Lead Contamination in Uruguay: The “La Teja” Neighborhood Case

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1 Introduction

Our last review, “Lead Contamination in Uruguay” (Mañay et al. 1999), provided essential background information for the lead contamination incident in the La Teja neighborhood of Montevideo, Uruguay. Our reports, including those cited in this review, were officially acted upon by Sanitary and Environmental authorities beginning in late 2000 (Mañay et al. 2003). Before the release of our review, information on lead contamination in Uruguay was dispersed and incomplete. Although health risks to residents associated with lead contamination and exposure in polluted areas

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often went unrecognized, contamination events were previously known. An example is the Malvín Norte neighborhood case described by Cousillas et al. (1998).

The Mañay et al. (1999) review was considered both interesting and useful to the scientific community, to the press, and to the general public. This review, together with associated scientific research results published by Mañay (2001a,b), by Schutz et al. (1997), or presented at scientific meetings, substantively contributed to recognition of lead poisoning as a rising health problem in Uruguay. Concomitantly, our research team also contributed its knowledge of lead blood analysis and biomonitoring on different Uruguayan populations to others working on the problem.

It was not until 2001 that official attention was increasingly being paid to environmental lead exposure, although our research group had published several studies during the 1990s, including those reviewed in Mañay et al. (1999). The understanding of environmental risks associated with lead contamination in Uruguay improved as data on lead concentrations in blood and soil samples accumulated. The growing scientific evidence, along with press reports and court cases, increased awareness and concern among Uruguayans for lead-induced health risks (Amorin 2001; Matos 2001). As a consequence, new research studies on Uruguayan populations became available, including some that had gone unpublished for several years. Some interdisciplinary study results were officially communicated to the public as they became available, particularly those designed to prevent environmental health risks to children.

To illustrate the growing momentum for change, in late 2003, the use of tetraethyl lead in gasoline was phased out in Uruguay. Although not as yet officially evaluated, this change was expected to reduce lead levels in air and consequently reduce human blood lead levels as well.

2 Lead Exposure in Uruguay

The adverse effects of lead are well known, environmentally exposed children being the most affected population. Lead exposure is known to threaten human health, and, although lead has no known biological role, it is frequently found as a residue in human tissues. There is a significant negative correlation between the mental development of children and environmental lead exposure (ACHS 2000; ATSDR 2003, 2005; IPCS 1995).

2.1 Sources of Lead

Uruguay is a small country comprising 3 million inhabitants, half of whom live in the coastal city of Montevideo, its capital. Most lead processing industries in Uruguay, such as metallurgies, foundries, manufacturers of batteries, and battery recyclers, are established in or around Montevideo, thus contributing to the contamination of the peripheral slums.

Until December 2003, gasoline used in Uruguay contained tetraethyl lead (TEL) as an antiknock additive in concentrations ranging from 150 to 300 mg/L (Barañano et al. 2005). Use of TEL in Uruguay was replaced in 2004 by methyl *tert*-butyl ether.

Montevideo still has several lead-emitting industries that pose some continuing exposure risk to people, and most of these are located in residential areas. Another source of population exposure to lead is through the use of lead pipes to conduct drinking water to and within old buildings. Individuals who live near manufacturing areas that do not handle lead materials or waste safely are also potentially at risk (Dol et al. 2004; IMM 2003; Mañay et al. 2003). Other potential sources of exposure, although not yet studied, include lead-based paint in old buildings and lead residues released from smoking tobacco (UNEP 2007; UNEP/OECD 1999).

2.2 Environmental Lead Exposure: The La Teja Case (Montevideo)

In 2001, lead exposure became a matter of public concern in Uruguay when several cases of children with blood lead levels (BLL) higher than 20 µg/dL were discovered. Burger and Pose (2001) described the first such case, a child with BLL of 31.2 µg/dL; after this, many more high BLL cases were discovered. The affected children were residents of a low-income neighborhood in Montevideo called La Teja (Mañay et al. 2003). It was reported that after lead handling factories were abandoned, many families settled in the area (La Teja) without either knowing it was polluted with lead or understanding the high risks to themselves or their children from living on this site.

In 2001, official lead surveillance analyses began on residents' blood and on environmental samples collected from those abandoned industrial areas (Ponzo 2002). The highest lead levels were found in soil samples from some slum settlements; residue levels exceeded 3000 ppm and resulted from lead scrap landfills (Dol et al. 2004; IMM 2003).

Uruguay had encountered many previous lead contamination episodes (Ascione 2001; Cousillas et al. 1998). However, in early 2001, the "Lead in La Teja" case became unique in Uruguay because it developed into an environmental, sanitary, and social emergency. As a result, an official multidisciplinary expert group with State University and community delegates was created. The serious nature of this pollution event resulted in an initiative by the Ministry of Health to hold periodic meetings and to undertake needed remediation.

Ascione (2001) pointed out that soil and dust are important sources of lead exposure for children. This article stressed the importance of pediatricians evaluating their patients for possible lead intoxication and following up by taking the proper clinical steps if symptoms were compatible with lead poisoning. Lead poisoning symptoms include behavioral disturbances, intellectual deficit, hyperactivity, falling behind in school, renal pathology, etc.

In Mañay et al. (2003), a preliminary approach to the environmental lead pollution problem in the La Teja neighborhood of Montevideo was presented through the appearance of high blood lead levels in children living there. These early BLL results were first discussed in a Latin-American lead workshop held in Lima, Perú (Mañay 2001a), and those data were obtained by analyzing venous BLL in children and pregnant women using atomic absorption spectrometry (AAS). Lead analyses on environmental samples were performed at the same time so as to identify the possible lead sources (e.g., drinking water, soil, and air). These data were collected within the framework of the Interinstitutional Lead Committee assembled in 2001.

The aforementioned paper (Mañay et al. 2003) also reported the onset of periodic health care visits to children who had BLL above 20 µg/dL. Those children were visited by a multidisciplinary team who studied their residential environment, possible sources of lead exposure, and socioeconomic and housing conditions. Educational and preventive initiatives concerning hygienic and dietary habits were also undertaken within the community. The children being studied either lived in children's homes or were getting medical assistance in a Paediatric Hospital. In the Mañay et al. (2003) paper, blood lead analyses of 2351 children (aged 2–15 yr) and 45 pregnant women were discussed. Drinking water, soil, and air samples were also analyzed.

