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# The El Paso Smelter 20 Years Later: Residual Impact on Mexican Children

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**Although there has been considerable concern regarding cross-border industrial contamination between Mexico and the United States, there are remarkably few data. One notable case study is the smelter in El Paso, Texas. In 1974 blood lead levels higher than 40 μg/dl were detected in 52% of children studied near the smelter, in the adjacent Mexican community of Anapra in Ciudad Juarez, Chihuahua. Lead smelting at this plant was halted in 1985, and as a result, lead levels in air decreased sharply; consequently, children's exposure to lead and other metals should have diminished accordingly. In order to assess the effect of removal of lead emissions from the area, three geographical locations in Anapra, varying in distance from the smelter source, were evaluated for lead, arsenic, and cadmium levels in soil and for lead in blood of children. It was found that lead levels in soil were inversely correlated with distance from the smelter. Arsenic and cadmium levels in soil were constant among the three sectors. However, at residential sites closer to the smelter, a higher percentage of children was found with blood lead levels exceeding the Centers for Disease Control's action level of 10.0 μg/dl. In the sector closest to the border 43% of children had blood lead levels greater than 10.0 μg/dl. Although blood lead levels in children living in Anapra have dropped approximately fourfold in 20 years, our results indicate a moderate continued risk of lead exposure. This study demonstrates the persistent impact that may result from cross-border contamination and raises provocative questions regarding appropriate action and the responsibility for financing such action.** 

## INTRODUCTION

Much public attention has been focused on the environmental impact of increased industrialization associated with North American economic integration within the Free Trade Agreement. Although there has been a large increase in the number of industries and in the population on the Mexico–United States border within the past 20 years, especially on the Mexican side, there are remarkably few data on exposures or on the health impacts resulting from industrial development in this region.

In El Paso, Texas, located on the Mexico–United States border, a smelter has been in operation since 1887 (Landrigan and Baker, 1981). The smelter has over time been the source of airborne metals contaminating the area. According to the El Paso City–County Health Department, over the 3-year period from 1969 to 1971 alone, the smelter emitted into the atmosphere 1012.0 metric tons of lead, 11.0 tons of cadmium, and 1.0 ton of arsenic (Landrigan and Baker, 1981).

A 1974 study conducted in Anapra, Ciudad Juarez, a Mexican community located directly across the Rio Grande River from the El Paso smelter, reported blood lead levels higher than 40 μg/dl in 52% of children studied within a 1-mile radius of the smelter (Ordoñez *et al.,* 1976). Mean soil lead levels within this radius were reported to be 492.0 mg/kg (Ordoñez *et al.,* 1976). At that time, air lead concentrations were extremely high. During 1971 mean air lead concentration, measured at the property boundary downwind of the smelter, was 92.0 $\mu g/m^3$ (range 15 to 269 $\mu g/m^3$; Landrigan and Baker, 1981).

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In August 1985, the smelting of lead at the facility was halted (TNRCC, 1994). Furthermore, the U.S. Environmental Protection Agency ordered the reduction of almost all lead in gasoline during the 1970s (CDC, 1991), and in 1985, use of leaded additives in gasoline was suspended (MacGregor and Mielke, 1995). As a result of these actions, lead levels in air decreased sharply, and since 1986, the City of El Paso has met the United States standard for airborne lead (1.5 $\mu$g/m$^3$) (TACB, 1992).

Leaded gasoline in Mexico has been an important source of lead until recently. The reduction of lead additives in Mexican gasolines started in 1980 and during 1990 an unleaded gasoline was introduced (SEDESOL, 1992). At present, two types of gasoline are used in Mexico, unleaded and "nova," which contains 0.5–1.0 ml of tetraethyl lead per gallon (Romieu *et al.*, 1994). New automobiles sold in Mexico require unleaded gasoline. Although there have been no studies about the impact of the continued use of leaded fuel on airborne lead in the Anapra area, it is reasonable to assume that there has been a decreasing contribution to airborne lead since 1991, when unleaded gasoline became available in all gas stations.

This study evaluates lead exposure in children living in Anapra, in order to assess the exposure to this metal due to long-term and residual contamination, now that the El Paso smelter no longer emits lead.

