Int. J. Hyg. Environ. Health 206, 363–369 (2003)

http://www.urbanfischer.de/journals/intjhyg

International Journal of Hygiene and Environmental Health

A global approach to childhood lead poisoning prevention

Pamela A. Meyer[a], Michael A. McGeehin[a], Henry Falk[b]

[a] Centers for Disease Control and Prevention, Division of Environmental Hazards and Health Effects, Atlanta, GA, USA
[b] Agency for Toxic Substances and Disease Registry, Office of the Assistant Administrator, Atlanta, GA, USA

Received September 3, 2002 · Revision received September 25, 2002 · Accepted September 25, 2002

Abstract

Childhood lead poisoning is an important, preventable environmental disease affecting millions of children around the world. The effects of lead are well known and range from delayed and adversely affected neurodevelopment to severe health outcomes including seizures, coma, and death. This article reviews the childhood effects of lead poisoning, the approach being taken to the problem in the United States, and the obstacles faced by developing nations in dealing with lead exposure. The United States has attacked the childhood lead poisoning problem by attempting to eliminate sources of exposure, including gasoline, solder in water pipes and cans, and industrial emissions. These actions have resulted in a dramatic reduction in the number of children with elevated blood lead levels in the United States over the last two decades. However, many developing countries are just beginning to address the problem. Successful efforts will need to incorporate epidemiologic methods, source identification, enforced regulations, and a long-term government commitment to eliminating lead as a threat to the next generation of children.

Key words: Lead poisoning – environmental health – policy

Introduction

Poisoning by lead is one of the most important environmental diseases affecting children, especially poor children in developing countries (George, 1999; United Nations Environment Programme [UNEP] and United Nations Children's Fund [UNICEF], 1997). The primary source of chronic exposures to lead in most developing countries is leaded gasoline. However, other important sources of lead that have been associated with childhood lead poisoning include local industry, consumer products, and methods of food preparation. The potential to have significant lead exposure remains very high for children in rapidly industrializing countries. This report will provide an overview of the history and health effects of lead poisoning, the United States' coordinated approach to reducing lead exposures and children's blood lead levels (BLLs), current international efforts to prevent lead poisoning, and areas that need to be addressed for the global elimination of childhood lead poisoning.

History of lead poisoning

Lead is a natural component of the earth's crust with trace amounts existing in soil, water, and plants

Corresponding author: Pamela A. Meyer, Ph.D., CDC/NCEH/EEHS/LPPB, 1600 Clifton Road, N.E. (MS F-30), Atlanta, Georgia 30333, USA. Phone: ++ 770 488 3633, Fax: ++ 770 488 3635, E-mail: pmeyer@cdc.gov

1438-4639/03/206-04-05-363 $ 15.00/0

(UNEP and UNICEF, 1997). Lead is practically immobile but becomes highly toxic when mined and used by people (Needleman, 1999). Lead has been mined, smelted, and used in cosmetics, internal and topical medicinal preparations, paint pigments, and glazes since early in recorded history (Nriagu, 1983). A Greek physician described the symptoms of lead poisoning in the second century B.C. (Major, 1945). Later, other physicians described the clinical manifestations of lead poisoning, but many failed to make a connection between the symptoms and the causative agent. Today's interest in lead's impact on the health and occupational fields can be attributed to an 1839 publication that described the clinical course of 1,207 people with lead colic and the types of work that exposed them to lead (des Planches, 1839). Observations that workers in the lead trade had problems with sterility, abortion, stillbirth, and premature delivery prompted a British Royal Commission in 1910 to recommend that women be excluded from the lead trades (Lane, 1949). Lead poisoning in children was first described in 1892 in Australia by Gibson, an ophthalmologist, who had identified the source of lead and its probable route of entry into children (National Research Council, 1993).