The preliminary results showed 61% of tested children had BLL above 10 µg/dL, which is considered as the medical and/or environmental intervention blood lead limit (CDC 1991). Higher BLL were found in younger children (>4 yr). Of the 45 pregnant women tested, 67% had BLL below 10 µg/dL. BLLs were significantly higher in boys (12.1 µg/dL) than girls (11.2 µg/dL) and tended to decrease with

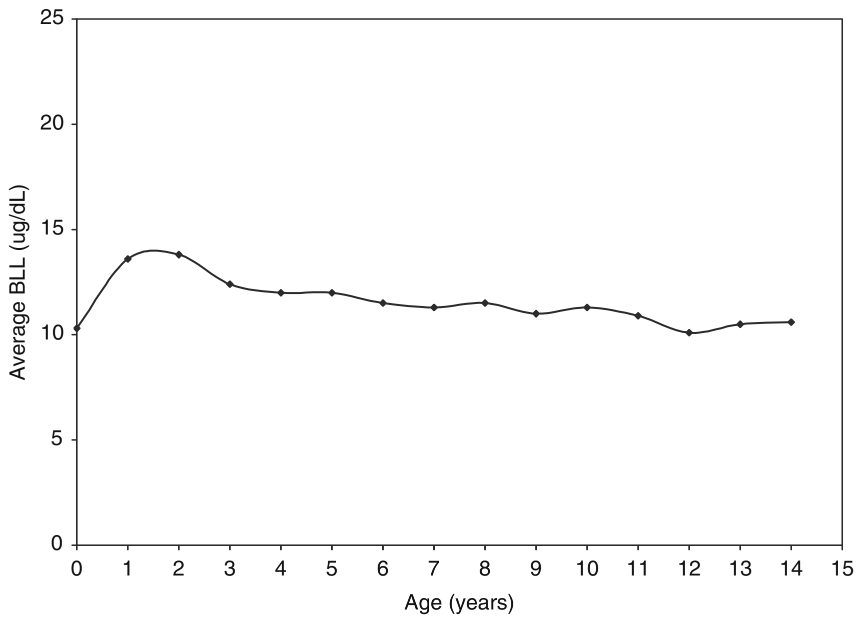

Fig. 1 Average blood lead levels (BLL) by age of children from "La Teja," Montevideo, Uruguay, 2001. (Adapted from Mañay et al. 2003, with kind permission from Salud Publica de Mexico.)

increasing age. Maximum BLLs were found in children about 2 yr old (Fig. 1), which is consistent with results of other studies (ATSDR 2003; IPCS 1995). Soil was apparently the principal source of the children's exposure because the area where they lived had been widely contaminated with lead scrap in the previous decades. This study also confirmed that the bare soil, which constituted the floor of most houses, was the main source responsible for lead uptake by children. To mitigate the health problems of those affected, priority criteria were developed to achieve favorable outcomes (reductions in BLL). These criteria emphasized education, hygiene, and nutrition.

Alvarez et al. (2003a) reported that, during 2001 and 2002, the Toxicology Department of the Faculty of Chemistry performed 10,131 lead analyses on blood samples as a community and advisory service. These samples represented 5,848 children and 1,268 adults; 3,015 samples were not specified as to gender. The data from these analyses are presented in Table 1. The average BLL found for children was 12.3 μg/dL; 60% of the values exceeded the 10 μg/dL limit (CDC 1991).

Beginning in 2001, children with BLL values higher than 20 μg/dL received public health and/or medical assistance at the Chemical Pollutants Medical Care Center of the Pereira Rossell Hospital. Those children received medical intervention, including iron supplementation and improved nutrition, and their mothers received hygienic-dietary instruction on how to reduce lead absorption. Alvarez et al. (2003b) reported follow-up testing on 387 of these children. The results of this testing statistically demonstrated that BLLs were significantly decreased with the adopted medical interventions (Fig. 2).

The Municipality of Montevideo carried out environmental surveillance of lead content in soil samples from several slum settlements associated with the environmental interventions (IMM 2003). The authors of this surveillance report attempted to assess the possible sources of lead pollution that caused the event. They suggested that the primary sources of pollution were poorly run smelters or metallurgical enterprises, deposition of industrial wastes in landfills, used battery recycling, other forms of lead waste mismanagement, burning wire for copper recovery, and contributions from vehicular traffic emissions. Soil is thus the major source of human exposure to lead. Lead-based paint and lead residues in water from lead pipelines were also recognized as potential sources of lead exposure.

In the same report (IMM 2003), the Municipality of Montevideo described results from surveillance of soil samples taken in different areas to correlate with

Table 1 Average blood lead levels (BLL) in three Uruguyan populations compared with the recommended value

	Children	Nonexposed adults	Exposed adults
Pb in blood (μg/dL)	12.3	14.6	37.1
Recommended value (μg/dL)	10	25	30
Percentage above the recommended value	>60%	13%	9%

Source: Adapted from Alvarez et al. (2003a).

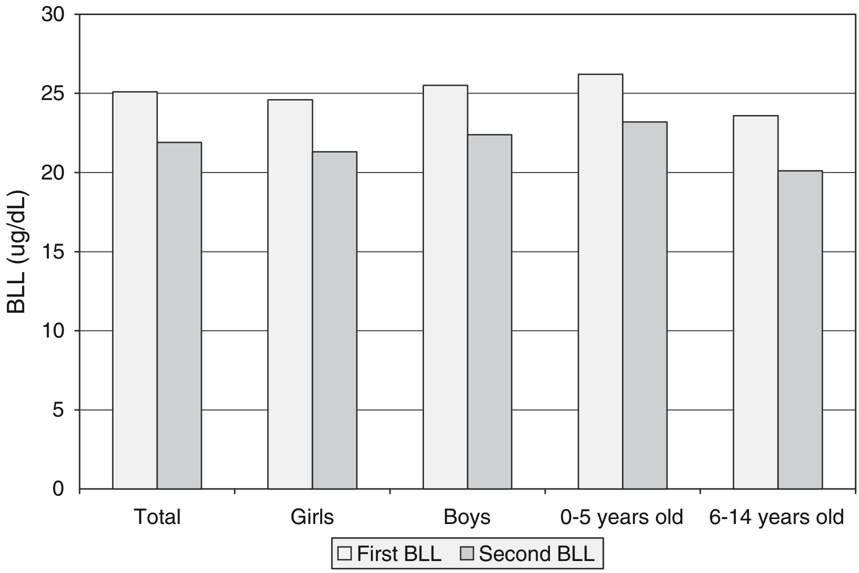

Fig. 2 Average values for first (original BLL sampling) vs. second (after medical intervention) BLL by sex and age (n = 387). (Adapted from Alvarez et al. 2003b.)

traffic lead emissions. They showed a correlation of lead levels in soil with traffic intensity in areas all over Montevideo before leaded gasoline was phased out.

