (3). The population in the region live in urban zones, and this trend toward urbanization will probably continue into the future. This fact, coupled with the observation that 30% of the population of the region (over 110 million people) is under 15 years of age, signifies that a large proportion of the children in the region are and will continue to be subject to high levels of lead exposure from vehicular emissions.

Lead is still widely used as an anti-knock compound in gasoline, and other sources of lead exposure are also highly prevalent in the region. The two largest countries in Latin America, Brazil and Mexico, have implemented the use of unleaded gasoline, with an observed impact on environmental and blood lead levels. Brazil began the National Alcohol Program in 1975 to reduce its

### Table 2. Lead content in gasoline (g/liter) in Latin American and Caribbean countries

| Country                | 1980 | 1985 | 1990 | 1994 | 1980 | 1985 | 1990 | 1994 |
|------------------------|------|------|------|------|------|------|------|------|
| Argentina              | 0.20 | 0.20 | 0.20 | 0.20 | 0.001 | 0.001 | 0.001 | 0.001 |
| Bolivia                | 0.10 | 0.08 | 0 | 0 | NS | NS | UN | UN |
| Cochabamba             | 0.10 | 0.08 | 0.06 | NS | NS | UN | UN | UN |
| La Paz                 | 0.10 | 0.08 | 0.06 | 0.04 | NS | NS | UN | UN |
| Brazil                 | 0.08 | 0.08 | 0 | 0 | NS | NS | UN | UN |
| Sao Paulo              | 0.08 | 0.08 | 0 | 0 | NS | NS | UN | UN |
| Sao Caetano do Sul     | 0.08 | 0.08 | 0 | 0 | NS | NS | UN | UN |
| Chile                  | NS | NS | 0.80 | 0.34 | NS | 0.01 | 0.01 | NS |
| Colombia               | 0.05–0.29 | NS | NS | NS | NS | NS | NS | UN |
| Dominican Republic      | 0.37 | NS | 0.53 | 0.52 | NS | NS | NS | UN |
| El Salvador            | NS | NS | 0.13–0.24 | 0.13–0.24 | NS | NS | UN | UN |
| Guatemala              | 0.22 | 0.22 | 0.22 | NU | NS | NS | NS | UN |
| Mexico                 | 0.92 | NS | 0.13–0.26 | 0.20 | 0.05 | 0.003 | 0.003 | 0.003 |
| Nicaragua              | NS | NS | NS | 0.79 | NS | NS | NS | NS |
| Panama                 | 1.00 | 1.00 | 1.00 | 1.00 | NS | NS | NS | NS |
| Peru, October 1984     | 0.06 | 0.06 | 0.06 | 0.06 | NS | NS | NS | UN |
| October 1995           | 0.14 | 0.14 | 0.14 | 0.14 | NS | NS | NS | UN |
| Surinam                | NS | NS | NS | 1.32 | NS | NS | NS | NS |
| Trinidad and Tobago    | NS | NS | NS | 0.55 | NS | NS | NS | NS |
| Uruguay                | NS | NS | NS | 85 Special: 0.09 | NS | NS | NS | UN |

| Country                | 0.05–0.29 | NS | NS | NS | NS |

**Abbreviations:** NS, not specified; UN, unleaded gasoline is used but the contents are unknown; NU, not used.

### Table 3. Monitoring of airborne lead (μg/m³) in Latin American countries

| Country               | 1980 | 1985 | 1990 | 1994 |
|-----------------------|------|------|------|------|
| Bolivia               | NS | NS | NS | NS |
| Brazil                | Annual average | 1.11 | 0.39 | 0.27 | NS |
| Sao Paulo             | NS | NS | 1.1 | NS |
| Ossasco               | NS | 0.16 | 0.18 | NS |
| Sao Caetano do Sul    | 1.16 | 0.31 | 0.41 | NS |
| Colombia              | Annual average | 1.3 | 3.0 | NS |
| Colombia (Bogota)     | Annual average | 1.9 | 0.27 | NS |
| Colombia (Medellin)   | Annual average | NS | NS | NS |
| Guatemala             | Annual average | NS | NS | NS | 0.17 |
| Honduras              | Annual average | NS | NS | NS | 1.83 |
| Mexico                | Annual average | NS | NS | NS | 1.11 |
| Mexico (3-month average) | 0.34–0.24 | 1.08–1.47 | 0.24–0.37 |
| Peru                  | Annual average | 1.9 | 2.2 | 2.1 |
| Peru (3-month average) | 1.8 | 1.9 | NS | NS |
| Venezuela             | Annual average | 1.7 | 1.5 | 1.6 | 1.7 |
| Caracas (El Silencio) | 4.5 | 2.6 | 1.9 | 1.6 |
| Maracaibo (Los Hatillos) | NS | NS | 1.2 | 1.1 |
| Puerto La Cruz        | 1.0 | 1.1 | 1.3 | 0.9 |