Health effects

No threshold for the toxic effects of lead has been identified (American Academy of Pediatrics, 1998). Very high blood lead levels in children (BLLs ≥ 80 µg/dl) can cause encephalopathy, coma, and even death (Centers for Disease Control and Prevention [CDC], 1991a). At lower lead levels, there may be no symptoms, but there may be adverse effects on the central nervous, renal, or hematopoietic systems. Young children are particularly vulnerable to lead's adverse effects. They absorb lead more readily than adults, and their developing nervous systems are more susceptible to the effects of lead than are those of adults (Agency for Toxic Substances and Disease Registry [ATSDR], 2000).

Numerous epidemiologic studies since the 1970s have found that lead exposure among young children was associated with reductions in IQ and attention span, learning disabilities, hyperactivity, behavior problems, impaired growth, and hearing loss (Needleman and Gastonis, 1990; Baghurst et al., 1992; Bellinger et al., 1992; McMichael et al., 1988). In recent years, research has been directed to more subtle neurotoxic effects of lead. This research has been aided by the creation of instruments that provide valid, reliable measures of attention, behavior, and other aspects of neurodevelopment. Using these instruments, some investigators have identified associations between lead exposure and weaknesses in attention/vigilance (Bellinger et al., 1994), aggression, somatic complaints, and antisocial or delinquent behaviors (Sciarillo et al., 1992; Needleman et al., 1996). Based on the growing body of evidence that lower BLLs can cause permanent harm, CDC lowered its level of concern for lead in blood from 25 µg/dl to 10 µg/dl in 1991. At the same time, CDC recommended that the blood lead test replace the use of the erythrocyte protoporphyrin (EP) test as the screening test of choice, because the EP test is not as sensitive in identifying children with BLLs < 25 µg/dl (CDC, 1991a).

The U.S. experience

The United States approached the lead poisoning problem by attempting to eliminate sources of exposure, including gasoline, solder in water pipes and cans, and industrial emissions. These actions have resulted in a dramatic reduction in the number of children with elevated blood lead levels (EBLLs) (BLLs ≥ 10 µg/dl) in the United States over the last two decades.

National lead policies

Since 1970, lead poisoning prevention efforts in the U.S. became source-directed rather than case-oriented. These efforts involved setting enforceable standards for environmental media and drinking water and placing specific restrictions on the use of lead. The establishment of new government institutions enabled these prevention efforts (Silbergeld, 1997). U.S. policies have attempted to provide a comprehensive approach to control multiple sources and pathways of exposure to lead. Three organizations with major responsibilities for controlling exposure to lead in the United States are the Environmental Protection Agency (EPA), the Department of Housing and Urban Development (HUD), and CDC.

EPA, established under the Clean Air Act of 1970, sets national standards for air quality and emissions of hazardous air pollutants and regulates motor vehicle fuels and fuel additives. In the early 1970s, EPA mandated the manufacture and sale of unleaded gasoline. As the use of unleaded gasoline became widespread, ambient air lead levels were dramatically reduced. Under the Safe Drinking Water Act (SDWA) of 1974, which was adopted to protect consumers from harmful contamination in the nation's drinking water, EPA set standards for contaminants in drinking water from public systems (EPA, 1999). SDWA limits the amount of lead that can be in water pipes, solder, and flux. The Toxic Substances Control Act (TSCA) assigns EPA primary responsibility for defining lead-based paint hazards and determining the environmental levels of lead paint that present health hazards (EPA, 2001). TSCA also directed EPA to develop regulations governing training and certification of persons who conduct renovation, remediation, or hazard assessment in housing with lead-based paint. EPA carried out a risk analysis and developed a rule defining locations and conditions of lead-based paint, and specific levels of lead in dust and soil, that constitute hazards.

HUD, under the Lead Poisoning Prevention Act of 1971, was authorized to eliminate levels of lead in paint in federally financed and subsidized housing and to fund research programs (Shea, 1996). HUD's responsibilities were subsequently expanded to include nonfederal residences. HUD has three main programmatic responsibilities: administering grants to states and localities for lead-based paint hazard control; developing and administering regulations for control of lead-based paint hazards in federally owned or assisted housing; and collaborating with EPA to develop regulations and regulatory guidance for control of lead hazards in housing (Department of HUD, 1997).

