Bridging Refugee Youth & Children's Services

This document is provided by the BRYCS Clearinghouse.

International Environmental Health for the Pediatrician: Case Study of Lead Poisoning

By Henry Falk

Reproduced with permission of American Association of Pediatrics

Elk Grove Village, IL

© 2003

BRYCS is a project of the United States Conference of Catholic Bishops/Migration and Refugee Services (USCCB/MRS)
1-888-572-6500/ info@brycs.org/ www.brycs.org

International Environmental Health for the Pediatrician: Case Study of Lead Poisoning

Henry Falk, MD, MPH

ABSTRACT. Childhood lead poisoning is a preventable illness. In the past 3 decades, removal of key lead sources and prevention of exposure in the United States have led to dramatic decreases in population blood lead concentrations and also in instances of severe lead poisoning requiring treatment. From an international perspective, childhood lead poisoning seems to be of greatest concern in developing countries. The phasing out of lead from gasoline is a critical first step in decreasing worldwide blood lead concentrations. However, many focal sources that can cause lead poisoning remain, such as lead from flour mills, lead-glazed ceramics, mining and smelting, and battery repair and recycling. A large and diverse country, such as India, may have many sources of lead. The challenge will be for developing countries to implement effective national and regional efforts to address their specific sources of lead. ***Pediatrics*** **2003;112:259–264;** ***international, environmental health, lead poisoning, child, developing nations.***

ABBREVIATIONS. DHHS, US Department of Health and Human Services; CDC, Centers for Disease Control and Prevention.

During the past decade, attention to children's environmental health issues has sharply increased, starting with the 1989 United Nations Convention on the Rights of the Child and culminating in a series of declarations and resolutions by international bodies in the past several years.[1] Most documents use a very broad definition of the environment and look at global forces and trends that can have an impact on children. This article focuses on a classic pediatric environmental illness—childhood lead poisoning—and after a brief overview of its current status in the United States explores newly emerging information on its international appearance. Although the clinical manifestations of childhood lead poisoning may not vary much worldwide, the sources of exposure, incidence, trends, control measures, treatment options, and preventive approaches vary strikingly, especially in developing countries, compared with the United States.

From the Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services, Atlanta, Georgia.
Received for publication Jul 26, 2002; accepted Jan 17, 2003.
Reprint requests to (H.F.) Agency for Toxic Substances and Disease Registry, US Department of Health and Human Services, 1600 Clifton Rd NE, MS E-28, Atlanta, GA 30341. E-mail: hxf1@cdc.gov
PEDIATRICS (ISSN 0031 4005). Copyright © 2003 by the American Academy of Pediatrics.

UNITED STATES

Extensive efforts to control childhood lead poisoning began in the late 1960s, with the growing awareness of the magnitude of the risk in large, urban areas with concentrated housing that contained lead-based paint; pediatric lead poisoning was a common reason for hospital admission in many inner-city pediatric wards. For example, mean blood lead concentrations among high-risk minority children screened in New York City in 1971 were >30 μg/dL in the most vulnerable age groups. The US Department of Health and Human Services (DHHS) has focused its efforts on public health programs, such as the screening and follow-up of high-risk children (led by the Centers for Disease Control and Prevention [CDC]), and health research to elucidate the relationship between blood lead concentrations and health effects (led by the National Institute of Environmental Health Sciences). The US Environmental Protection Agency has orchestrated the decrease in environmental sources, such as the removal of lead from gasoline, and the Department of Housing and Urban Development has developed programs to decrease lead paint in housing. As a consequence, blood lead concentrations diminished dramatically from the second (1976–1980) to the third (1989–1994) National Health and Nutrition Examination Survey; the percentage of children 1 to 5 years of age with blood lead concentrations >10 μg/dL decreased in this period from 88% to 4.4%, primarily reflecting the removal of lead from gasoline and other national efforts to prevent exposure.[2–4] Recent data compiled by the CDC show a continuing decrease in blood lead concentrations in high-risk children screened by state programs in 1997–1998, which probably reflects the continuing benefits from targeted screening of high-risk groups and increasing efforts by the Department of Housing and Urban Development to prevent exposure to lead from high-risk housing. Although some of the decrease is attributable to turnover of housing stock (old housing demolished, new housing built), targeted remediation of lead sources in existing homes must also be beneficial. These trends in the decreased rate of lead poisoning are consistent with the 1991 DHHS strategic plan for the elimination of childhood lead poisoning by the year 2011.[5] Achievement of this goal undoubtedly will require continued vigilance and creative approaches to the continued remediation of older housing that contains decaying, lead-based paint, particularly in inner-city urban areas with large concentrations of minority populations. Many groups, especially the