**Abbreviations:** NS, not specified.

*1982.
*1986.
*1990.
*1992.
dependence on oil (47). Since then, atmospheric lead in urban areas decreased by approximately 72–82%. For example, in a zone located in São Paulo with high vehicular traffic density, the lead concentration diminished from an annual average of 1.16 to 0.43 μg/m³ between 1978 and 1983. In 1990, Mexico introduced a program to minimize potential sources of lead exposure. In the Mexico City metropolitan area, air has been continuously monitored since 1986 and there has been a drastic reduction in the air lead concentrations, from an annual average of 1.95 μg/m³ in 1988 to 0.28 μg/m³ in 1994. Similarly, a reduction of blood lead concentrations has been observed in Mexico City residents (36,42–44). In general, residents in areas of intense vehicular traffic have blood lead levels much higher than populations exposed to less vehicular traffic (45). Continued attention should therefore be given to reducing the lead content of gasoline because this will markedly reduce lead exposure for a significant proportion of the LAC population.

In order to evaluate the impact of phasing out lead gasoline on the blood lead levels in high risk populations (particularly in children and women of reproductive age), it would be useful to develop and implement a standardized surveillance system in different countries. In Mexico, such a system has been established and the decrement of blood lead levels in a randomly selected sentinel population was observed in relation to the decrement in atmospheric lead as low-lead and unleaded gasoline was introduced (36). The phasing out of lead gasoline has clearly shown a positive benefit with respect to cost (46). A similar evaluation conducted in Mexico has also provided evidence of such economical benefits (43). Although leaded gasoline is a major source of lead exposure in many countries, it is important to remember that there are other important sources of exposure, such as industrial use (including paint, varnishes, and batteries) and contamination of food and water. However, there are few data on the effects of these other uses have on population lead exposure. Broad-based coalitions are needed between policy makers, industry, workers, unions, health care providers, and the community in order to implement actions to reduce environmental and occupational lead exposure and to prevent lead poisoning in all the countries of the Americas (47).

REFERENCES

1. Grant LD, Davis JM. Effects of low-level lead exposure on pediatric neurobehavioral and physical development: current findings and future directions. In: Lead exposure and child development: an international assessment (Smith M, Grant LD, Sors A, eds). Lancaster, UK: MTP Press, 1990; 49–115.

2. CDC. Preventing lead poisoning in young children. A statement by the Centers for Disease Control. Atlanta, GA: Centers for Disease Control and Prevention, 1991.

3. ATSDR. Lead. TP-92/12. Atlanta, GA: Agency for Toxic Substances and Disease Registry, 1993.

4. U.S. Department of the Interior, Bureau of Mines. Minerals yearbook 1992, vol III. Minerals in the world economy. International review. Washington, DC: U.S. Government Printing Office, 1994.

5. Corey G, Galvao LAC. Plomo. Meteper. Edo. Mexico, Mexico: Centro Panamericano de Ecologia Humana y Salud ECOHEP/OPS/OMS, Serie Vigilancia no. 8, 1989.

6. Albert L, Badillo F. Environmental lead in Mexico. Rev Environ Contam Toxicol 117:1–49 (1991).

7. Hernández-Augilera M, Romieu I, Rios C, Rivero A, Palazuelos E. Lead-glazed ceramics as major determinants of blood lead levels in Mexican women. Environ Health Perspect 94:117–120 (1991).

8. Marte TD, Figueras JP, Ostrowski S, Burr G, Jackson-Hunt L, Keenslyside RA, Baker EL. Lead poisoning among household members exposed to lead-acid battery repair shops in Kingston, Jamaica. Int J Epidemiol 14:874–881 (1989).

9. Rapine M, Florin K, eds. The global dimensions of lead poisoning. Washington, DC: Alliance to End Childhood Lead Poisoning and Environmental Defense Fund, 1994.

10. U.S. Department of the Interior, Bureau of Mines. Minerals yearbook 1988. Metals and minerals. Washington, DC: U.S. Government Printing Office, 1990.

11. U.S. Department of the Interior, Bureau of Mines. Minerals yearbook 1992. Metals and minerals. Washington, DC: U.S. Government Printing Office, 1994.

12. Consejo de Recursos Minerales. Secretaría de Energía, Minas e Industria Paraestatal. Subsecretaría de Minas. México City: Anuario Estadístico de la Minería Mexicana, 1993.