The 1988 Lead Contamination Control Act authorized CDC to make grants to state and local agencies for comprehensive programs to prevent lead poisoning among children (CDC, 1991b). CDC also provides technical assistance to state and local health departments for lead poisoning prevention programs, conducts surveillance of children's BLLs, provides technical guidance to states for blood lead surveillance, conducts applied research on the effectiveness of interventions for primary prevention of lead poisoning, and provides a reference laboratory for blood lead surveillance and research studies.

Since 1989, a federal partnership called the Interagency Task Force on the Prevention of Lead Poisoning has worked to eliminate childhood lead poisoning as a public health problem. Currently, 15 federal agencies are part of this partnership, including HUD, EPA, and CDC.

Tracking blood lead levels

CDC tracks BLLs in the U.S. population using the National Health and Nutrition Examination Survey (NHANES), an ongoing series of national examinations of the health and nutritional status of the civilian noninstitutionalized population. During the period from the late 1970s to the early 1990s, the prevalence of BLLs $\geq$ 10 μg/dl among young children in the United States dropped dramatically from 88.2% to 4.4% (CDC, 1997a). This decline in BLLs was probably a direct consequence of the regulatory and voluntary bans enacted on the use of lead in gasoline, household paint, food and drink cans, and plumbing systems (Pirkle et al., 1994). The effects of these changes benefited all U.S. population groups studied. In addition, BLLs may have been reduced in some groups as the result of lead paint abatement programs, the promulgation of a standard for lead exposure in industry, and childhood lead poisoning prevention efforts undertaken by public health agencies.

Recent data have indicated that while the prevalence of EBLLs was declining nationally, specific groups of children remained at high risk (CDC, 1997a). Children aged 1 to 5 years who were studied by CDC in 1991–1994 were more likely to have BLLs $\geq$ 10 μg/dl if they were poor, were African-American, or lived in older housing. In response to these findings, CDC changed its national blood lead screening recommendations from universal screening to an approach focused on the children at the highest risk of lead poisoning. In 1997, CDC called on state health departments to develop plans to ensure screening of all children at high risk for having EBLLs (CDC, 1997b).

Global lead risk reduction

The general trend observed in all countries engaged in lead risk reduction programs over the last two decades is declining BLLs. For example, average BLLs in children declined 25 to 45 percent between 1978 and 1988 in Belgium, Canada, Germany, New Zealand, Sweden, and the United Kingdom (von Schirnding, 1999). In contrast, many developing countries are just becoming aware of the problem. More developed countries can help by sharing their knowledge of and experience with lead sources, pathways, control measures, and health effects with countries beginning to implement prevention programs.

To that end, scientists in the field, public policy specialists, industry leaders and senior government officials involved in health and environmental issues convened in February 1999 in Bangalore, India. The conference was called the International Conference on Lead Poisoning Prevention and Treatment, and one of its aims was to initiate development of a framework for a national program for prevention and treatment of lead poisoning in developing countries. The message from the conference was that the principles and methods used for prevention and treatment of lead poisoning are applicable worldwide. Current scientific knowledge of lead and the successful lead prevention experiences in several countries can be examined and adapted to circumstances in developing countries.

Lead poisoning prevention efforts in developing countries are hampered by the challenge of implementing and enforcing new environmental and occupational regulations. Resources have not been allocated to adequately assess, evaluate, control, and prevent lead exposure. For example, with the exception of leaded gasoline, most sources remain understudied and uncontrolled. In addition, many developing countries lack surveillance systems to identify and track lead poisoned children, adequate medical training to identify the disease, and the infrastructure to provide adequate follow-up and care. Few published studies exist from developing countries, and most do not study children at highest risk, aged 6 to 24 months (Hernandez-Avila et al., 1999a). Epidemiologic studies are needed (1) to characterize sources of exposure and populations at risk so that interventions can be effectively targeted, and (2) to reduce lead hazards and emissions.