American Academy of Pediatrics, through its leadership and ongoing guidance to pediatricians,[6] and the Agency for Toxic Substances and Disease Registry, as a result of its very influential 1988 report to Congress,[7] have contributed greatly to the remarkable success of the childhood lead poisoning prevention program.

INTERNATIONAL ISSUES

In the developing world, which is the main focus of this article, exposure sources are often very different from those in the United States and vary dramatically from country to country.[8] Limited economic conditions and poverty have a strong impact on environmental exposures, health care delivery, and the potential for environmental protection. Also, many factors enhance or magnify the impact of lead exposures (Table 1); for example, industrial sites are often located in residential areas, warm climates contribute to full-year exposures to outdoor environments, and poor nutritional status magnifies the effects of lead exposure.

From a public health perspective, laboratory capacity for measuring blood lead (or even environmental lead) concentrations is very limited; consequently, almost no data exist in many countries on blood lead concentrations. In addition, health care systems usually have limited ability to deal with toxic chemical exposures, such as lead poisoning, and chelating agents are often unavailable or markedly limited to treat severe poisoning.

From the perspective of environmental protection, similar deficiencies are strikingly apparent, such as lack of monitoring instruments, poor engineering controls, absent or ineffective regulations (which, even when present, are often inadequately implemented), and limited funding for new programs. Furthermore, efforts to screen and treat children for lead poisoning will be ineffective if the child continues to live in or returns to the same high-lead environment; health benefits depend on decreased exposures.

A significant recent advance has been the development of a hand-held, low-cost, rapid instrument for measuring blood lead concentrations from capillary blood samples, which can be used for on-the-spot results in field studies. This has opened the way in the last several years to a surge in blood lead measurements in developing countries that is revealing many previously unidentified problems with significant public health impact.

TABLE 1. Developing World—Risk Factors for Lead Toxicity

Exposure
Multiple sources: differ from those in the United States
Industrial sites located in or near residential areas
Hot climates; more intense exposure to outdoor environments
Child labor
Inadequate environmental monitoring capacity and data
Inadequate tracking of lead use and consumption
Health
Poor nutrition enhances lead toxicity
Limited knowledge of toxic chemicals among caregivers
Laboratory monitoring capacity inadequate; lack of equipment and training
Absence or incomplete disease surveillance
Drug treatment (chelating agents) often unavailable
Prevention
Lack of protective or safety equipment or technology
Poor industrial engineering controls
Limited safety and hygiene programs
Absent or inappropriate regulations
Uneven implementation of standards and regulations
Rare or infrequent inspections or enforcement
Slow or incomplete adoption of new measures

International Sources: Leaded Gasoline

On the basis of the US experience, the global reduction and eventual elimination of leaded gasoline seems to be the most certain and direct route to preventing childhood lead poisoning, especially when one considers the more limited use of lead-based paint in most of the developing world. As a result, international health agencies (eg, the World Health Organization), national governments (eg, India), and major donor organizations (eg, the World Bank, US Agency for International Development) have focused on the phasing out of lead from gasoline.[9] In developing world urban centers, the impact of leaded gasoline may be amplified by a variety of factors, including high population density near roads, poor-quality automobiles, hot climates, and dusty conditions, all of which contribute to increased exposure. Numerous studies document high blood lead concentrations in large international cities, and some studies have shown sharply decreased levels after initiating the phasing out of leaded gasoline (eg, Bangkok, Mexico City).[10–13] The reduction of leaded gasoline use has been proceeding unevenly but inexorably during the past decade. Most significant, this effective and feasible approach has proved economically viable, although often only with supplemental funding from donor organizations.