## METHODS

*Study areas.* The study was carried out in Anapra, a semirural, arid, and dusty community in Ciudad Juarez, Chihuahua, Mexico. This impoverished community has poor housing built of cardboard sheets, wood, and adobe brick. It lacks potable water, sewage systems, paved streets, or local medical services. Educational level is low, and rates of unemployment are high. For the study, Anapra was divided into three sectors of increasing distance from the smelter: sector I within 600 m, sector II between 600 m and 1200 m, and sector III between 1200 m and 1800 m (see Fig. 1). A control area was identified 25 km away from the smelter.

*Selection of children.* Families were selected at random within the overall study area. From these families, all children between 5 and 13 years of age with at least 2 years residency in the Anapra area were invited to participate; 44 children were eventually included in the study. All parents filled out a lead exposure questionnaire modified from a questionnaire previously used in studies in Mexico (Hernández-Avila *et al.*, 1991).

*Biological samples.* Blood was obtained by venous puncture using lead-free tubes containing EDTA as anticoagulant.

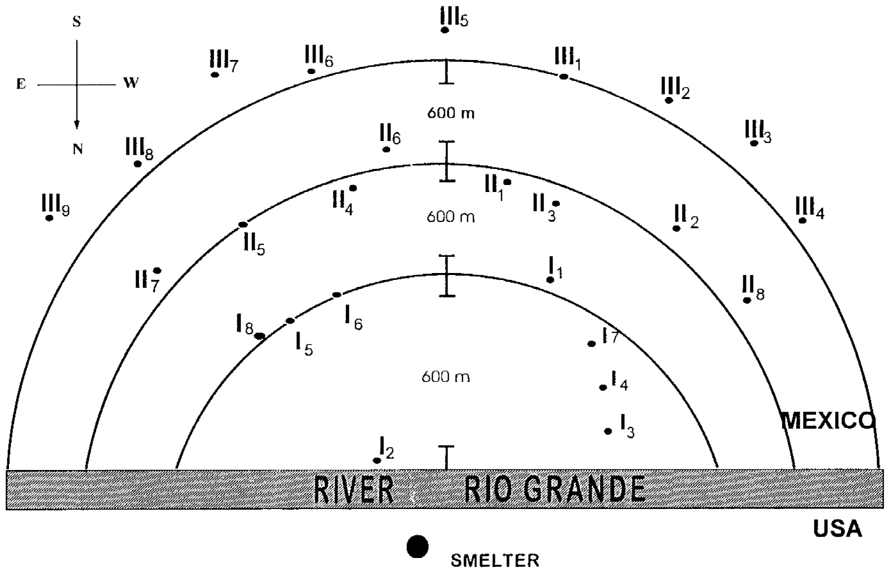


**FIG. 1.** The community of Anapra, on the Mexican side of the border, was divided into three sectors of increasing distance from the smelter. Sector I, within 600 m. Sector II, between 600 m and 1200 m. Sector III, between 1200 m and 1800 m. Mexico and the United States are divided by the Rio Grande River. The position of the smelter in El Paso, Texas, is shown with a big dot. The sites of environmental and biological sampling were the same (see Methods). They are numbered in each sector in the map.

*Environmental monitoring study.* From each sector at least four surface soil samples were obtained in areas repeatedly used by children. Household dust from window sills was collected in each sector, from residences selected at random among those where the children in the study reside.

*Analytical methods.* Soil and household dust samples were treated by microwave digestion in the presence of a 25% nitric acid solution. Lead in blood was analyzed with matrix modifier (diammonium hydrogenphosphate–Triton X-100 in the presence of 0.2% nitric acid) according to Subramanian (1987). All the analyzes were done with a Perkin–Elmer 2380 atomic absorption spectrophotometer. A graphite furnace was used for cadmium and lead; arsenic was analyzed by the hydride evolution technique.