Field epidemiology capacity

Countries that want to conduct surveys to assess the prevalence of EBLLs, to identify sources, and to analyze and interpret data need to have trained epidemiologists. CDC partners with countries interested in developing epidemiologic expertise through the Field Epidemiology Training Programs (FETPs) that have been established in more than 20 countries. FETPs provide critically needed epidemiologic expertise and leadership within those countries and produce people who become part of an ever-growing global network of qualified epidemiologists partnering with CDC in global health activities.

Source identification and control

The effects of lead exposure may be attributed to widespread contamination or to a local, focused source. For this reason, multiple sources (e.g., leaded gasoline, industrial processes, paint, solder in canned foods, water pipes, etc.) and pathways (air, household dust, street dirt, soil, water, and food) may all play a role (von Schirnding, 1999). Any efforts to prevent lead poisoning must consider identifying and reducing children's exposures to all possible sources of lead. Some sources of lead that have been identified by epidemiologic investigations are described below.

Leaded gasoline

Automobiles that burn leaded gasoline are a major source of lead in air, dust and soil in many developing countries (UNEP and UNICEF, 1997). In large cities where leaded gasoline is still used, it accounts for 80 to 90 percent of airborne lead (Lovei, 1999). Inspired by the successful U.S. phase-out of leaded gasoline and the concurrent decline in national BLLs, international health agencies (e.g., World Health Organization), national governments (e.g., India, Indonesia, Mexico) and major donor organizations (e.g., World Bank, U.S. Agency for International Development) have taken steps to stimulate the phase-out of lead in gasoline in other countries (Lovei, 1999). Studies in several large international cities have shown sharply reduced lead levels after initiating the phase-out of leaded gasoline (Reinhard et al., 2001; Hernandez-Avila, 1999a).

Ceramic glazing

High lead levels were reported among children in a village in Ecuador where the primary occupation was producing lead-glazed ceramics (Counter et al., 2000). The lead used in the process was extracted from discarded automobile batteries. Children lived, ate, and played near the lead glazing kilns. Among the 166 children aged 4 months to 15 years tested in the area, the mean BLL was 40 μg/dl and the highest BLL was 119 μg/dl. The use of ceramic ware for food preparation and storage is widespread in Mexico (Hernandez-Avila et al., 1991a). Other investigators have linked high BLLs with using lead-glazed ceramic ware (Azcona-Cruz et al, 2000; Hernandez-Avila et al., 1991).

Battery recycling

Battery recycling has been shown to be a significant source of lead in a number of studies. After the close of an auto battery recycling plant in 1997 in Haina, Dominican Republic, children who lived nearby were tested for lead poisoning. When the plant closed in March, 116 children were tested, and 146 were tested in August of the same year (Kaul and Mukerjee, 1999; Kaul et al., 1999). In March, the mean BLL was 71 μg/dl (range 9 to 234 μg/dl) and by August the mean had fallen to 32 μg/dl (range 6 to 130 μg/dl). Considerable contamination of the area continued to expose children to lead dust.

In a study of ten battery recyclers in Manila, Philippines, mean BLLs were 54 μg/dl for battery workers compared with 13 μg/dl for unexposed adults (Suplido and Ong, 2000). Children living near the battery shops had a mean BLL of 50 μg/dl, while unexposed children had a mean BLL just under 10 μg/dl. The exposed children's homes were located near the shops, and the children played and spent considerable time in the work area. These findings suggest that lead dust generated from the disassembly of batteries and the storage of battery parts can result in high blood lead levels in children.

Lead ore storage and transportation

An investigation of BLLs among children living adjacent to a port facility in Lima, Peru, that involved storage, ship loading, and truck transportation of lead laden ore revealed a mean BLL of 25 μg/dl (Hernandez-Avila et al., 1999b). Dissemination of lead dust was facilitated by the dry climate, unpaved streets and alleys, and homes with mud floors and unsealed roofs.