13. Frenz P, Vega J, Marchetti N, Torres J, Rojas L, Kopplin E, Vega F, Delgado I. Seguimiento infantil: ambiental lead exposure in Chilean infants. 6th Conference of ISEE, September 1994, Research Triangle Park, NC, USA.

14. Tirlone CE, Veiga de Campos MA, Junqueira-Aguilar LS. Diagnóstico preliminar de la contaminación ambiental por chumbo en niños de la Tonolli del Brasil S.A. Indústria e Comércio de metais-Jacarei-S.P. Brazil: CETESB, 1994.

15. Ramos de Queiroz I, Munhoz Guido AM, Ferreira N, Kimo R, Machado de Campo AG, Cassia Mendes de Barros N, Queiroz Rocha B, Brito R. Avaliação Toxicológica da qualidade da água distribuída à população do Estado de São Paulo-Janeiro. Brazil: CETESB, 1994.

16. Romieu I, Carreon T, Lopez L. Environmental urban lead exposure and blood lead levels in children of Mexico City. Environ Health Perspectives.
| Country          | Sample type                | Locality             | Level       | Laboratory method | Laboratory certificate | Year |
|-----------------|----------------------------|----------------------|-------------|-------------------|------------------------|------|
| Argentina       | Cultivated vegetables (leaves) | Buenos Aires         | 0.35 ppm   | AAS               | NS                     | 1975 |
|                 |                            | Santiago del Estero  | 2 ppm   | AAS               | NS                     | 1975 |
|                 | Soil                       | Buenos Aires         | 6–12 ppm   | AAS               | NS                     | 1975 |
|                 |                            | Santiago del Estero  | 6–12 ppm   | AAS               | NS                     | 1975 |
| Bolivia         | Air                        | La Paz               | 1.11 µg/mL | Selection         | NS                     | NS   |
|                 | Smoke                      | Santa Cruz           | 0.003 mg/m³ | AAS               | NS                     | NS   |
|                 | Smoke and fumes            | Santa Cruz           | <0.15 mg/m³ | AAS               | NS                     | NS   |
|                 | Dust and smoke             | Oruro                | <0.15 mg/m³ | AAS               | NS                     | NS   |
| Brazil          | Water                      | Ribeira de Iguape River | <20–70 µg/l | AAS               | NS                     | 1994 |
|                 | Sediment                   | Ribeira de Iguape River | 3–4 µg/g | AAS               | NS                     | 1994 |
|                 | Fish (muscle)              | Ribeira de Iguape River | <0.03–12 µg/g | AAS               | NS                     | 1994 |
|                 | Fish (guts)                | Ribeira de Iguape River | <0.06–161 µg/g | AAS               | NS                     | 1994 |
|                 | Aquatic macrophytes        | Ribeira de Iguape River | <10–1,000 µg/g | AAS               | NS                     | 1994 |
|                 | Soil                       | Jacareí-SP           | 51–338 ppm | NS                | NS                     | 1994 |
|                 | Plants                     | Jacareí-SP           | 14–129 ppm | NS                | NS                     | 1994 |
|                 | Sediment                   | Jacareí-SP           | 10–9,100 ppm | NS                | NS                     | 1994 |
|                 | Water                      | Estado de São Paulo  | 0.0028 ppm | AAS               | NS                     | 1994 |
| Chile           | Vegetables                 | Temuco Bay           | 20 ppm*    | AAS               | NS                     | NS   |
|                 | Air at work                | Temuco Refinery      | 0.23 mg/m³ | AAS               | NS                     | NS   |
|                 | Sedimented dust            | Temuco                  | 200 g/kg | AAS               | NS                     | NS   |
|                 | Sedimented dust            | Houses                 | 0.39 g/kg | AAS               | NS                     | NS   |
|                 | Canned shellfish           | South of the country  | 0.98 ppm  | NS                | NS                     | NS   |
| Colombia        | Water                      | Magdalena River      | 26–38 ppm  | AAS               | NS                     | 1994 |
|                 | Water                      | Cuauca River          | 0.0025 mg/l | AAS               | NS                     | 1988 |
|                 | Water                      | Nechi River           | 0.0023 mg/l | AAS               | NS                     | 1988 |
| Dominican Republic | Water                | Santo Domingo         | 0.08 mg/g | Photometric       | NS                     | NS   |
| Guatemala       | Air                        | Capital               | 0.18 µg/m³ | GC                | NS                     | NS   |
|                 | Fish (filet)               | Lago Yojoa            | 0.30 mg/kg | AAS               | NS                     | NS   |