2.3 Occupational Lead Exposure

Areas near the La Teja neighborhood were never systematically evaluated for environmental lead residues. However, when lead handling industries were operating, some studies on workers' exposure to lead were conducted. As reviewed by Mañay et al. (1999) and Pereira et al. (2003), studies on exposed workers from different manufacturing industries, i.e., battery factories, foundries, wire factories, etc., showed that almost 60% of BLL analyses made were above 40 µg/dL. In addition, a pilot study with workers from a battery storage plant who were sampled for control purposes showed mean BLLs of 48.2 µg/dL (n = 60; range, 29.0–80.0); 94% of samples exceeded 30 µg/dL (Pereira et al. 1998).

The Committee of Occupational Health from the Medical Trade Union (Danatro et al. 2001) reported that, in 2001, Uruguay's adopted lead limits for workplace environments were still those of a Ministry of Health resolution of October 1982; these limits were the same as the American Conference of Governmental Industrial Hygienists (ACGIH) reference levels for workplaces in place at that time. That legal norm did not include biological limits for lead. It was not until 2004 (MSP 2004) that the Ministry of Health first established biological reference values, "safe levels," for chemicals to which workers are exposed. It was also in 2004 that a new legal framework to regulate the control of workers' blood lead exposure levels (Legislative Power 2004a) was created. However, there is no official BLL limit for the nonoccupationally exposed adult community.

3 Description of Lead Studies and Projects in Uruguay Following the La Teja Case

3.1 Official Actions, Projects, and Reports

3.1.1 Lead in Soil

Since 2001, the Laboratory of Environmental Hygiene of the Montevideo Municipality, in coordination with the Soil Division of the Ministerial Division of Environment (IMM 2003), has worked on the study and assessment of lead-, chromium-, and cadmium-contaminated sites. Because Uruguay lacks legal norms to regulate the concentration of contaminants in soil, guideline values were adopted from international organizations (Table 2).

The results of completed studies emphasize the influence of leaded gasoline as a source of lead contamination in soil in areas of high vehicle traffic (IMM 2003). Such contamination was clearly demonstrated by comparison of lead concentrations in soil samples from urban high versus suburban and rural moderate vehicle traffic areas (Table 3).

Table 2 International recommendations for lead levels in soil

	Recommended value (mg/kg soil)	
USA (EPA)	400	Residential
Canada (Canadian Council of Ministries of the Environment)	140	Recreational

Table 3 Influence of vehicular traffic intensity on soil lead levels

Source of soil samples	Urban area	Suburban area	Rural area
Number of samples	47	16	15
Samples with lead concentration ≥400 mg/kg (%)	83	100	100
Samples with lead concentration between 140 and400 mg/kg (%)	17	0	0
Samples with lead concentration >400 mg/kg (%)	0	0	0
Average lead concentration (mg/kg)	95	33	28

Source: From IMM (2003).

Results of soil sample surveillance from various slum areas showed that, of 354 analyzed samples taken from 57 settlements, only 65 samples had residue levels above those recommended (140 mg/kg; CCME 2006), as shown in Table 4 and Fig. 3. This study was performed on samples collected by the Ministry of Health during the course of another study in which families living in their homes were being evaluated for effects of lead exposure on health. Some samples other than soil (blood) were also collected and analyzed.

3.1.2 Phase-Out of Leaded Gasoline

By 2003, a United Nations report on "Progress on Phasing out Lead in Gasoline" stated that decision makers in an increasing number of countries, including Uruguay, had recognized that eliminating the use of lead additives is a cost-effective way of reducing lead poisoning, especially in children; as a result, the phase-out of lead from gasoline had gained wide support. The phase-out of leaded gasoline in Uruguay was gradual, as described in reports from the United Nations Environment

Table 4 Distribution of lead levels in soils from settlements studied by the Laboratory of Environmental Hygiene

Number of settlements	57
Number of samples	354
Number of samples with Pb < 140 mg/kg	209
Number of samples with Pb between 140 and 400 mg/kg	80
Number of samples with Pb in soil > 400 mg/kg	65
Number of settlements having at least one sample with Pb > 400 mg/kg	19

Source: From IMM (2003).

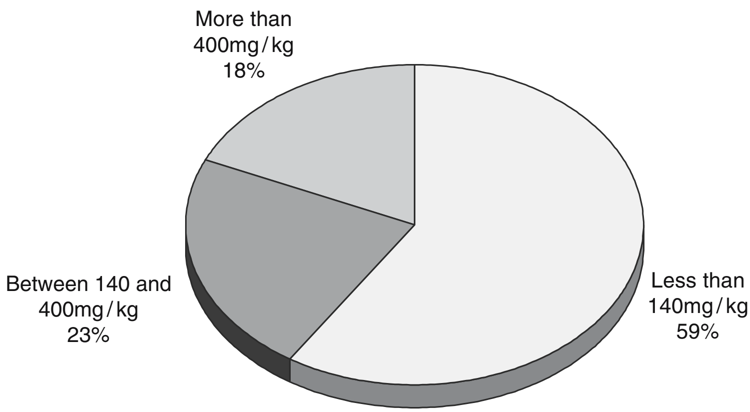

Fig. 3 Lead levels in soil from settlements studied by the Laboratory of Environmental Hygiene (IMM 2003)

Program (UNEP/OECD 1999, UNEP 2002). Finally, in November 2003, the State Refinery (ANCAP) began production of lead-free gasoline, which was first marketed in January 2004 (UNEP 2007).

3.1.3 Industrial Surveillance

In 2001, more than 100 enterprises, affiliated in some manner with lead contamination, were targeted for soil sampling by the Laboratory of Environmental Hygiene of the Montevideo Municipality. A total of 427 soil samples from industrial premises and their surroundings were taken. Resultant lead levels from these samples, as analyzed by atomic absorption spectrometry, ranged from nondetectable up to "hundreds of grams per kilogram of soil" (IMM 2003).