International Lead Poisoning: Other Major Sources

Recent studies, augmented by the use of the hand-held, portable blood lead analyzers, have shown that the phasing out of leaded gasoline is a dramatic and significant step but is insufficient by itself to eradicate severe childhood lead poisoning. As in the United States, numerous focal sources and regional practices can lead to widespread and severe childhood lead poisoning in specific populations (Table 2). Exposure pathways vary considerably: some are from ingestion of contaminated foods and medications, and many are from environmental (particularly soil) contamination affecting children who live near (or may even work in) local industries.

The specific sources in each country depend on

TABLE 2. Childhood Lead Poisoning—Major Sources

United States
Lead paint
Worldwide
Lead gasoline
Lead-glazed ceramics
Mining and smelting
Battery repair and recycling
Cottage industries
Flour mills
Medication and cosmetics
Consumer products
Other

dietary, consumer, industrial, and other practices that vary among countries and regions; some main sources were not even anticipated, because they were rare or absent in the United States and other developed nations. The following examples illustrate the potential impact of focal lead sources in a number of countries.

Flour Mills

A 1966 outbreak of symptomatic lead poisoning in Aswan, Egypt, was investigated by health authorities with assistance from the CDC. Mean blood lead concentrations among hospitalized patients ($n = 17$) exceeded 90 μg/dL; mean blood concentrations among household members, many of whom were also symptomatic, were close to 80 μg/dL. Lead concentrations in soil, dust, water, and paint were negative, and in this rural setting, industrial and gasoline sources were not significant. However, lead levels in flour were high, and consumption of flour was closely correlated with the onset of illness.

Rural Egypt has thousands of local flour mills, with 1 or more for each village. During the harvest season, families bring their wheat to be milled, and the flour is their diet staple for the next several months.

Molten lead (because it is effective, available, inexpensive, and easy to work with) is used frequently to attach the upper grinding stone to the iron bar connected to the axle that rotates the grinding stone (Figs 1 and 2). As the grinding surface wears down from repeated use, the lead is unevenly deposited in the flour; low-level contamination probably occurs frequently, punctuated by episodes of very high contamination. In addition, molten lead may be used to fill in cracks in the grinding stone or to balance the grinding stone, and some of this lead will also eventually be ground into the flour.

Outbreaks of lead poisoning have been reported elsewhere in the Middle East,[14] and cases have been reported in other regions, such as the Balkans and South America. Tens of thousands of such flour mills may operate in a number of countries stretching from Croatia to India. Preventive actions after outbreaks have been taken in Egypt and other countries to provide for improved maintenance of the flour mills and the attachment and balancing of grinding stones without the use of molten lead. In the Aswan outbreak, the removal of lead-contaminated flour resulted in a sharp decrease in blood lead concentrations among affected individuals. Clearly, however, the widespread use of rural flour mills in many developing countries still presents a potential threat for severe lead poisoning.

Ceramics

Lead glazing of ceramics to produce higher quality materials and the use of lead-glazed ceramics for food storage and cooking is a focal or regional source, especially in parts of Latin America, that can result in frequent and occasionally very high increases in blood lead concentrations. Counter et al[15] recently reported on blood lead concentrations in children from the village of La Victoria, Ecuador, where the production and lead glazing of ceramics is the primary occupation. Lead is extracted from discarded automobile batteries and used in a glaze primarily for the production of roof tiles. Children live, play, and eat near the lead-glazing kilns, and many assist their families in the production process. The mean blood lead concentration in 166 children 4 months to 15 years of age was 40.0 μg/dL; the highest was 119 μg/dL (mean blood lead concentration for 56 children in a reference area was 6.6 μg/dL, with a high of 18 μg/dL).

Although the above numbers represent a particularly striking but very localized instance of toxicity from lead glaze, the use of ceramic vessels for food

Fig 1. Construction of flour mill grinding stone in Egyptian village.