*Quality control considerations.* Analysis of primary standard reference material in each run was conducted as an internal quality control. For soil/dust, NIST-SRM 2710 (Montana soil) was used with recoveries of 96% for lead; 97% for arsenic; and 95% for cadmium. The laboratory conducting blood lead analysis participates in the blood lead proficiency testing program of the Centers for Disease Control. Each sample was analyzed in duplicate. Distilled–deionized water was used for all analytical work, and glassware and other materials were soaked in 10% nitric acid, rinsed with doubly distilled water, and dried before use.

*Estimates of lead exposure.* The Integrated Exposure Uptake Biokinetic Model for Lead in Children of the Environmental Protection Agency (USEPA, 1994) was used with the following modifications. *For the year 1974:* air [outdoor air concentration, 92.0 $\mu g/m^3$ (Landrigan and Baker, 1981); time outdoors, 6.0 hr]; diet [9.3 $\mu$g Pb/day (Batres *et al.*, 1995)]; water [lead concentration 3.5 $\mu$g/L; water consumption 1.0 L/day]; soil/dust [soil concentration 492.0 $\mu$g/g and house dust concentration 1322.0 $\mu$g/g (Ordoñez *et al.*, 1976); soil ingestion 350 mg/day and percentage soil:dust 66% (Yáñez *et al.*, 1996)]. *For the year 1994:* air [outdoor air concentration, 0.13 $\mu g/m^3$ (TACB, 1994); time outdoors, 6.0 hr]; diet [9.3 $\mu$g Pb/day (Batres *et al.*, 1995)]; water [lead concentration 3.5 $\mu$g/L; water consumption 1.0 L/day]; soil/dust [soil concentration 302.0 $\mu$g/g and house dust concentration 285.0 $\mu$g/g (this study); soil ingestion 350 mg/day and percentage soil:dust 66% (Yáñez *et al.*, 1996)]. As can be observed, for the calculations for 1994, the model was used only with the values of sector I, which is located less than 600 m from the plant.

*Statistical analysis.* Simple linear regression was used to estimate the association between soil lead levels, distance to the smelter, and blood lead concentrations. Differences in soil lead levels in the three sectors were examined by analysis of variance (Kruskal-Wallis test). A $\chi^2$ test for trend was used to investigate the proportion of blood lead levels exceeding 10 $\mu$g/dl with respect to sector (distance to the smelter). For statistical analysis, the blood lead levels were log transformed. The SPSS-PC statistical package was used for these analyses.

## RESULTS

Lead levels in surface soil were inversely correlated with distance from the smelter, and the mean value in sector I was seven times higher than the background level (Table 1). In the 1974 study, lead soil concentration 1 mile from the smelter was reported to be 492 mg/kg (Ordoñez *et al.*, 1976). In this work, lead levels for a similar sector were found to be 270 mg/kg (mean value of sector I + sector II). With respect to household dust, no correlation between distance from the smelter and lead levels was found in the present study (Table 1).

Arsenic and cadmium mean levels in surface soil and household dust were similar in all three sectors; nevertheless, soil levels in Anapra were two to three times higher than respective background levels (Tables 2 and 3).

Blood lead levels in children living in Anapra are shown in Table 4. Although little difference in mean blood lead levels was observed among the sectors, a higher percentage of children with blood lead levels above 10.0 $\mu$g/dl was observed as the distance from

**TABLE 1**

**Lead Levels in Surface Soil and Household Dust**

| | *n* | Mean | SD | Range |
|---|---|---|---|---|
| Soil | | | | |
| Sector I | 6 | 302 | 111 | 150–425 |
| Sector II | 8 | 241 | 174 | 28–537 |
| Sector III | 8 | 81 | 58 | 31–197 |
| Control | 3 | 43 | 21 | 26–73 |
| Dust | | | | |
| Sector I | 3 | 285 | 8 | 280–295 |
| Sector II | 7 | 356 | 176 | 215–721 |
| Sector III | 9 | 202 | 121 | 21–363 |

*Note.* Concentrations in mg/kg. The control sector was located 25 km away from the smelter in a nonpolluted area. Levels in surface soil were inversely correlated with distance from the smelter ($P = 0.003$).