Flour milling

Following a report of an outbreak of gastrointestinal diseases in southern Egypt, an investigation revealed that these illnesses were caused by lead toxicity, and the source of the outbreak was flour contaminated with lead during the grinding process (Pertowski, 1999). Flour is a diet staple, and each village in rural Egypt has at least one flour mill. Molten lead is frequently used to attach the grinding stone to the iron bar connected to the axle that rotates the grinding stone. As the grinding surface wears down from repeated use, lead is deposited in the flour. Preventive actions were taken in Egypt and other countries to improve maintenance of the flour mills and discontinue use of molten lead. However, although contaminated flour was first described as an important source of endemic lead poisoning in the Middle East almost 20 years ago, the use of lead in community flour mills has not been eliminated and continues to represent a significant environmental risk (Richter et al., 2000). Similar mill practices have been observed in communities throughout Latin America and in parts of Asia.

Laboratory capacity

In many countries, laboratory capacity for measuring blood lead or environmental lead levels is limited. Global standardization of laboratory lead measurements is essential to better compare the extent of the problem throughout the world. CDC has assisted laboratories in Australia, Brazil, Canada, Israel, Korea, Peru, Poland, South Africa, Taiwan, Trinidad and the United Kingdom in standardizing methodologies for measuring lead (CDC and ATSDR, 1999). Standardization will help improve analytical accuracy and precision and provide better data on which to base clinical care and public health programming decisions.

CDC's technological training in the use of the new portable lead analyzer for blood and environmental analyses held in Chile, Mexico, Poland and Russia strengthened these countries' capacity to improve research on lead. The development of a portable blood lead analyzer has made testing more feasible in developing countries because the analyzer is a portable, precise, and accurate instrument that involves minimal expense and does not require a high level of skill to operate (CDC and ATSDR, 1999).

Future directions

Environmental problems are often complex, costly, and controversial and require creative solutions. Incorporating human health concerns explicitly into environmental policymaking is critical. Health problems arise from beyond the health sector, and solutions must be sought in the same arena (e.g., in the environmental, social, commercial, economic, and political sectors) (CDC and ATSDR, 1999).

In developing countries, lead poisoning competes for limited resources with other important health problems such as low immunization coverage, malnutrition, or sanitation deficiencies, that are considered higher priority (Hernandez-Avila, 1999a). Preventing lead poisoning in these countries will require use of improved methods to identify and provide interventions to groups at high risk, identify sources, and reduce exposure to children. Some international lead poisoning studies support what we have learned in the United States, that lead exposure is not equally distributed. Sources vary by country and even by geographical areas within countries. It is important to conduct investigations to identify the specific lead sources affecting a population. Intervention and prevention activities can then be targeted to those areas, and children with EBLLs can be provided appropriate medical follow-up.

Recent studies have shown that the neurocognitive effects and developmental deficits caused by lead poisoning in early childhood can be irreversible despite appropriate medical follow-up. These studies increasingly demonstrate the need for primary prevention, i.e., reducing children's exposure to lead in their environment. The challenge the global community faces is to develop strategies that can prevent children from ever becoming poisoned by lead – the only satisfactory solution to this devastating problem.

The permanent impact that childhood lead exposure has on a person's life argues strongly that the only truly effective public health response to lead poisoning is primary prevention. The difficult challenge of primary prevention can only be met when a nation's government makes a concerted effort, including protective legislation, effective enforcement, judicious application of scarce resources, and cooperation among environmental health, public health, and private health care systems. This type of national response has often been supplemented by financial and technical assistance provided by non-governmental organizations and countries that have developed lead poisoning prevention programs. The full and healthy development of the future generations of the world's children deserve no less.

References

Agency for Toxic Substances and Disease Registry: Case studies in environmental medicine: lead toxicity. U.S. Department of Health and Human Services, Atlanta (2000).

American Academy of Pediatrics: Screening for elevated blood lead levels. Pediatrics 101, 1072–1078 (1998). May be accessed on CDC website: http://www.aap.org/policy/re9815.html.

Azcona-Cruz, M. I., Rothenberg, S. J., Schnaas, L., Zamora-Munoz, J. S. and Romero-Placeres, M.: Lead glazed ceramic ware and blood lead levels of children in the city of Oaxaca, Mexico. Arch Environ Health. 55, 217–222 (2000).