Fig 2. Upper grinding stone turned over, showing molten lead (see pen pointer) used to attach stone to iron bar that is turned by axle/diesel motor.

preparation and storage is widespread in Mexico, with an estimated 5000 kilns in the country producing such vessels. A number of reports have demonstrated increased blood lead concentrations in users of such ceramic vessels; the degree of increase has been correlated with specific foods as well as cooking and food storage practices.[11,16–18]

Matte et al[19] reported a striking incident at the US Embassy in Mexico, when a child who drank leftover fruit punch from the official lead-glazed punch bowl used at a party developed a blood lead concentration of 92 μg/dL; it was estimated that each individual glass of punch raised the blood lead concentrations in individuals at the party by 6 μg/dL when measured 6 weeks after exposure (presumably, the acute increase in blood lead concentration was even greater).

Battery Repair and Recycling

Lead poisoning in children who live near backyard smelters or even work in small-scale battery recycling operations has been reported in many parts of the world. Matte et al[20] described such a situation in Jamaica in 1989, emphasizing the proximity of such operations to residential areas, the ready access of children to the work area and to lead-containing wastes, and the frequency and ease of exposure in a year-round hot climate enhancing outdoor exposures.

Two recent reports highlight the potential severity of such exposures. Suplido and Ong[21] studied lead exposure among small-scale battery recyclers and automobile radiator mechanics and their children in Manila, Philippines. Notably, the 10 battery recyclers studied were small shops that did repairs and separations of batteries; only 1 performed smelting on site. Mean blood lead concentrations were higher for battery workers (54 μg/dL) than for radiator workers (20 μg/dL) or unexposed adults (13 μg/dL). Children (n = 10) near the battery shops also had the highest blood levels, with a mean blood lead concentration of 50 μg/dL; children near radiator shops had a mean concentration of 12 μg/dL; and unexposed children had a mean concentration of just under 10 μg/dL. Homes were situated in the immediate vicinity of the shops, at times sharing a single entrance, and children clearly played and spent considerable time within the workplace itself. It seems that lead dust generated from the disassembly of batteries and the storage of battery parts can cause significant elevation of blood lead concentration.

Kaul et al[22,23] studied children near an auto battery recycling plant in Haina, Dominican Republic. When the plant closed in March 1997, 116 children were surveyed, and again in August 1997, 146 children were surveyed. Mean blood lead concentrations were 71 μg/dL (range: 9–234 μg/dL) in March and 32 μg/dL (range: 6–130 μg/dL) in August. Although secondary smelting of batteries was stopped at the time of the first survey, considerable waste materials remained; smelted lead dust is finer and more readily absorbed than mined or unsmelted lead dust. Similar exposures have been reported elsewhere.[24,25]

Mining and Smelting of Lead

The CDC[26] and Landrigan et al,[27,28] in their studies at Kellogg, Idaho, and El Paso, Texas, demonstrated very high blood lead concentrations in children who resided near lead smelters. The potential for such high exposures when emission controls and preventive measures are not fully implemented has been amply demonstrated in many parts of the developing world. Even exposure to mined ore dust, which is less readily bioavailable than is smelted dust, may lead to very high exposures and blood lead concentrations in children. A recent investigation in the Lima, Peru,[29] area has shown mean blood lead concentrations of approximately 25 μg/dL in children who live in Callao near the port area (and highest concentrations for those closest to the port). The high-risk community has an ore storage site on 1 side, a road for truck transport on the second side, and a site for loading ore onto ships on the third side. All are potential sources of significant lead dust exposure. Compounding the problem in this port community are a dry climate with minimal rainfall, unpaved streets and alleys, and mud floors and unsealed roofs in homes, all of which facilitate the dissemination of lead dust. In addition, poverty and malnutrition contribute to extreme forms of pica behavior and excess intake and absorption of lead from nonfood items. Finally, the unavailability of chelating agents for children with high concentrations of lead in blood precludes treatment even of highly intoxicated children. There are undoubtedly many other parts of the developing world where mining and smelting have been or continue to be significant sources of lead exposure.[30,31]

INDIA

In February 1999, a conference on lead poisoning prevention and treatment was held in India, jointly sponsored by the George Foundation, The World Bank, the CDC, the Environmental Protection Agency, and the World Health Organization.[32] The purpose of the conference was to review the status of lead poisoning in India and then develop the outline of a proposed national program for preventing lead poisoning in India and, by extension, in other developing countries. The conference succeeded in reporting efforts at measuring lead exposures in a large and diverse population, such as India, including environmental measurements as well as initial efforts at blood lead screenings.