The variability of results was concluded to result from the following:

- Differences among the surveyed industries in the way they created environmental emissions, the degree to which their handling of wastes was inappropriate, etc.
- Distance from sampling site to primary site of lead production or lead waste processing (levels generally diminished with increasing distance).
- Duration of poor lead handling practices. Because lead is a permanent contaminant and can be mobilized by wind, rain, etc., high lead levels can persist at facility sites and their surroundings long after a company ceases to operate.

3.1.4 Lead Remediation

The Montevideo Municipality established an agreement with the Faculty of Agriculture of the State University in June 2002 to study the possibility of remediating lead-contaminated urban areas. The remediation technique consisted of applying phosphorus from apatite mineral, a natural compound of calcium phosphate, to the contaminated soil. Apatite (with lead) forms a mineral called piromorphite. The resulting mineral is less bioavailable because it is an insoluble lead compound that is not easily absorbed by humans.

In 2002, major work was undertaken to diagnose the degree of contamination at selected sites in the La Teja neighborhood. Remediation and follow-up took place during 2003 (IMM 2003).The final report of the Faculty of Agriculture was scheduled for delivery late in 2004 but is not yet available.

3.1.5 Groundwater

In September 2003, the Montevideo Municipality, along with the National Mining and Geology Direction of the Ministry of Industry and Energy, agreed to undertake a groundwater study in lead-contaminated areas. Pilot studies were conducted in various neighborhoods to better select areas deserving future attention (IMM 2003). Data from these undertakings are expected in the future.

3.1.6 Other Environmental Projects and Current Action

After 2001, several areas with different landfills of industrial origin (not involving lead scrap) were discovered and were considered a potential health risk because they potentially could turn into slum settlements. The Ministry of Housing and Environment took official action to minimize health and environmental risks in such polluted areas beginning in 2001. Environmental authorities, with help from international sources, established criteria to assess different environmental issues and pollution sites of concerns. Unfortunately, few data from these actions have been published, other than those concerning new environmental lead regulations, as discussed next.

In 2003, an inventory of contaminated sites in a southwest industrial area of Uruguay was assembled by the Ministry of Housing and Environment. The inventoried region once had both lead smelters (recently closed) and a lead-acid battery factory. These sites were environmentally profiled regarding potential exposure risks (DINAMA 2004). The conclusion was that, although there were some cases of negative impact on the environment, they did not demand urgent attention. No further data on this inventory are yet available.

3.2 Research Studies

3.2.1 Children

Several research studies addressed the health status of Uruguayan children in the context of the La Teja neighborhood case.

A study on lead-exposed children was evaluated by Cousillas et al. (2003). The studied population comprised 333 children whose BLLs were analyzed before 2001. These children either lived in polluted areas surrounding smelters, or near high vehicular traffic areas where leaded gasoline was used, or had families working with lead at home. The average age of children studied was 5.9 yr. These children had average BLL values of 15.7 µg/dL; by comparison, 60% of children from all lead-polluted areas studied had BLL values that exceeded the intervention level of 10 µg/dL (CDC 1991).

Cousillas et al. (2005) conducted field studies on randomly sampled volunteer children (0–14 yr) from Montevideo and one rural area of Uruguay. These children were divided into three groups:

- The first group comprised children ($n = 112$) who were presumably only exposed to ambient environmental pollution; these were regarded as a control group. This group represented three residential areas of Montevideo (107 children) and one rural location (5 children) (Table 5).

Table 5 Distribution by age and gender of children exposed only to ambient levels of environmental lead

Center	Children	Number	Age (yr)
Centers I, II, III[a]	Total	107	7.8 (2–14)
	Girls	51	7.6 (3–14)
	Boys	56	7.5 (2–14)
Rural center			
	Total	5	8.0 (6–11)
	Girls	3	8.6 (7–11)
	Boys	2	7.5 (6–9)

[a] Centers I–III represent three residential areas of Montevideo.
Source: Reproduced from Cousillas et al. (2005), with kind permission from Springer Science + Business Media

Table 6 Distribution by age and gender of children known to have had lead exposure

Children	Number	Age (yr)
Total	62	7.5 (0–14)
Girls	25	6.8 (0–14)
Boys	37	7.5 (0–14)

Source: Reproduced from Cousillas et al. (2005), with kind permission from Springer Science + Business Media

- The second group was composed of children (n = 62) who lived in an area known to be contaminated from the operation of an iron and lead scrap smelter (Table 6).
- The third group comprised four siblings (aged 4–13 yr) whose father recycled batteries at home.

Data were collected on each individual, with particular attention paid to age, where they lived and attended school, intensity of traffic near their homes, and smoking habits of their parents.

In the first group (ambient environment), average BLL was 9.4 µg/dL. This level is definitely higher than those reported for correspondingly exposed children in other countries. Approximately 30% of the tested children presented with BLL values above the CDC (1991) intervention level (10 µg/dL). Children from the first group who resided in the rural location had low BLL values, but those BLLs showed an inverse relationship with age (Fig. 4). No significant correlation between BLL and sex was found in this population of Uruguayan children.

Obviously, lead exposure is higher in areas where lead-related industries contributed to the environmental pollution of air, soil, and water. All 62 children in the second group had high BLLs. Soil samples from the second group (residential areas) were analyzed and found to be contaminated; soil lead levels varied from 0.1 to 2.1 mg/g (Schutz et al. 1997). Average BLL in the 62 children from the second