**TABLE 2**
**Arsenic Levels in Surface Soil and Household Dust**

| | *n* | Mean | SD | Range |
|---|---|---|---|---|
| Soil | | | | |
| Sector I | 8 | 25.2 | 17.1 | 5–51 |
| Sector II | 7 | 21.4 | 14.7 | 3–36 |
| Sector III | 4 | 19.5 | 6.2 | 13–27 |
| Control | 3 | 8.6 | 6.7 | 2–18 |
| Dust | | | | |
| Sector I | 4 | 38.7 | 17.5 | 30–65 |
| Sector II | 6 | 29.5 | 23.0 | 3–67 |
| Sector III | 4 | 18.7 | 6.5 | 13–27 |

*Note.* Concentrations in mg/kg.

the smelter decreased. Blood lead distributions for each sector are depicted in Table 5.

Blood lead levels found in this study were markedly different from those found in 1974 (Ordoñez *et al.*, 1976). Considering that this difference is likely due to the reduction in the air lead concentration, USEPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) (USEPA, 1994) was used to estimate the lead exposure in Anapra. Since estimates provided by the model agreed with the real values for blood lead levels in 1974 and 1994 (Table 6), we applied the model to estimate the contribution of sources for lead uptake for those years. The results from the model are illustrated in Table 7. Total lead uptake estimated for 1994 was four times lower than that for 1974. During 1974, air was the principal pathway of exposure, and soil/dust was the second most important. During 1994, soil/dust became the main pathway and air was the least important pathway of exposure to lead.

## DISCUSSION

The results of this study confirm the expected decrease of lead exposure in children in Anapra due to the reduction of lead emissions from the El Paso smelter. However, a significant percentage of children still have blood lead levels higher than the Centers for Disease Control's action level of 10.0 μg/dl (CDC, 1991). An inverse correlation with distance to the smelter was found for the percentage of children having blood lead levels higher than 10.0 μg/dl. Although this suggestive trend was only marginally statistically significant ($P = 0.09$), the power of the study is limited by the relatively small sample size.

Since airborne lead from the smelter is no longer a major source of contamination, it is important to identify the current source of lead exposure for this population. Soil lead levels clearly increase as the distance to the smelter decreases; however, this pattern was not seen in household dust. Thus, this study suggests that the primary source of lead now is contaminated soil. Measured lead levels in dust may not be different between sectors, either as a result of random nonrepresentativity of the small number of dust samples collected or as a result of the windy conditions in Anapra.

The importance of soil as the source of lead is consistent with estimated lead uptake from the IEUBK model, which estimates that 82.7% of the total lead uptake in children is attributable to lead content in the soil. The model's predicted mean blood levels agreed with the results found in this study. Although there are some limitations to the IEUBK modeling results, given the lack of comprehensive data, particularly for 1974, apparently there has been a shift in the relative importance of air and soil as sources of exposure.

**TABLE 3**
**Cadmium Levels in Surface Soil and Household Dust**

| | *n* | Mean | SD | Range |
|---|---|---|---|---|
| Soil | | | | |
| Sector I | 8 | 6.9 | 5.5 | 0.5–16 |
| Sector II | 7 | 8.2 | 4.5 | 1–13 |
| Sector III | 4 | 5.5 | 3.7 | 2–9 |
| Control | 3 | 2.5 | 2.2 | 0.4–6 |
| Dust | | | | |
| Sector I | 4 | 10.0 | 4.4 | 6–15 |
| Sector II | 6 | 6.8 | 4.8 | 0.1–12 |
| Sector III | 4 | 6.2 | 1.0 | 5–7 |

*Note.* Concentrations in mg/kg.

**TABLE 4**
**Blood Lead Levels in Children Living in Anapra (μg/dl)**

| | *n* | Mean | SE | Range | Children with Pb levels ≥10 μg/dl |
|---|---|---|---|---|---|
| Sector I | 7 | 9.9 | 3.1 | 6–16 | 43% |
| Sector II | 19 | 7.9 | 3.1 | 4–16 | 21% |
| Sector III | 18 | 7.8 | 3.2 | 5–19 | 11% |

*Note.* Age range, 5–13 years. Results are presented as geometric means and standard errors. Test for trend ($\chi^2$) $P = 0.09$.