The largest blood lead screening survey was called Project Lead-Free: A Study of Lead Poisoning in Major Indian Cities.[33] Although not a formal study of a representative population, >21 000 blood lead concentrations were measured (approximately two thirds from children younger than 12 years), providing some perspective on blood lead in major Indian cities.

Of children tested initially with blood lead rather than screened by hematofluorometer, >50% younger than 12 years had blood lead concentrations ≥10 μg/dL; in New Delhi and Calcutta, almost 20% had blood lead concentrations ≥20 μg/dL (Table 3). Data presented in discussions at the conference showed much higher levels in local areas. For example, 1 survey in New Delhi noted that ~15% of children had blood concentrations >70 μg/dL, with no certainty about the key source of exposure. Recent published reports also highlight high concentrations in discrete areas of the country related to local practices and exposure.[34–36]

There were several reports at the conference regarding the multiple sources of exposure,[37,38] and a white paper was developed by the conference executive committee on needed actions for decreasing blood lead concentrations.

India represents a large population with multiple sources of lead and increased blood lead concentrations widely distributed among children, with many focal areas of particularly high exposures. Although the phasing out of lead from gasoline will be critical,[39] undoubtedly many other sources of exposure will need to be addressed (Table 4).

CONCLUSIONS

Childhood lead poisoning is a preventable environmental illness. In the past 3 decades, removal of key lead sources and prevention of exposure in the United States have led to dramatic decreases in population blood lead concentrations and also in instances of severe lead poisoning requiring clinical treatment. With the removal of widespread sources, such as lead in gasoline, focal sources—particularly lead paint in older housing—dominate. With increasing attention to remediating lead in high-risk housing and to more effective screening of children in high-risk areas, the DHHS hopes to meet its strategic goal of eliminating childhood lead poisoning in the United States by the year 2011.

From an international perspective, childhood lead poisoning seems to be of greatest concern in developing countries. During the past decade, attention has been most heavily focused on the phasing out of lead from gasoline, which has led to sharp decreases in average blood lead concentrations in children where this phaseout has been implemented. However, with the increased emphasis on blood lead as well as environmental lead screening, it is becoming increasingly clear that many focal sources of lead that are capable of leading to widespread and severe childhood lead poisoning also exist in developing countries. The sources are multiple and varied, as outlined in this brief article, and include ingestion of lead from use in flour mills and in lead-glazed ceramics and environmental exposure to industrial sources, such as mining and smelting, and cottage industries, such as battery repair and recycling. Many other sources, such as consumer products, cosmetics, and traditional medicines, also contribute to lead exposure. In a large and diverse country such as India, many, if not most, of these sources will be found.

The challenge will be for developing countries to

TABLE 3. Blood Lead Levels in Children Younger Than 12 Years: George Foundation Lead Screening Survey, 1999[33]

Cities	*N*	Lead Concentration ≥ 10 μg/dL	%	Lead Concentration ≥ 20 μg/dL	%
Bangalore	631	252	39.9	33	5.2
Calcutta	294	164	55.7	55	18.7
Chennai	185	112	60.5	19	10.2
Delhi	451	244	54.1	84	18.6
Mumbai	291	180	61.8	43	14.7
Total	1852	952	51.4	234	12.6

TABLE 4. Some Identified Sources of Lead in India

Automobile exhaust from leaded gasoline
Lead-battery recycling plants
Lead smelting, as in silver refining for jewelry and articles
Lead-based pigments and paints
Printing presses
Ceramic pottery glazes
Lead contained in cosmetics and folk medicines

implement effective national and regional efforts to address their specific sources of lead. Global coordination among national groups (governmental and private), international agencies, and major donor organizations will greatly assist in achieving the goal of worldwide lead poisoning prevention.