Baghurst, P. A., McMichael, A. J., Wigg, N. R., Vimpani, G. V., Robertson, E. F., Roberts, R. R. and Tong, S. L.: Environmental exposure to lead and children's intelligence at the age of seven years: the Port Pirie Cohort Study. N Engl J Med. 327, 1279–1284 (1992).

Bellinger, D. C., Stiles, K. M. and Needleman, H. L.: Low-level lead exposure, intelligence and academic achievement: a long-term follow-up study. Pediatrics. 90, 855–861 (1992).

Bellinger, D., Hu, H., Titlebaum, L. and Needleman, H. L.: Attentional correlates of dentin and bone lead levels in adolescents. Arch Environ Health. 49, 98–105 (1994).

Centers for Disease Control and Prevention: Preventing lead poisoning in young children: a statement by the Centers for Disease Control. U.S. Department of Health and Human Services, Atlanta (1991a).

Centers for Disease Control and Prevention: Strategic plan for the elimination of childhood lead poisoning in young children. U.S. Department of Health and Human Services, Atlanta (1991b).

Centers for Disease Control and Prevention: Update: blood lead levels – United States, 1991–1994. MMWR. 46, 141–146 (1997a).

Centers for Disease Control and Prevention: Screening young children for lead poisoning: Guidance for state and local public health officials. U.S. Department of Health and Human Services, Atlanta (1997b).

Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry: Global Health Activities Annual Report FY 1998. U.S. Department of Health and Human Services (1999).

Counter, S. A., Buchanan, L. H., Ortega, F., Amarasiriwardena, C. and Hu, H.: Environmental lead contamination and pediatric lead intoxication in an Andean, Ecuadorian village. Int J. Occup Environ Health. 75, 169–7 (2000).

Department of Housing and Urban Development: Moving toward a lead-safe America: A report to the Congress of the United States. February 1997. Accessed on 07/10/2002 at HUD website: http://www.hud.gov/offices/lead/reports/annrept.pdf.

des Planches, T.L. Traite des maladies de plomb ou saturnines. Translated and edited by S.L. Dana, 1848. In: Lead diseases. Daniel Bixby & Co., Lowell, Massachusetts (1839).

Environmental Protection Agency: The Safe Drinking Water Act, 25 Years of the Safe Drinking Water Act: History and Trends. EPA 816-R-99-007. 1999. EPA website accessed on 07/10/2002 at: http://www.epa.gov/safewater/consumer/trendrpt.pdf.

Environmental Protection Agency: Toxic Substances Control Act: Residential Lead Hazard Standards – TSCA Section 403, 2001 EPA website accessed on 07/10/2002 at: http://www.epa.gov/opptintr/lead/leadhaz.htm.

George, A. M.: Introductory remarks by conference organizer and host. In: Lead poisoning prevention and treatment: Implementing a national program in developing countries (A. M. George, ed.), p. 9. The George Foundation, Bangalore, India (1999).

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

Hernandez-Avila, M., Cortez-Lugo, M., Munoz, I., Tellez, M. M. and Soliz, R.: Lead exposure in developing countries. In: Lead poisoning prevention and treatment: Implementing a national program in developing countries (A. M. George, ed.), pp. 87–94. The George Foundation, Bangalore, India (1999a).

Hernandez-Avila, M., Espinoza Lain, R. and Carbajal, L.: Environmental health project Activity Report No. 72. Estudio de Plomo en Sangre en Poblacion seleccionada de Lima y el Callao. U.S. Agency for International Development. Washington, DC (1999b).

Kaul, B. and Mukerjee, H.: Elevated blood lead levels and erythrocyte protoporphyrin levels of children near a battery-recycling plant in Haina, Dominican Republic. Int J Occup Environ Health. 5, 307–312 (1999).

Kaul, B., Sandhu, R. S., Depratt, C. and Reyes, F.: Follow-up screening of lead poisoned children near an auto battery recycling plant, Haina, Dominican Republic. Environ Health Perspect. 107, 917–920 (1999).

Lane, R. E.: The care of the lead worker. Br J Ind Med. 6, 125–143 (1949).

