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Environmental lead poisoning among children in Porto Alegre state, Southern Brazil

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Intoxicação ambiental por chumbo em crianças de Porto Alegre

ABSTRACT

OBJECTIVE: To estimate the prevalence of lead poisoning in children and to identify associated factors, as well as possible local sources of contamination.

METHODS: A cross-sectional prevalence study conducted in 2006 with a random sample of 97 children age zero to five years from a neighborhood in Porto Alegre, Southern Brazil. Blood lead levels were measured and a questionnaire administered to collect information on sociodemographics, recycling and dwelling. A preliminary environmental evaluation was carried out with direct analysis of soil and indirect analysis of air pollution with bioindicators to identify possible sources of contamination. To analyze lead concentrations from the different collection sites, for each type of material studied, ANOVA was performed with a Brown-Forsythe adjustment for heteroscedasticity and with Dunnett's T3 procedure for multiple comparisons of unequal variances.

RESULTS: Blood lead levels ≥ 10.0 µg/dL was found in 16.5% of children. Recycling of waste at home, low father's education level, and increased age of children were associated with increase blood lead levels. High lead levels were found in soil, and there was little indication of lead air pollution.

CONCLUSIONS: A high prevalence of lead poisoning was identified, and the potential sources of contamination in this community appear related to waste recylcing activities. Studies should be conducted with other populations of Brazilian children and evaluate potential sources of local and general contamination, to accurately characterize this issue in Brazil.

DESCRIPTORS: Child. Lead Poisoning, epidemiology. Environmental Exposure. Cross-Sectional Studies.

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RESUMO

OBJETIVO: Estimar a prevalência de intoxicação por chumbo em crianças e identificar fatores associados, bem como possíveis fontes de contaminação local.

MÉTODOS: Estudo transversal de prevalência com amostra aleatória de 97 crianças de zero a cinco anos de uma vila em Porto Alegre, RS, em 2006. O nível de chumbo no sangue foi medido e foi aplicado questionário para coletar informações sociodemográficas, reciclagem e moradia. Foi realizada avaliação ambiental preliminar com análise direta do solo e indireta da poluição atmosférica utilizando bioindicadores para averiguar possíveis fontes de contaminação. Para avaliar diferenças significantes entre as concentrações encontradas nos pontos de coleta, para cada tipo de material estudado, foi realizada ANOVA com correção de Brown-Forsythe para heterocedasticidade com comparações múltiplas de Dunnett T3 para variâncias desiguais.

RESULTADOS: O total de 16,5% das crianças apresentou chumbo sanguíneo ≥ 10,0µg/dL. Reciclagem de lixo no local de moradia, baixo nível educacional do pai e maior idade das crianças estiveram associados com maior concentração de chumbo no sangue. Foram encontrados níveis elevados de chumbo no solo e pouca indicação de poluição atmosférica por esse metal.

CONCLUSÕES: Foi observada prevalência significativa de intoxicação por chumbo e as possíveis fontes de contaminação nessa comunidade parecem relacionar-se a atividades de reciclagem de lixo. Estudos devem ser conduzidos com outras populações infantis brasileiras, avaliando possíveis fontes de contaminação locais e gerais, para que se possa dimensionar corretamente essa questão no País.

DESCRITORES: Criança. Intoxicação por Chumbo, epidemiologia. Exposição Ambiental. Estudos Transversais.

INTRODUCTION

Environmental exposures are causes of many adverse health effects among children and adolescents, despite uncertainty as to their magnitude and regional distribution. According to Valent et al,[15] indoor and outdoor air pollution, unsafe water conditions, lead exposure and injuries account for about one-third of the total burden of disease in children and adolescents aged zero to 19 years. Although it is not an important cause of mortality, lead poisoning is considered one of the main causes of morbidity by environmental exposure, reaching global dimensions.[14]