ACKNOWLEDGMENTS

Many colleagues at the National Center for Environmental Health of the CDC and at the Agency for Toxic Substances and Disease Registry have been part of a distinguished group that has contributed greatly to the prevention of childhood lead poisoning. Several who participated directly in some of the international investigations cited here include Tom Matte, Jerry Hershwitz, Carol Pertowski, Gary Noonan, Rachel Kaufmann, Robert Jones, Carol Rubin, Michael McGeehin, Jim Pirkle, and Dick Jackson. I have also learned much and benefited from colleagues who stimulated our international lead activities, including Isabelle Romieu and Mauricio Hernandez of the National Institute of Public Health, Cuernavaca, Mexico; John Borrazzo of the US Agency for International Development; Richard Ackermann and Carter Brandon of the World Bank; and Abraham George, founder of the George Foundation.

REFERENCES

1. 1997 Declaration of the Environment Leaders of the Eight on Children's Environmental Health. *Can J Public Health.* 1998;89(suppl 1):S5–S8
2. Brody DJ, Pirkle JL, Kramer RA, et al. Blood lead levels in the US population. Phase 1 of the Third National Health and Nutrition Examination Survey (NHANES III, 1988 to 1991). *JAMA*. 1994;272:277–283
3. Pirkle JL, Brody DJ, Gunter EW, et al. The decline in blood lead levels in the United States. The National Health and Nutrition Examination Surveys (NHANES). *JAMA*. 1994;272:284–291
4. Pirkle JL, Kaufmann RB, Brody DJ, Hickman T, Gunter EW, Paschal DC. Exposure of the U.S. population to lead, 1991–1994. *Environ Health Perspect*. 1998;106:745–750
5. Mason JO. U.S. Public Health Service's strategic plan to eliminate childhood lead poisoning. From the Assistant Secretary for Health, US Public Health Service. *JAMA.* 1991;265:2049 (editorial)
6. American Academy of Pediatrics, Committee on Environmental Health. Screening for elevated blood lead levels. *Pediatrics.* 1998;101:1072–1078
7. Agency for Toxic Substances and Disease Registry. *The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress.* Atlanta, GA: US Department of Health and Human Services; 1988
8. Tong S, von Schirnding YE, Prapamontol T. Environmental lead exposure: a public health problem of global dimensions. *Bull World Health Organ*. 2000;78:1068–1077
9. Lovei M. Eliminating a silent threat: World Bank support for the global phase-out of lead from gasoline. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment*, *February 8–10, 1999.* Bangalore, India: The George Foundation; 1999:169–180
10. Kaiser R, Henderson AK, Daley WR, et al. Blood lead levels of primary school children in Dhaka, Bangladesh. *Environ Health Perspect*. 2001;109:563–566
11. Hernandez-Avila M, Cortez-Lugo M, Munoz I, Tellez MM, Soliz R. Lead exposure in developing countries. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment, February 8–10, 1999.* Bangalore, India: The George Foundation; 1999:87–94
12. Bitto A, Horvath A, Sarkany E. Monitoring of blood lead levels in Hungary. *Cent Eur J Public Health*. 1997;5:75–78
13. Maravelias C, Athansalelis S, Dona A, Chatzioanou A, Priftis C, Koutselinis A. Reduction of lead pollution in Greece during the past two decades. *Arch Environ Health*. 1998;53:424–426
14. Richter E, El-Sharif N, Fischbein A, et al. Re-emergence of lead poisoning from contaminated flour in a West Bank Palestinian village. *Int J Occup Environ Health*. 2000;6:183–186
15. Counter SA, Buchanan LH, Ortega F, Amarasiriwardena C, Hu H. Environmental lead contamination and pediatric lead intoxication in an Andean Ecuadorian village. *Int J Occup Environ Health*. 2000;6:169–176
16. Hernandez Avila 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*. 1991;94:117–120
17. Azcona-Cruz MI, Rothenberg SJ, Schnaas L, Zamora-Munoz JS, Romero-Placeres M. Lead-glazed ceramic ware and blood lead levels of children in the city of Oaxaca, Mexico. *Arch Environ Health*. 2000;55:217–222