Lovei, M.: Eliminating a silent threat: World Bank support for the global phase-out of lead from gasoline. In: Lead poisoning prevention and treatment: Implementing a national program in developing countries (A. M. George, ed.), pp. 169–180. The George Foundation, Bangalore, India (1999).

Major, R. H.: Classic descriptions of disease, 3rd Ed. Charles C. Thomas, p. 312. Springfield, Illinois (1945).

McMichael, A. J., Baghurst, P. A., Wigg, N. R., Vimpani, G. V., Robertson, E. F. and Roberts, R. J.: Port Pirie Cohort Study: environmental exposure to lead and children's abilities at the age of four years. N Engl J Med. 319, 468–475 (1988).

National Research Council: Beginning of public health interest in lead. In: Measuring Lead Exposure in Infants, Children and Other Sensitive Populations. p. 24. National Academy Press, Washington, DC (1993).

Needleman, H. L. and Gastonis, C. A.: Low-level lead exposure and the IQ of children: a meta-analysis of modern studies. JAMA. 263, 673–678 (1990).

Needleman, H. L., Riess, J. A., Tobin, M. J., Biesecker, G. E. and Greenhouse, J. B.: Bone lead levels and delinquent behavior. JAMA. 275, 363–369 (1996).

Needleman, H. L.: History of lead poisoning in the world. In: Lead poisoning prevention and treatment: Implementing a national program in developing countries (A. M. George, ed.), p. 17. The George Foundation, Bangalore, India (1999).

Nriagu, J. O.: Lead exposure and lead poisoning. In: Lead and lead poisoning in antiquity, p. 309. John Wiley and Sons, New York (1983).

Pertowski, C.: Health services in childhood lead poisoning prevention: the experience of the Cairo lead survey, 1997–1998. In: Lead poisoning prevention and treatment: Implementing a national program in developing countries (A. M. George, ed.), p. 197. The George Foundation, Bangalore, India (1999).

Pirkle, J. L., Brody, D. J., Gunter, E. W., Kramer, R. A., Paschal, D. C., Fiegal, K. M. and Matte, T. D.: The decline of blood lead levels in the United States: the National Health and Nutrition Examination Surveys (NHANES). JAMA. 272, 284–291 (1994).

Reinhard, K., Henderson, A. K., Daley, W. R., Naughton, M., Khan, M. H., Rahman, M., Kieszak, S. and Rubin, C.: Blood lead levels of primary school children in Dhaka, Bangladesh. Environ Health Perspect. 109, 563–566 (2001).

Richter, E., El-Sharif, N., Fischbein, A., Konijn, A., Gorodetsky, R., El-Sharif, H., Kaul, B., Hershko, C., Grauer, F., Foner, H., Al-Baba, A., Dweik, Z. and Lihsounat, M.: Re-emergence of lead poisoning from contaminated flour in a West Bank Palestinian village. International Journal of Occupational & Environmental Health. 6, 183–186 (2000).

Sciarillo, W. G., Alexander, G. and Farrell, K. P.: Lead exposure and child behavior. Am J Public Health. 82, 1356–1360 (1992).

Shea, E. E.: Lead Regulation Handbook. Government Institutes, Inc. Rockville, Maryland (1996).

Silbergeld, E. K.: Preventing lead poisoning in children. Annu Rev Public Health. 18, 187–210 (1997).

Suplido, M. L. and Ong, C. N.: Lead exposure among small scale battery recyclers, automobile radiator mechanics and their children in Manila, the Philippines. Environ Res (section A). 82, 231–238 (2000).

United Nations Environment Programme (UNEP) and United Nations Children's Fund (UNICEF): Childhood lead poisoning: Information for advocacy and action. 1997. Accessed on 07/03/2002 at: http://www.unicef.org/programme/wes/pubs/lead/lead_en.pdf.

von Schirnding Y.: The impact of lead poisoning on the workforce and society. In: Lead poisoning prevention and treatment: Implementing a national program in developing countries (A. M. George, ed.), pp. 41–46. The George Foundation, Bangalore, India (1999).