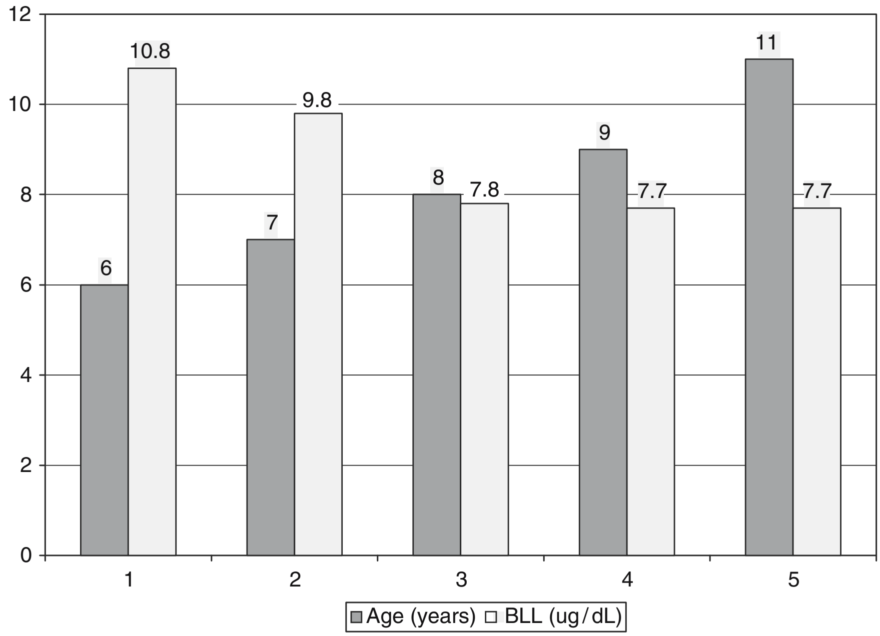

Fig. 4 BLL by age from rural children exposed to lead in the ambient environment. (Adapted from Cousillas et al. 2005, with kind permission from Springer Science + Business Media.)

group was 11.8 µg/dL, with 59% of the children having values above 10 µg/dL and 29% above the WHO Limit Value (15 µg/dL) (OMS 1980).

Results from the third group of children (four siblings) are shown in Fig. 5. All these children had had very high exposure. Lead residues were found in the soil of their garden (86 mg/g) and in window dust samples taken from their home (41 mg/g). Lead body burden was studied (CDC 1991) for these four exposed siblings to determine if treatment with chelates would be appropriate. Such treatment with calcium ethylenediaminetetraacetic acid (EDTA) can dramatically reduce BLL and bone burden. To judge treatment effectiveness, the amount of lead excreted in urine (µg) is monitored in relation to the dose of EDTA administered (mg). The test is positive if the ratio of excretion is greater than 0.6 (calculated as µg Pb excreted in urine/mg Ca EDTA dose). Results were 0.3 (4 yr old), 0.6 (7 yr old), 0.7 (11 yr old), and 0.5 (13 yr old); therefore, the physicians decided not to give the treatment.

Preliminary results comparing BLLs from two similar populations of children, one monitored for exposure in 1994 and the second in 2004, were obtained as described by Alvarez et al. (2005) and Cousillas et al. (2004). BLLs of the 60 children studied (average age, 5.2 yr) in 1994 and of 180 children (average age, 6.3 yr) studied in 2004 were compared to observe differences. Both populations were sampled at the same health care center under similar conditions. Table 7 shows the results obtained for both populations. Results indicated that the children's BLL values diminished in a statistically significant way between 1994 and 2004 ($P < 0.0001$).

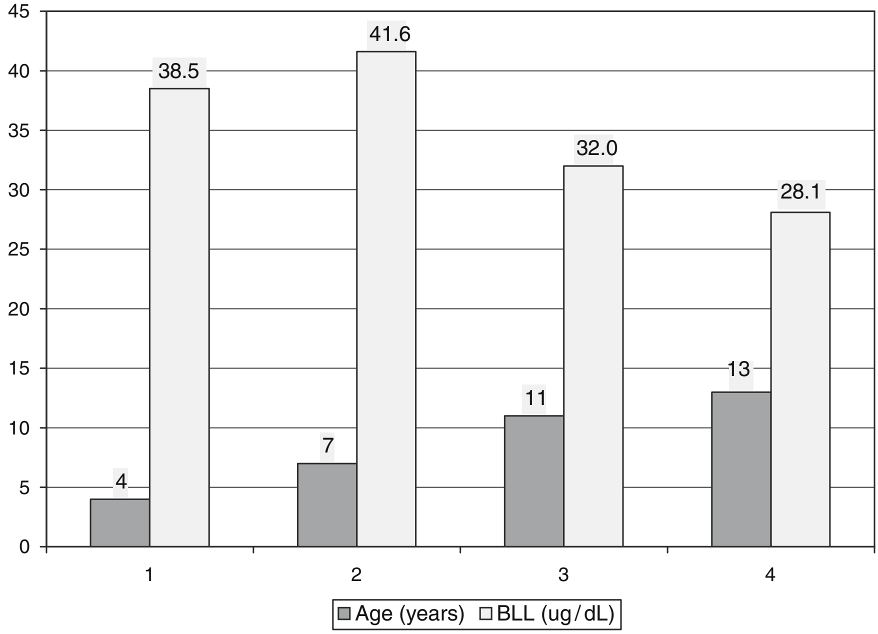

Fig. 5 BLLs by age in four children exposed to lead in their homes. (Adapted from Cousillas et al. 2005, with kind permission from Springer Science + Business Media.)

Table 7 Comparison of BLL between populations of children sampled 10 yr apart

Year	*n*	Average BLL (μg/dL)	% BLL > 10 μg/dL
1994	60	9.9	41.7
2004	180	5.7	6.7

Source: Adapted from Alvarez et al. (2005).

Possible reasons for the BLL decrease include the following:

- After rising concern for lead pollution, beginning in 2001, people became sensitive to the possible effects of lead pollution on children's health and took action to make changes in nutrition and hygiene habits.
- The phase-out of leaded gasoline.
- Action was taken to replace lead water pipes with plastic pipes in many households.

Dol et al. (2004) reported analyses of 44 samples from 15 slum settlements; 19 samples had soil lead levels higher than those recommended for housing by the Canadian guidelines (CCME 2006) (Table 8). The BLL values found in children were directly proportional to the lead level values found in soil (Dol et al. 2004). As part of this study, the Ministry of Health also ordered BLL analysis in children under 15 yr of age when the soil lead levels were found to exceed international limits.

Table 8 Distribution of soil lead levels in soils from various settlements

Lead in soil (mg/kg)	Number of samples	Number of settlements
<140	25	4
140–400	7	3
>400	12	8
Total	44	15

Source: Reproduced from Dol et al. (2004), with kind permission from RETEL.

3.2.2 Workers

Pereira et al. (2003) surveyed studies conducted on workers either exposed to lead or not exposed during 1991–2001. Biological monitoring of blood lead levels was addressed in five different occupationally exposed worker populations ($n=219$), and results from these were compared to those from four control populations ($n=139$).