At high blood levels (> 50µg/dL), lead can cause acute effects in children ranging from gastrointestinal symptoms to severe neurological effects, and eventually, encephalopathy and death. At lower levels (≥ 10 µg/dL), epidemiological studies show effects such as lower intelligence quotient and learning disabilities, and this value has been used to define lead poisoning. Lead is harmful even at blood concentrations < 10 µg/dl, and there may be no safe threshold.[3]

The sources of lead contamination can be divided into those associated to localized exposure from industrial contamination or mining activities and those resulting from environmental exposure of the population in general. Leaded gasoline was one of the main causes of environmental and human contamination during the 20th century and was banned from most countries.[a] Industrial processes, automotive pollution from origins other than gasoline and lead pigments in paint, among other sources, may be responsible for high blood lead levels (BLL) in children.[15]

In Brazil, lead has not been used in automotive gasoline since 1993, and in 1996, primary lead smelting facilities ceased operations. The main causes of known poisoning in Brazil are lead-acid battery production, recycling plants and mining areas.[6,12] Although not

[a] United Nations Environment Programme Partnership for clean fuels and vehicles. Geneva; 2010[cited 2010 Nov 10]. Available from: http://www.unep.org/transport/pcfv/

considered an important source of lead contamination, the gasoline used in airplanes in Brazil still contains lead as an additive.[b]

Factors associated with environmental lead poisoning in children include poverty, urban area dwelling and proximity to intense traffic.[14]

The dimension of this problem around the world is variable, depending mainly on control measures adopted. According to Valent et al,[15] the prevalence of lead poisoning (BLL ≥ 10µg/dL) in children aged zero to five years range from 0.1% in countries such as Germany, France and Czech Republic, to 17% in Russia and Hungary.

Few studies assessed the prevalence of lead poisoning in Brazilian children; two studies investigated children that lived in places without previously reported environmental lead contamination. A study found a 33% prevalence of BLL ≥ 10µg/dL among children age two to 39 months, attending a daycare center in Salvador in 1993. There were no indications about possible sources of lead contamination, but this study was carried out the same year that lead was phased out from automotive gasoline in Brazil.[2]

A recent study in a poor community of Rio de Janeiro evaluated BLL of 64 children and teenagers from zero to 16 years, and the prevalence of lead poisoning was 5%. The sources of lead among this population were related to local traffic, industrial plants and house dust.[9]

The present study aimed to estimate the prevalence of environmental lead poisoning in children and to identify associated factors, as well as possible sources of lead contamination in the area.

METHODS

A cross-sectional study was carried out with a random sample of 97 children age zero to five years residing in Vila Dique, a district of the city of Porto Alegre, Southern Brazil, in 2006. Vila Dique is a low socioeconomic area and is highly exposed to solid waste, since most of the residents work with recycling activities. The region is situated close to high traffic road, to the city airport and to an area of mid-sized factories (Figure).

The study population was selected from the register of the Primary Care Unit serving the area, which contained the names of around 3,800 residents and is frequently updated by community health agents.

The sample size was determined using as parameters the 553 children aged zero to five residing in the village, a prevalence of lead poisoning among urban children of 4.4%,[1] an acceptable error of 0.06 and a 95% confidence level.

A random sample was taken using the program SPSS 13 to select the necessary 116 children. The characteristics of the sampled children were compared with the entire local population of children, according to sex, local of residence, parents' schooling and housing characteristics, reaching similar results.

The parents or guardians of each child were invited to come to the health unit with their children, and a 2 ml blood sample was collected.

BLL was determined by graphite furnace atomic absorption spectrometry, with a detection limit of 0.5 µg/dl and a precision of 5%.The reference formulas used in analysis were from Merck®, and the blood sample matrices were investigated in recovery studies using Utaka material as reference. The laboratory participated in intercalibration analysis on a monthly basis with the laboratory at Fiocruz. Every child whose blood sample presented a concentration of lead > 10 µg/dl was considered to have lead poisoning.[3,c] The critical level considered for referral to hospital care for treatment with chelating agents was 44 µg/dl.[4]

A questionnaire was administered to the parents or guardians to assess factors associated with lead contamination. It contained information on child's age and gender; the material used in the construction of the house (masonry or wood); the place where the child sleeps (floor or elevated bed); the residence's location according to micro-areas established by the local health unit (Figure); the mother's and father's schooling (in years); the presence of waste recycling in the household and the length of time the family resided in the neighborhood.