|                 | Ceramics                   | Tegucigalpa           | 0.12–38.6 mg/l | AAS             | NS                     | NS   |
| Honduras        | Air                        | Tegucigalpa           | 1.11 µg/m³ | AAS               | NS                     | NS   |
|                 | Sediment                   | Lago Yojoa            | 371 mg/kg | AAS               | NS                     | NS   |
|                 | Fish (filet)               | Lago Yojoa            | 0.30 mg/kg | AAS               | NS                     | NS   |
|                 | Floor                      | Mexico, D.F.         | 0.03 µg/cm² (SD = 0.08) | Y               | 1995                  |
|                 | Carpet dust                | Mexico, D.F.         | 0.06 µg/cm² (SD = 0.007) | Y               | 1995                  |
|                 | Furniture dust             | Mexico, D.F.         | 0.009 µg/cm² (SD = 0.003) | Y               | 1995                  |
|                 | Window dust                | Mexico, D.F.         | 0.11 µg/cm² (SD = 0.19) | Y               | 1995                  |
|                 | Street dust                | Mexico, D.F.         | 205.6 ppm (SD = 182.1) | Y               | 1995                  |
|                 | Floor                      | Mexico, D.F.         | 117.2 ppm (SD = 305.2) | Y               | 1995                  |
|                 | Water                      | Mexico, D.F.         | 0.004 ppm (SD = 0.003) | Y               | 1995                  |
|                 | Air (24-hr average)        | Mexico, D.F.         | 0.54 µg/m³ (SD = 0.59) | Y               | 1995                  |
|                 | Sardines                   | Mexico, D.F.         | 0.00–0.05 ppm   | AAS             | NS                     | 1989 |
|                 | Tuna                       | Mexico, D.F.         | 0.00–1.25 ppm  | AAS             | NS                     | 1989 |
|                 | Jalapeño chili             | Mexico, D.F.         | 0.13–2.35 ppm  | AAS             | NS                     | 1989 |
|                 | Chipotle chili             | Mexico, D.F.         | 1.10–2.08 ppm  | AAS             | NS                     | 1989 |
|                 | Fried beans (brown)        | Mexico, D.F.         | 0.27–1.52 ppm  | AAS             | NS                     | 1989 |
|                 | Fried beans (black)        | Mexico, D.F.         | 0.41–0.83 ppm  | AAS             | NS                     | 1989 |
|                 | Canned pineapple           | Mexico, D.F.         | 0.00–2.08 ppm  | AAS             | NS                     | 1989 |
|                 | Canned peaches             | Mexico, D.F.         | 0.83–3.38 ppm  | AAS             | NS                     | 1989 |
|                 | Vegetable salad            | Mexico, D.F.         | 0.00–1.24 ppm  | AAS             | NS                     | 1989 |
| Peru            | Air                        | Lima                 | 1.5–2.0 µg/m³* | AAS             | NS                     | NS   |
| Trinidad and Tobago | Iodized salt          | Imported              | 6.4 ppm*    | NS                | NS                     | NS   |
|                 | Road dust                  | Port of Spain        | 571–4,775 ppm* | AAS             | NS                     | NS   |
|                 | Road dust                  | Tunapuna             | 646–2,082 ppm* | AAS             | NS                     | NS   |
| Uruguay         | Sediment                   | Montevideo           | 20–160 ppm  | XRF              | NS                     | NS   |
|                 | Water                      | Montevideo Bay       | 0.3–6 ppm   | AAS               | NS                     | 1986 |
|                 | Water                      | Ao. Miguelete (MUD)  | 0.35–0.4 ppm  | AAS               | NS                     | 1986 |
|                 | Water                      | Ao. Manga (MUD)      | 0.2–0.4 ppm  | AAS               | NS                     | 1986 |
|                 | Water                      | Ao. Pantanoso (MUD)  | 0.35–0.9 ppm  | AAS               | NS                     | 1986 |
|                 | Bivalve shellfish          | Seashore             | 6–32 ppm*    | XRF              | NS                     | 1992 |
| Venezuela       | Filtered particles         | Caracas (El Silencio) | 1.6 µg/m³  | AAS               | NS                     | NS   |
|                 | Filtered particles         | Caracas (Bello Campo) | 0.8 µg/m³  | AAS               | NS                     | NS   |
|                 | Filtered particles         | San Cristobal        | 1.5 µg/m³   | AAS               | NS                     | NS   |
|                 | Filtered particles         | Maracaibo            | 1.1 µg/m³   | AAS               | NS                     | NS   |
|                 | Filtered particles         | Puerto La Cruz       | 0.9 µg/m³   | AAS               | NS                     | NS   |

Abbreviations: AAS, atomic absorption spectrophotometry; GC, gas chromatography; Y, yes; SD, standard deviation; XRF, X-ray fluorescence.