Results obtained from the five exposed worker populations showed that 60%–95% exceeded the ACGIH reference value. The average BLL obtained from the control populations were also remarkably lower (only 9%–15% exceeded the reference value). This retrospective surveillance clearly demonstrated the need to improve working conditions in Uruguay. At the time this study was published, there was neither official action being taken to redress lead exposure nor specific occupational safety and health assessments being made to address the concern for lead pollution in Uruguay.

3.2.3 Nonoccupationally Exposed Adults

As a consequence of the attention paid to lead pollution after 2001, a need existed for a systematic study of BLLs in the Uruguayan adult population. In particular, reference background data on "unexposed" (those exposed only to background or ambient environmental concentrations of lead) Uruguayans for future research purposes became evident. The Toxicology and Environmental Hygiene Department, together with a private occupational health clinic, undertook an epidemiological study to address the need (Barañano et al. 2005). The research aims were to determine BLLs of working, but nonoccupationally exposed (to lead), adults living in selected areas of Montevideo. Gasoline sampling was also undertaken to measure lead content before and after the phase-out of leaded gasoline (December 2003).

A population of 700 volunteers between 20 and 64 yr who lived in Montevideo was selected for blood lead analysis and monitoring of other health parameters. The city was divided into five geographic sections according to population density, traffic intensity, industrial areas known for handling metals, and meteorological factors such as wind intensity. The results showed an overall average BLL of 5.46 µg/dL (range, 2.0–21.5 µg/dL). Considering that the international reference value for adults in the general population is a BLL less than 25 µg/dL (WHO 1995), this study reveals that these background levels for Montevideo adults are lower than the reference level and also very far below the reference limit of ACGIH for lead-exposed workers (BLL < 30 µg/dL).

3.2.3 Dogs as Sentinels of Lead Pollution

Uruguay still lacks a relevant surveillance screening program for lead-polluted areas. In studying children's risk of lead exposure, Mañay et al. (2005) discovered that dogs can be very useful as sentinels for environmental lead pollution. Dogs may show early symptoms of lead intoxication at statistically significant lower BLLs than those found in children. Moreover, dogs can also have significantly higher BLL than those in children when exposed to and living in the same polluted area.

Two populations of dogs were studied: a preliminary group of stray dogs ($n = 48$), and a main group comprising randomized stray dogs ($n = 49$) and pet dogs ($n = 151$). BLLs were determined for all animals to evaluate the significance of variables such as age, sex, size, area of residence, and possible sources of lead and lead-related symptoms. Associations between BLL and single variables were then evaluated using statistical analysis.

Simultaneously, a BLL surveillance screening study on Uruguayan children was underway for an advisory report to the Municipality as described by Cousillas et al. (2003) and Mañay et al. (2005). This screening study was also made up of two groups, a preliminary one (n = 34); and a main group (n = 134), both randomly selected in the same way as were dogs. This similarity allowed the authors to compare BLL in dogs with those in children. Both studies were performed independently with comparable parameters and also included internal and external quality controls for the analytical methods and data processing.

The results (Table 9) showed higher BLL for dogs (mean, 16.3 µg/dL) than for children (mean, 9.7 µg/dL). The number of dogs with BLL <greater than> 10 µg/dL was 40% greater than for children. Significant statistical relationships between

Table 9 BLL in comparable studies with dogs and children: (I) preliminary study; (II) main study

Dogs	*n*	Mean (µg/dL)	BLL > 10 µg/dL (%)
Stray dogs (I)	48	14.6	81
Stray dogs (II)	49	16.3	84
Pet dogs (II)	151	16.0	56
Children	***n***	**Mean (µg/dL)**	**BLL > 10 µg/dL (%)**
Total (I)	34	9.5	59
Total (II)	134	9.7	35
Girls (II)	38	9.4	32
Boys (II)	96	9.8	36
< 6 years of age	37	10.8	69
≥ 6 years of age	33	9.0	28

Source: Adapted from Mañay et al. (2005).

BLL in dogs were discerned for the following variables: age ($P < 0.001$), size ($P < 0.0001$), area of residence ($P < 0.01$), and lead-related symptoms ($P < 0.0001$). Similar statistical correlations for age, sex, area of residence, traffic intensity, and parental smoking habits were also observed for children. Correlations in BLL between pet dogs and children were tested in 12 La Teja neighborhood homes inhabited by lead-exposed families. BLLs in pet dogs were significantly higher than those for children living in the same family ($P < 0.01$) (Fig. 6).

It was concluded that a systematic surveillance on BLL in dogs can be a very useful tool to prevent and assess lead risk for children when alternatives are not available. This procedure has several advantages: lower cost than some environment screening programs such as biomonitoring (children) or analyzing environmental samples (e.g., soil, air and water); the greater sensitivity to lead of dogs; and the technique is an *in vivo* method that directly correlates to lead bioactivity. The use of dogs as sentinels may also be useful to health and environment authorities in developing countries as a first step to diagnose lead pollution problems.

3.2.4 Changes of BLL in Uruguayan Populations

Lead exposure risks have been a matter of public concern in Uruguay since 2001 when lead pollution first received official attention. In response to the public con-

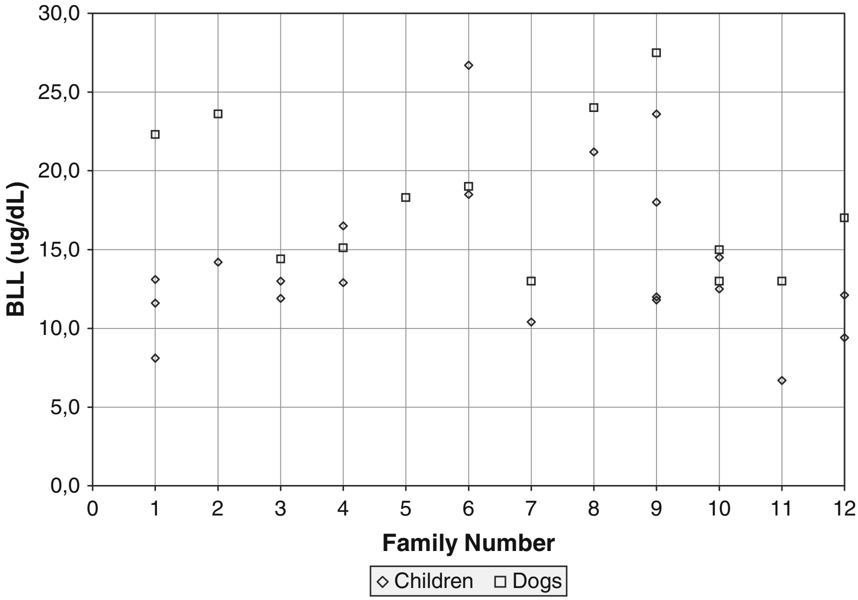

Fig. 6 BLLs in pet dogs and children from 12 "La Teja" neighborhood families. (Adapted from Mañay et al. 2005.)

cern, social and political action was taken and included creation of new regulations designed to provide for health risk management and control.