A total of 97 participants had blood samples collected and questionnaires applied (83.6%). Of the 19 children who did not take part in the study, 17 were not in the area during the period of sample collection and two guardians refused to participate. Data was analyzed using a generalized linear model (GLM) with log-link function with a gamma distribution to explain BLL according to the variables of interest. The distribution of BLL was asymmetrical, i.e., there were a large number of children with low concentrations and a few children with high concentrations. It is common to perform a log transformation of the original variable to deal with asymmetrical distributions and then use normal linear regression. However, this approach assumes constant variance, which underestimates the dispersion of the

[b] Agência Nacional do Petróleo. Gás natural e biocombustíveis. Resolução n.5 de 04 de fevereiro de 2009. Dispõe sobre estabelecimento das especificações e a garantia do suprimento de derivados de petróleo, gás natural e biocombustíveis em todo território nacional. *Diario Oficial Uniao.* 04 fev 2009;Seção1:1.
[c] United Nations Environment Programme. Interim review of scientific information on lead [online].Geneva; 2008[cited 2010 Nov 10]. Available from: http://www.chem.unep.ch/Pb_and_CD/SR/Files/2008/UNEP-Lead-review-Interim-APPENDIX-mar102008.pdf

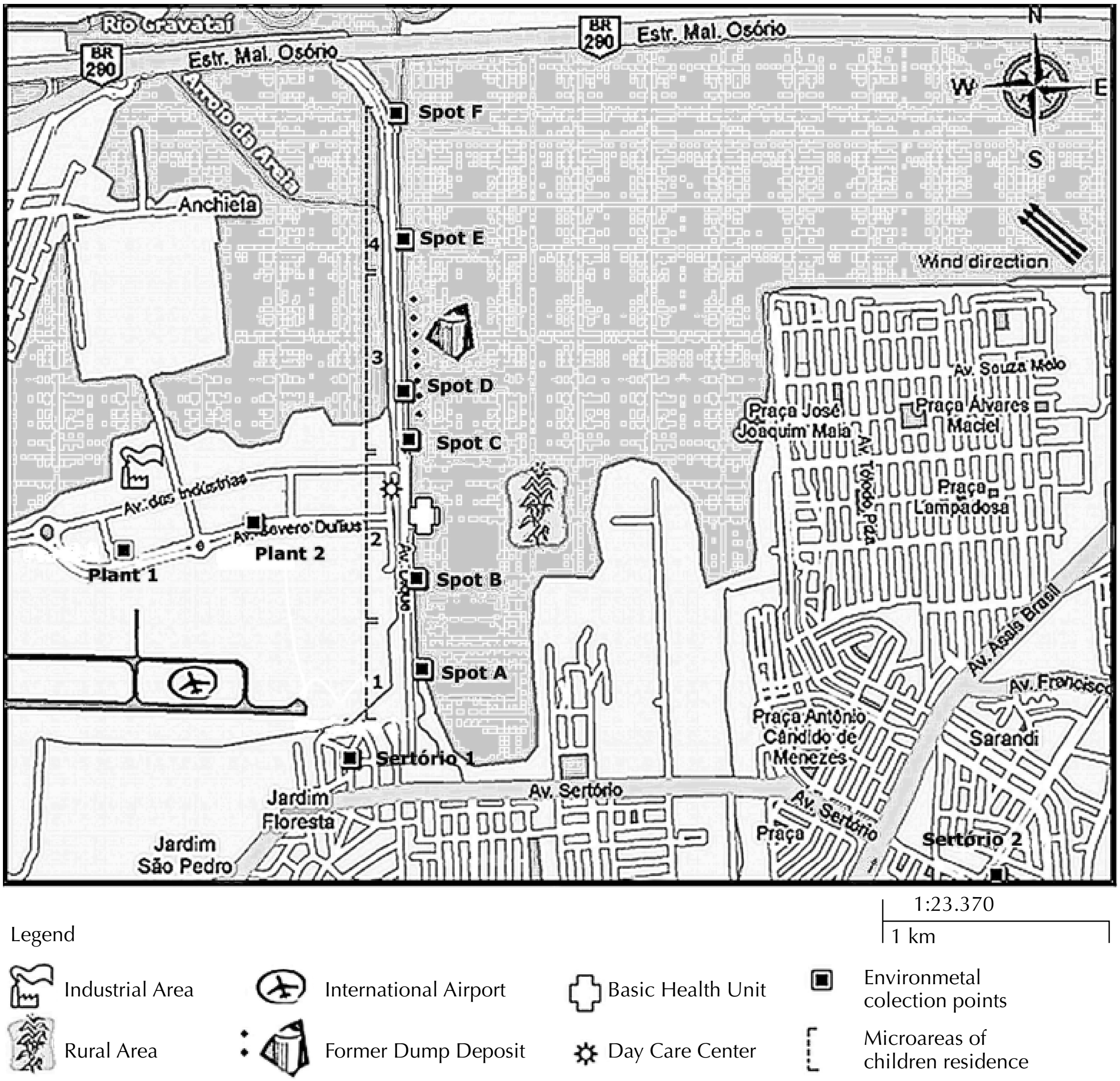

Figure. Area of Vila Dique and the collection points used in the environmental analyses. Porto Alegre, Southern Brazil, 2006.

original values, leading to distorted results. The GLM approach does not have the assumption of constant variance and works directly with the original value of the variable, following a probability distribution within the exponential family. The estimates on the parameters of interest are straightforward, and there are no problems in their dispersion.[10]

