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Lead exposure in an urban community: Investigation of risk factors and assessment of the impact of lead abatement measures ☆

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Abstract

Introduction: A battery recycling plant located in an urbanized area contaminated the environment with lead oxides. The Secretary of Environment of the State of São Paulo demanded an evaluation of lead exposure among the population in the vicinity of the plant.
Objectives: To assess the lead exposure of children, to propose control measures and evaluate the impact of these measures.
Methods: Cross-sectional study of all children < 13 years old in a radius of 1 km from the plant responsible for the contamination. Blood lead levels (BLL) were determined for each child and questionnaires were applied to their parents. Mean BLL were compared before and after control measures were implemented. Logistic regression identified risk factors of lead exposure.
Results: Of the 850 investigated children, 311 presented BLL above the action limit established by the World Health Organization. Overall, the median BLL was 7.3 μg/dL and it varied according to age of children (higher among 1–5 years old) and distance of the residence from the plant. Risk factors identified for BLL > 10 μg/dL were: to live in unpaved areas, parent working in the plant, distance from the plant, to play on the ground, pica, and to drink locally produced milk. After control measures were implemented (closing the plant, soil removal, dust vacuum-cleaning in the households, etc.), a reduction of 46% in BLL was observed considering the 241 re-evaluated children with levels > 10 μg/dL.
Conclusions: This study showed that combined abatement measures were effective in reducing BLL in children living close to a contaminating source. These results informed the decision-making process regarding management of contaminated areas in Brazil.

Keywords: Lead; Child; Contaminated areas; Surveillance; Intersectorial approaches

1. Introduction

Lead, even in low concentration, can affect the children central nervous system, causing retarding psychomotor development, reducing hearing capacity, and impairing learning and cognitive capabilities (Bellinger et al., 1987; Needleman et al., 1990). Nutritional factors and personal habits can influence lead absorption, increasing risk of

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intoxication especially in low income family children (Mahaffey, 1995; Gallicchio et al., 2002).

Since 1979 Brazil has progressively substituted tetra-ethyl-lead in gasoline by ethanol (Paoliello and De Capitani, 2005). It has also replaced lead-based soldering in food cans by heating and electronic soldering (Brasil, 1999), and has been recycling most of the used acid-lead batteries. An enforcement act regulating lead plants installation was put into effect in the 1980s (Brasil, 1986).

Despite those official efforts in reducing environmental lead contamination during the last three decades, very little effort has effectively been made to controlling lead oxides airborne emissions from old primary and secondary smelting plants.

A battery recycling plant located in Bauru, West of the state of São Paulo, Brazil, started its activities in 1974 at what was considered a rural area at that time. In 1997, a low economic population started to occupy the area in a process of urbanization around the plant. That population lives in poorly constructed houses, mostly in unpaved roads. Due to the absence of effective anti-emissions equipments, the plant contaminated its neighboring residential area with lead oxides during the last 8 years. The environment lead contamination has recently been assessed by CETESB (State Authority for Environmental Control), which notified the State Health Authority in February 2002, when the plant had its operations suspended (Companhia de Tecnologia de Saneamento Ambiental (CETESB), 2002). Average airborne lead measured in samples collected around the plant was 9.7 $\mu g/m^3$ (mean of 3 months) and maximum value of 37.3 $\mu g/m^3$ from June 2001 to September 2001 (EPA limit value = 1.5 $\mu g/m^3$) (United States Environmental Protection Agency (USEPA), 2000).

The city of Bauru has a tropical temperate weather with average temperature of around 26 °C (13 °C in winter and 32 °C in summer). It is relatively dry with average humidity ranging from 60% to 75% and annual rainfall of 100 mm. These climatic conditions favors that children play outdoors in a rather dusty environment.

Children are known to be more susceptible to lead toxic effects because of their higher rate of gastrointestinal absorption and because of their hand–mouth behavior (Davies et al., 1990; Centers for Disease Control (CDC), 1991; Lanphear and Roghmann, 1997; Lanphear et al., 1998; Baghurst et al., 1999; Lane and Kemper, 2001).

Aiming to assess children lead exposure around the plant, a multidisciplinary team was set including epidemiologists and toxicologists from environmental agencies and Universities, together with local and regional technical and political health authorities.

2. Population and methods

Initially a pilot study was designed to confirm the exposure of the local population and to evaluate the need of a deeper investigation. Following the guidelines proposed by Kjellström and Mage (1995), a small group of 29 children living close to the plant, and a control group of 30 children living about 11 km farther away from the plant were evaluated. Blood lead levels (BLL), measured by graphite furnace atomic absorption spectrometry (GF-AAS), using Zeeman background correction (Model SIMMAA 6000-Perkin-Elmer), were compared and showed to be statistically different, with much higher levels in the group of children living close to the plant, warranting an investigation of a larger sample of children.

A cross-sectional study of the whole children population (857 children eligible, age 0–12 were) living within 1000 m from the plant was carried out from February to November 2002 (Landrigan and Baker, 1981). The study protocol was approved by an Ethical Committee and a written informed consent was signed by all children's parents or legally responsible adult.

All households within 1000 m from the plant were visited and interviews were performed using a standardized questionnaire with questions assessing variables and factors which could be related to children lead exposure and absorption. After the parent's consent, blood samples were collected from each children less than 12 years old using heparin vaccuntainers for BLL measurements. When children were not present at the moment of the interview a new visit was agreed and scheduled with the parents.

The municipal and state health authorities guaranteed comprehensive medical care for the whole population in the area (AAP, 1998), and children with BLL above 10 $\mu g/dL$ had blood reassessed and if levels were confirmed were appointed for pediatric, neurological, and neurobehavioral specialized assessments.

When BLL were below the quantification limit of the method (2 $\mu g/dL$), the value of the detection limit (0.54 $\mu g/dL$) was assumed for calculation purposes.

During the whole period of investigation the plant remained closed. A new BLL evaluation was performed 1.5 years later, after environmental controlling actions were performed which consisted of indoor vacuum-cleaning of households, removal of a 5 cm deep layer of soil around the houses, paving of nearby streets, and establishment of specific hygiene and educational programs targeted to the local population.

Lead concentrations in soil, water, and in vegetables, eggs, dairy products and poultry grown in the area were analyzed by GF-AAS (CETESB, 2002; AOAC, 1995; APAH, 1998).

3. Statistical analysis

For continuous variables means and medians were calculated. Correlation between distance from the contaminating source, age, and BLL was tested. The information about age and the distance from the contaminating source were categorized and χ^2-tests for trend were performed.

Logistic regression models were used to estimate the association between BLL and age, sex, hand–mouth habit,