Consistent with actions to reduce public exposure to lead, Mañay et al. (2006) reviewed several studies and compared changes in BLLs in Uruguayan populations over a 10-yr period. This report included comparisons of similar populations (children, exposed and unexposed adults, and lead workers) that were sampled within this 10-yr period. BLL determinations were performed by the toxicology team at the Faculty of Chemistry using appropriate quality control methodology.

The study, which was carried out in 2004, involved sampling three populations: children (n = 180), nonoccupationally exposed adults (n = 714), and lead workers (n = 81). A framework was established to correlate BLL with variables such as age, sex, area of residence, available environmental lead data, and possible lead exposure sources (Table 10). To assess the change in risk, analytical results were statistically compared with similar screening study results performed in 1994. Blood samples were analyzed using atomic absorption spectrometry with appropriate quality controls. Results showed significantly lower BLL levels in children (5.7 μg/dL) and nonoccupationally exposed adults (5.5 μg/dL) than similar populations sampled in 1994 (9.9 μg/dL and 9.1 μg/dL, respectively). Children in 1994 showed a positive relationship between BLL and traffic intensity, and 40% of their BLL exceeded 10 μg/dL, while in 2004, only 7% were above that intervention level. These changes suggest a decrease is occurring in the contribution of environmental lead to the overall exposure of children and nonoccupationally exposed adults in Uruguay.

Workers occupationally exposed to lead did not show significant BLL differences between 1994 and 2004, and they showed mean values (49.0 Pb μg/dL vs. 42.0 Pb μg/dL, respectively) that exceeded the ACGIH Biological Exposure Index (BEI) of 30 μg/dL. It is concluded, from this comparative study, that although Uruguay still lacks a surveillance screening program for lead-polluted areas, significant improvements in preventing nonoccupational lead exposure have been made. This outcome can presumably be attributed to the phase-out of leaded gasoline and to improvements in nutrition, hygiene, and related habits for children as well as a favorable response to the official multidisciplinary actions taken. New laws have also been approved to address lead occupational exposure that require lead content of blood to be periodically monitored as part of the workers health certificate protocol.

Table 10 BLL from different Uruguayan human populations sampled in 2004 versus reference limit values and incidence above those limits

Populations (2004)	n	Average BLL (μg/dL)	Range of BLL (μg/dL)	Reference BLL (μg/dL)	BBL> reference (%)
Children	180	5.7	3.0–16.0	>10	6.7%
Nonoccupationally exposed adults	714	5.5	3.0–24.0	>25	0%
Occupationally exposed adults	81	41.9	9.0–69.0	>30	76.5%

Source: Reproduced from Mañay et al. (2006), with kind permission from Metal Ions in Biology and Medicine, vol 9

4 Legal Framework

At present, lead pollution issues in Uruguay are managed under several new regulations.

4.1.1 Law N° 17.774

"Lead in Blood Analysis in Exposed Workers" (Legislative Power 2004a) states that the determination of BLLs is mandatory and must be included in the examinations for workers health certificates. The law requires venous blood to be sampled and analyzed only by laboratories officially recognized by the Ministry of Health.

Workers with high exposure risk (foundries, lead battery factories, plumber soldering of lead, among others) must have their BLL checked twice annually. Workers with medium exposure must have BLL checked annually, whereas those with low exposure are checked every 2 yr. Office workers from lead industries may also be monitored, but at less frequent intervals than those mentioned. Another important legal change requires plumbism to appear on the list of diseases reportable by physicians to the Ministry of Health and to the State Insurance Agency.

In addition, this law addresses other procedures important to managing lead exposure. For example, there are recommendations for proper lead-bearing dust cleanup (wet instead of dry aspiration), handling of production process waste, recycling, or storage. Moreover, this law establishes some mandatory precautions, e.g., industrial effluents must be collected and evacuated in closed pipelines to prevent environmental pollution; wastes and effluents must be removed to treatment plants; and extraction devices must contain proper filters and be of a height to prevent exposure by inhalation.

There is a specific prohibition against lead solid wastes going to landfills, or being stored in buildings or other facilities, if such waste poses a risk to the public health or environment. Furthermore, new occupational rules require employers to provide separate dressing rooms for exposed workers; street and work clothes must be separated and work clothes must be washed separately.

Before eating, workers must change clothes and dining rooms must be independent from associated work areas. Employers must also provide workers with the proper clothing, shoes, gloves, or other necessary protective equipment.

4.1.2 Law N° 17.775

This law addresses other lead contamination issues: "Prevention of Lead Contamination" (Legislative Power 2004b).

- After December 31, 2004, gasoline with more than 13 mg/L lead is banned. New motor vehicles must be adapted to use unleaded fuel, and leaded gasoline must be fully removed from all dispensatories (gas stations) after December 2004.

- Lead-bearing paints cannot contain more than the maximum lead level allowed by a future ruling.
- Containers with leaded products must carry a label in Spanish, which must give the lead content and provide precautionary directions for use.
- Pipes for the distribution of water intended for human or animal use must not be made of lead, and alternative materials (i.e., plastics, galvanized iron) must not contain more than 8 % Pb; the rule also sets a maximum limit of lead in solder of 0.2%.
- Lead is banned from toys and other products used directly and frequently by children and adolescents.
- It is forbidden to store food, whether produced locally or imported, in leaded containers.
- All lead-containing products must be clearly so labeled, including the percent of lead content.
- A national register must be kept for all lead processing industries and commercial lead-containing products, including origin, storage, transit, and destination of such products.
- The law prohibits the disposal or deposit of lead-containing wastes in soil without permission. The Ministry of the Environment, together with the Municipalities, are responsible for the survey and analysis of soil in contaminated areas.
- Lead-containing storage batteries must be returned to the producers or importers after use for proper disposal; noncommercial storage batteries must be delivered to the Municipalities.