*Samples exceeding specific norms for lead content.
### Table 5. Blood lead levels in several population groups in Latin American and Caribbean Countries

| Country            | Population | Place   | Number | Age (years) | Average | Range     | >10 μg/dL (%) | Laboratory method | Laboratory certificate | Year of study |
|--------------------|------------|---------|--------|-------------|---------|-----------|---------------|-------------------|-----------------------|---------------|
| Argentina          | Children   | Urban   | 229    | 6–12        | 18.4 ± 8.6 | NS        | NS            | NS                | AAS                   | N             | 1986          |
| Brazil             | Children   | Urban   | 125    | 5–15        | 22.1 ± 7.5 | 7–42      | NS            | NS                | AAS                   | N             | 1989          |
|                    | Adults     | Urban   | 156    | 15–49       | 11.8 ± 5.2 | 2.8–27.2  | NS            | NS                | AAS                   | NS            | 1989          |
|                    | Adults     | Fixed source | 71    | 15–63       | 27.2 ± 5.7 | 9.2–42    | NS            | NS                | AAS                   | N             | 1983          |
|                    | Children   | Urban   | 199    | 4–5         | 9.5 ± 4.6  | 0.6–35.7  | NS            | NS                | AAS                   | N             | 1984          |
|                    | Adults     | Urban   | 8      | 2–7         | 39.0 ± 5.0 | 34–45     | 100           | 100               | AAS                   | Y             | 1984          |
|                    | Children   | Urban   | 202    | 12 months   | 5.3 ± 1.7  | 0.5–19    | NS            | NS                | AAS                   | Y             | 1994          |
| Ecuador            | Children   | Urban   | 64     | 7           | 28.8      | 17–54     | 100           | AAS                | AAS                   | NS            | 1994          |
|                    | Children   | Urban   | 27     | Newborn     | 14.4      | 6–20      | 60            | 60                | AAS                   | NS            | 1994          |
|                    | Adults     | Urban   | 83     | Pregnant    | 18.4      | NS        | 60            | 60                | AAS                   | NS            | 1994          |
| Mexico             | Children   | Urban   | 200    | 0–5         | 9.0 ± 5.8  | 1–31      | 27.8          | 27.8              | AAS                   | Y             | 1995          |
|                    | Adults     | Urban   | 200    | 15–55       | 9.7 ± 6.2  | 1–39      | 36.8          | 36.8              | AAS                   | Y             | 1995          |
|                    | Adults     | Fixed source | 2,023 | 13–46       | 11.2      | 5–66.2    | 47            | 47                | AAS                   | Y             | 1995          |
|                    | Adults     | Rural   | 92     | 15–62       | 12 ± 7.2  | 1.6–39    | 50            | 50                | AAS                   | Y             | 1994          |
| Uruguay            | Children   | Urban   | 48     | 2–14        | 9.5       | 1–31      | NS            | NS                | NS                    | NS            | 1994          |
|                    | Adults     | Rural   | 50     | 1–6         | 11.5 ± 3.7 | 8.3–53.6  | 45            | 45                | AAS                   | Y             | 1991          |
| Nicaragua          | Children   | Fixed source | 94    | 1–6         | 11 ± 3.7  | 8.3–53.6  | 45            | 45                | AAS                   | Y             | 1991          |
|                    | Adults     | Urban   | 19     | Newborn     | 3.4 ± 1.5 | 0–8.7    | 0             | 0                 | AAS                   | Y             | 1997          |
|                    | Children   | Battery recycling | 20 | 3 months–19 years | 72 ± 10 | 20–235 | 100           | AAS                | Y             | 1990          |

Abbreviations: NS, not specified; AAS, atomic absorption spectrophotometry; N, no; Y, yes.
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Environ Health Perspect 102:384–389 (1994).
45. Romieu I, Palazuelos E, Meneses F, Hernández M. Vehicular traffic as a determinant of blood-lead levels in children: a pilot study in Mexico City. Arch Environ Health 47(4):246–249 (1992).

46. U.S. EPA. Cost and benefits of reducing lead in gasoline. Final regulatory impact analysis. Washington, DC: Environmental Protection Agency, 1985.

47. Institute of Medicine, USA, and National Institute of Public Health, Mexico. Lead in the Americas: a call for action (Howson CP, Hernández-Avila M, Rall DP, eds). Cuernavaca, Mor., Mexico: Instituto Nacional de Salud Publica, 1996.

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