Samples of tree bark and leaves were collected to examine the presence of atmospheric environmental lead contamination. Sampling the naturally accumulated airborne particulate matter on biological media is an effective, low cost and reliable method of assessing airborne heavy-metal contamination.[13] Samples of superficial soil were collected at the same spots to access the mean lead concentration in that media.[8]

Ten collection spots were chosen according to the availability of the chosen tree species and overlap with the micro-areas established by the local Primary Care Unit. (Figure) Six spots were in the area of Vila Dique (A, B, C, D, E and F), and four spots were in nearby areas: two at Avenida das Indústrias (plant 1 and plant 2), a neighboring locality with a strong presence of manufacturing plants, potential source for lead contamination; and two on Avenida Sertório (sertorio 1 and sertorio 2), a residential area close to the study area. The approximate distance between the collection spots was 450 m.

The samples of bark and leaves were collected from trees of the species *Melia Azedarach L.*, commonly known as Cinnamomum and frequently distributed throughout the metropolitan area of Porto Alegre. Its leaves grow 150 cm above the ground, avoiding contamination by re-suspension material, a necessary condition for the analysis of bioaccumulation.[13] The sample collection was carried out in June 2008, when the leaves were beginning their annual renewal process.

The leaves and bark were washed and dried, manually grounded using an agate mortar and pestle and sifted to obtain homogenous particles. Between 0.5 and 0.6 grams of each individual sample, was placed in a steel cylinder along with approximately 1 g of boric acid (H_3BO_3 p.a.) and compressed using 1 ton of force for 60 seconds. The result of this process was thin discs with a 20 mm diameter, made of a mixture of boric acid and the original organic material. The soil samples were sifted and followed the same procedure applied to the other samples. Lead was measured using an energy dispersive X-ray fluorescence spectrometer (EDX 700-HS, Shimadzu Corporation Analytical Instruments Division, Kyoto, Japan). The instrument employed a low power Rh-target tube, at a voltage of 5–50 kV and a current of 1–1000A.