**TABLE 5**
**Distribution of Blood Lead Levels in Children Living in Different Sectors of the Anapra Area**

| Sector | Blood lead levels (μg/dl) <10.0 | 10.0–15.0 | >15.0 |
|---|---|---|---|
| I | 57% | 29% | 14% |
| II | 79% | 16% | 5% |
| III | 89% | 6% | 5% |

**TABLE 6**

**Blood Lead Levels for Children Living in Anapra: Comparisons between the IEUBK Model Estimations and Real Values for 1974 and 1994**

| | $\mu$g/dl | >40 $\mu$g/dl |
|---|---|---|
| 1974 | | |
| Model predictions (age 1–7 years) | 40.6 | 52.4% |
| Real values (age 1–9 years)[a] | 38.7 | 51.7% |
| 1994 | | |
| Model predictions (age 5–7 years) | 9.7 | 42.7% |
| Real values (age 5–7 years)[b] | 9.7 | 33.3% |

[a] Mean value (from Ordoñez *et al.*, 1976).
[b] Geometric mean found in this work among six children of sector I. USEPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children was used, with the modifications described under Methods. The model predicts geometric means.

Although the levels of lead in soil found in Anapra now are not as high as those found in other areas contaminated by lead smelting (Díaz-Barriga *et al.*, 1993; Hartwell *et al.*, 1983; Baker *et al.*, 1977), they exceed the 250 mg/kg level recommended in areas without grass cover (such as Anapra) and repeatedly used by children below 5 years of age (Madhavan *et al.*, 1989). The soil and household dust concentrations of arsenic and cadmium were not of health concern, although they were higher than their respective background levels.

The El Paso smelter historically has been the most important source of lead exposure in the area, and the soil lead concentrations are consistent with smelting activity which has demonstrably contaminated both sides of the border for 100 years. This study, like previous studies in this area, demonstrates significant cross-border industrial contamination. Furthermore, it shows how persistent the impact of such exposure can be, even after the source of contamination has been controlled.

The risk of modestly increased exposure to lead associated with residence in the Anapra area may represent a public health hazard, as this metal has been shown to cause serious health effects at low levels. Of principal concern is the decrement in intelligence quotient in exposed children (ATSDR, 1993; CDC, 1991). Indeed, one of the early studies which demonstrated an impact of lead on intelligence was conducted on the United States side of the border in the community surrounding the El Paso smelter (Landrigan *et al.*, 1975).

**TABLE 7**

**Lead Uptake Estimations for Children Living in Anapra during 1974 and 1994**

| | 1974 | 1994 |
|---|---|---|
| Total uptake ($\mu$g/kg) | 129.0 | 30.8 |
| Soil/dust[a] | 42.5% | 82.7% |
| Air[a] | 54.2% | 0.3% |
| Diet[a] | 2.4% | 12.4% |
| Water[a] | 0.9% | 4.6% |

[a] Percentage of total uptake. Results were obtained with the USEPA's Integrated Exposure Uptake Biokinetic Model for Lead in Children, as stated under Methods. Data are for children 36–48 months.

One of the limitations of the current study was the relative difficulty in obtaining participation by younger children, who are more likely to eat soil and dust, and who therefore may have higher lead levels than those studied. The participation by children younger than 5 years of age, who are at high risk of neurological damage, would make for a more conclusive comparison to previous studies of children living near the smelter. Such participation might be facilitated as part of a public health screening campaign and other remedial actions, such as paving the streets or planting ground cover.

Such a public health campaign might raise interesting questions within the context of the North American Free Trade Agreement, questions which include the extent of corporate responsibility for cleanup activities in a foreign country, the appropriate legal standards (Mexican or United States) which may apply to such responsibility, whether it is pertinent to limit growth in contaminated areas, and who should bear the cost of such restrictions which may result from industrial contamination. Finally, it is appropriate to ask whether it is convenient to invest remediating the modest overexposure to lead in a community where a greater beneficial impact on health might be achieved by investment in potable water and sanitation. Although these questions are still hypothetical, the Anapra experience provides a concrete example of the necessity for a legal framework which will answer these and other related questions within the context of the Free Trade Agreement.

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