In 2002, a National Commission was created to survey, using a multidisciplinary approach, potential areas with lead (or other chemical) contamination for the purpose of taking preventive actions necessary to preserve human health. This Commission, officially at work since 2003, is composed of members from the Ministry of the Environment, Ministry of Health, Ministry of Work and Social Security, Ministry of Industry and Energy, University of the Republic, Congress of Municipalities, and Bureau of Planning and Budget, and it is led and coordinated by the Public Health Care Division of the Ministry of Health.

In 2004, the Ministry of Health issued a National Code concerning mandatory declaration of diseases associated with lead (national decree 64/004) and established a maximum permitted BLL of 15 μg/dL. The decree also included exposure risk limits for other pollutants, such as mercury, and some pesticides (Executive Power 2004). Also in 2004, a health ministerial decree (337/004) established reference values for health vigilance of chemically exposed workers. In this document, biological monitoring of BLLs is asked for; the maximum limit for BLL was set at 30 μg/dL (MSP 2004).

Another decree, number 373/2003, regulates the disposal of lead-acid batteries. It was issued by the National Direction for the Environment (DINAMA) of the Ministry of Housing and Environment (Executive Power 2003). Among its many articles, this decree requires management, recovery, and appropriate final disposition of batteries or electric storage batteries of lead-containing components and acid, to be carried out in a manner that will not damage the environment. The decree also prohibits the placement, storage, transportation, or improper processing of lead-containing batteries. The decree implements a master plan for recovery, return, and/or final destination of used batteries. At the same time, users or final consumers or holders of used batteries should return such batteries only to special reception centers capable of properly handling them. Batteries are also banned from disposal in home waste. Several examples of registration forms to gain approvals of disposal activities controlled by the National Direction for the Environment from the Ministry of Environment are also provided for by the decree.

5 Summary

Lead, ubiquitous in the environment as a result of mining and industrialization, is found as a contaminant in humans although it has no known physiological function there. Lead-exposed children are known to be the population with the highest potential health risks. The recommended biomarker to assess environmental lead exposure in animals is lead level in blood. Before 2001, the Department of Toxicology and Environmental Hygiene was the only team to produce human monitoring data on Uruguayan populations (Manay 2001a,b; Mañay et al. 1999).

Lead pollution in Uruguay first received official attention during the 2001 La Teja poisoning episode. It was in the La Teja neighbourhood of Montevideo that high BLL were found in children (as high as 20 μg/dL), prompting corrective responses from Health and Environmental authorities.

Growing awareness of environmental lead pollution and consequential human health effects from that event, resulted in public debate and demands for solutions from Health and Environmental authorities. Citizens demanded public disclosure of information concerning lead pollution and wanted action to address contaminated Uruguayan sites. In response, the Ministry of Health assembled an interinstitutional multidisciplinary committee, with delegates from health, environmental, labor, educational, and social security authorities, as well as community nongovernmental organizations (NGOs), among others. The University of the Republic was designated to serve as the main responsible entity for technical advice and support.

After 2001, new research on lead pollution was undertaken and included multidisciplinary studies with communities in response to health risk alerts. The main emphasis was placed on children exposed to environmental lead.

Major sources of Uruguayan lead contamination, similar to those in other developing countries, result from metallurgical industries, lead-acid battery processing, lead wire and pipe factories, metal foundries, metal recyclers, leaded gasoline (before December 2003), lead water pipes in old houses, and scrap and smelter solid wastes, among others. Nonoccupational lead exposure usually results from living in or near current or former manufacturing areas or improper handling of lead-containing materials or solid wastes (a particularly important health risk for children).

In this chapter, we reviewed available studies published or reported after the pollution events first announced in 2001. These studies include data on exposure, health, and actions taken to mitigate or prevent lead exposure from pollution events in Uruguay. Uruguay adopted CDC’s 10 µg/dL as the reference BLL for children (CDC 1991) and a BLL of 30 µg/dL for workers (from the ACGIH standard). Environmental authorities adopted the Canadian reference concentrations for soil: residential and playgrounds (>140 mg/kg) or industrial areas (>600 mg/kg) (CCME 2006).

Most studies reviewed addressed soil pollution as the main source of lead exposure. Results of thousands of analyses indicated that most children had BLL above reference intervention limits. A significant decrease in BLL was also found over time in the study results, demonstrating the importance of medical intervention, nutrition, and environmental education. The severity of lead pollution discovered required official governmental actions, both to reduce sources of lead contamination and to address the health implications for children who had been exposed to environmental or industrial lead pollution.

Dogs were discovered to be useful sentinels for environmental lead pollution; they had higher BLL than children when exposed to the same polluted environment and developed symptoms of lead intoxication earlier and at lower BLL than did children. This same pattern was also observed in families with children and pet dogs living in the La Teja neighborhood. This discovery renders dogs prospectively useful in lead pollution monitoring and diagnosis, particularly in developing countries.

BLL results from similar human lead exposure studies conducted 10 yr apart showed significant BLL reductions, after 10 yr, for nonoccupationally exposed Uruguayans. The phase-out of leaded gasoline is thought to have contributed to this improvement.

New laws to address occupational and environmental exposures were passed to prevent new cases of lead contamination, and new research studies are underway to monitor lead pollution. Moreover, a systematic surveillance screening program for lead workers and children is planned, although it is not yet underway. The sensitization of the public to the lead pollution problem has been a key driver of governmental action to mitigate and prevent further lead pollution in Uruguay.

The changes made since 2001 appear to have yielded positive results. BLL from different populations studied more recently show decreased lead levels, suggesting a lower contribution of environmental lead to exposure of children and nonoccupationally exposed adults. The diverse analytical data collected on lead pollution in Uruguay between 2001 and 2004 were the main ingredient that allowed effective identification of lead pollution in Uruguay and paved the way for official intervention to prevent new pollution events. Nevertheless, full research studies must still be done, including both spot analysis of environmental soil, air, and water samples, and extensive screening of BLL.

Future health and environmental actions are needed, not only to remediate known areas of lead pollution, but also to investigate other sources of potential health risks.

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