18. Hibbert R, Bai Z, Navia J, Kammen DM, Zhang J. High lead exposures resulting from pottery production in a village in Michoacan State, Mexico. *J Expo Anal Environ Epidemiol*. 1999;9:343–351
19. Matte TD, Proops D, Palazuelos E, Graef J, Hernandez Avila M. Acute high-dose lead exposure from beverage contaminated by traditional Mexican pottery. *Lancet*. 1994;344:1064–1065
20. Matte TD, Figueroa JP, Ostrowski S, et al. Lead poisoning among household members exposed to lead-acid battery repair shops in Kingston, Jamaica. *Int J Epidemiol*. 1989;18:874–881
21. Suplido ML, Ong CN. Lead exposure among small-scale battery recyclers, automobile radiator mechanics, and their children in Manila, the Philippines. *Environ Res*. 2000;82:231–238
22. Kaul B, Mukerjee H. Elevated blood lead and erythrocyte protoporphyrin levels of children near a battery-recycling plant in Haina, Dominican Republic. *Int J Occup Environ Health*. 1999;5:307–312
23. Kaul B, Sandhu RS, Depratt C, Reyes F. Follow-up screening of lead-poisoned children near an auto battery recycling plant, Haina, Dominican Republic. *Environ Health Perspect*. 1999;107:917–920
24. Saraci M, Ziegler-Skylakakis K. Determination of lead in the blood of children in the town of Berat, Albania. *Chemosphere*. 1999;39:689–696
25. Nriagu JO. Toxic metal pollution in Africa. *Sci Total Environ*. 1992;121:1–37
26. Centers for Disease Control and Prevention. Human lead absorption—Texas. *MMWR Morb Mortal Wkly Rep*. 1997;46:871–877
27. Landrigan PJ, Gehlbach SH, Rosenblum BF, et al. Epidemic lead absorption near an ore smelter—the role of particulate lead. *N Engl J Med*. 1975;292:123–129
28. Landrigan PJ, Baker EL. Exposure of children to heavy metals from smelters: epidemiology and toxic consequences. *Environ Res*. 1981;25:204–224
29. Hernandez-Avila M, Espinoza Lain R, Carbajal L. Environmental health project. Activity Report No. 72. *Estudio de Plomo en Sangre en Poblacion seleccionada de Lima y el Callao.* Washington, DC: US Agency for International Development; 1999
30. Fitzgerald EF, Schell LM, Marshall EG, Carpenter DO, Suk WA, Zejda JE. Environmental pollution and child health in Central and Eastern Europe. *Environ Health Perspect*. 1998;106:307–311
31. Billig P, Gurzau E, Vultur C, Stoica A, Filimon V, Puscas M. Innovative intersectoral approach reduces blood lead levels of children and workers in Romania. *Int J Occup Environ Health*. 1999;5:50–56
32. George AM. Lead poisoning prevention and treatment: implementing a national program in developing countries. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment, February 8–10, 1999.* Bangalore, India: The George Foundation; 1999
33. The George Foundation. Project lead-free: a study of lead poisoning in major Indian cities. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment, February 8–10, 1999.* Bangalore, India: The George Foundation; 1999:79–85
34. Kumar RK, Kesaree N. Blood lead levels in urban and rural Indian children. *Indian Pediatr*. 1999;36:303–306
35. Kaul B. Lead exposure and iron deficiency among Jammu and New Delhi children. *Indian J Pediatr*. 1999;66:27–35
36. Patel AB, Williams SV, Frumkin H, Kondawar VK, Glick H, Ganju AK. Blood lead in children and its determinants in Nagpur, India. *Int J Occup Environ Health*. 2001;7:119–126
37. Seth PK, Saxena DK. Studies of lead levels in the environment in India. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment, February 8–10, 1999.* Bangalore, India: The George Foundation; 1999:159–168
38. Empirical evidence on lead sources and pathways in India. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment, February 8–10, 1999.* Bangalore, India: The George Foundation; 1999:221–240
39. Shankar C, Ayyar PVR. Lead phase-out from motor gasoline at "Indian Oil" refineries. In: George AM, ed. *Proceedings of the International Conference on Lead Poisoning Prevention and Treatment, February 8–10, 1999.* Bangalore, India: The George Foundation; 1999:277–285