The characteristic X-ray radiation emitted was detected by a Si(Li) detector. X-ray fluorescence emission spectra were collected for 240 s, on a 10-mm surface area of samples in a vacuum atmosphere. Each sample was analyzed five times. The sample intensities were converted to element concentrations (gg−1) according to calibrations using the NIST Standard, SRM 1547 Peach Leaves (National Institute of Standards, Gaithersburg, MD, USA) for barks and leaves and SRM 2710 Montana Soil (National Institute of Standards, Gaithersburg, MD, USA) for soil samples. The spectra were reduced with WinQXAS software, available from the website of the International Atomic Energy Agency.[d]

Analysis of variance was carried out to assess significant differences in the lead concentrations between collection spots for each type of material studied with Brown-Forsythe correction for heteroscedasticity and with Dunnett's T3 procedure for multiple comparisons of unequal variances.[11]

This study complied with the Declaration of Helsinki and was approved by the Ethics Research Committees of Grupo Hospitalar Conceição (Process n. 034/05 from July 14/2005) and Faculdade de Medicina da Universidade de São Paulo (Process n. 1031/08 from December 17/2008).

RESULTS

The mean age was 2.6 years (standard deviation (SD) = 0.1) and 52.6% were male. The majority lived in the area since birth and were of low socioeconomic position according to their father's level of education (Table 1).

Children's age was correlated with BLL (Spearman r= 0.328, p=0.001); 16.5% exhibited BLL≥ 10 µg/dL. The median value of BLL was 5.2 µg/dL. Few presented high concentrations, and none of the blood samples collected showed an amount superior to the critical level for treatment using chelating agents. More than half of the samples presented BLL above 5 µg/dL (51.5%) (Table 2).

Table 1. Blood lead levels according to socioeconomic and demographic characteristics of children. Vila Dique, Porto Alegre, Southern Brazil, 2006. (N = 97)

Variable	n	%	Mean	SD	p
Gender					0.049
Male	51	52.6	6.7	3.9	
Female	46	47.4	5.6	4.1	
Type of dwelling					0.672
Masonry	13	13.4	6.4	5.0	
Wood	84	86.6	6.1	3.9	
Place where child sleeps		0.0			0.957
Bed	87	89.7	6.2	4.1	
Floor	10	10.3	5.9	3.1	
Lives in the area since birth					0.339
Yes	87	89.7	6.3	4.1	
No	10	10.3	4.0	2.5	
Waste recycling in the household					0.012
Yes	20	20.6	8.6	5.2	
No	77	79.4	5.6	3.5	
Microarea					0.151
1	29	29.9	6.2	3.9	
2	35	36.1	5.6	4.5	
3	13	13.4	6.0	3.7	
4	20	20.6	7.3	3.5	
Mother's schooling (years)					0.084
≤ 4	40	41.2	6.7	4.7	
5 to 7	32	33.0	6.6	3.6	
≥ 8	25	25.8	4.7	3.1	
Father's schooling (years)					0.032
≤ 4	25	26.9	7.0	4.7	
5 to 7	45	48.4	6.3	3.6	
≥ 8	23	24.7	4.3	2.7	

Children›s age, father's schooling and waste recycling in the household remained significantly associated with BLL (p< 0.05) in the multiple logistic model (Table 3).

High concentrations of lead were mainly found in locations within the area of Vila Dique, spot C and spot D. There were statistically significant differences in the lead concentrations of soil from different spots (Table 4).

[d] International Atomic Energy Agency. Quantitative X-ray Analysis System. [cited 2010 Nov 10]Available from: http://www.iaea.org/OurWork/ST/NA/NAAL/pci/ins/xrf/pciXRFdown.php

Table 2. Blood lead levels of children. Vila Dique, Porto Alegre, Southern Brazil, 2006. (N = 97)

BLL (µg/dL)	n	%
0 to 4.9	47	48.5
5.0 to 9.9	34	35.0
10.0 to 14.9	11	11.3
≥ 15	5	5.2

BLL: Blood Lead Levels

Table 3. Estimated variation in blood lead levels according to socioeconomic and demographic characteristics of children. Vila Dique, Porto Alegre, Southern Brazil, 2006. (N = 97)

Variable	β	SE	Lower	Upper	p
Intercept	2.12	0.61	0.94	3.31	0.0005
Age (years)	0.87	0.31	0.27	1.47	0.005
Waste recycling in household (Yes/No = reference)	2.37	1.02	0.38	4.37	0.02
Father's schooling (in years; reference = ≤8)					
0 to 4	1.85	0.91	0.07	3.62	0.04
5 to 7	1.8	0.65	0.53	3.07	0.005

Higher concentrations of lead in bark samples were found in plant 2 and spot D, and there were significant statistical differences among the different sample collection spots. The concentration of lead in leaves was low, and no significant differences were found between the different spots (Table 4).

DISCUSSION

This study examined children from a poor community, without any previously known specific source of exposure. The prevalence of lead poisoning (BLL ≥10µg/dL) was 16.5%; 51% of the children presented BLL above 5 µg/dL. Factors associated with higher BLLs in these children include older age, low father's educational level and presence of recycling activities in the household.

Table 4. Lead concentration (mean and standard deviation, in µg/g) in samples of soil, bark and leaves. Vila Dique and neighboring areas, Porto Alegre, Southern Brazil, 2008.

Variable	Soil	Bark	Leaves
Collection Spot	Mean (SD)	Mean (SD)	Mean (SD)
Spot A	70.9 (10.3)	1.1 (0.1)	1.3 (0.5)
Spot B	72.7 (6.4)	1.3 (0.3)	1.1 (0.7)
Spot C	118.2 (19.7)	1.2 (0.4)	1.0 (0.5)
Spot D	601.7 (54.3)	2.3 (0.6)	1.1 (0.3)
Spot E	50.1 (5.9)	1.8 (0.4)	1.1 (0.2)
Spot F	52.6 (11.2)	1.7 (0.4)	1.0 (0.1)
Plant 1	60.1 (8.9)	1.3 (0.4)	1.2 (0.2)
Plant 2	46.02 (6.03)	3.26 (0.66)	1.15 (0.22)
Sertorio 1	20.91 (5.67)	0.96 (0.56)	1.27 (0.29)
Sertorio 2	64.66 (8.89)	2.03 (0.93)	1.28 (0.30)
p	< 0.001	< 0. 001	0.94

The prevalence of BLL ≥ 10µg/dL is higher than those in children from the USA, Germany, France, Czech Republic, and others.[3,15] The percentage of children with BLL above 5 µg/dL is higher than in the USA child population (31.4% from 1988 to 1991 and 7.4% from 1999 to 2004).[7] These studies include child samples from the general population, i.e., of various socioeconomic conditions, while in Vila Dique children were of low socioeconomic status.

Studies conducted in Brazil found similar or higher prevalence of lead poisoning among children.[12] However, an important local source of lead contamination was identified beforehand and prompted most of these studies. A few studies have investigated children populations from places with no previous report of environmental contamination. Carvalho et al[2] found a higher prevalence of BLL, but this study was carried out on the same year when lead was phased out from automotive gasoline in Brazil. A recent study conducted by Mattos et al[9] found a lower prevalence of lead poisoning, but included children and adolescents.

This study is consistent with previous research showing a higher prevalence of elevated BLLs according to age and socioeconomic conditions.[3] Older children exhibited higher BLLs, and this might be due to children at this age having greater contact with soil and dust, possible sources of lead contamination.

Even though the general population of Vila Dique is socioeconomically deprived, it cannot be considered as a homogeneous population. Father's low education was associated with higher BLL among children. Considering low education level an indirect measure of deprived socioeconomic condition, this finding was consistent with the literature.[3,7,14] Solid waste recycling in the home's yard was also associated with higher blood lead levels. Most of the families of Vila Dique work with solid waste collecting and recycling, and some do it at their homes, without any control as to the origin and storage of this material. This can enhance the exposure to garbage and dust, leading to the high BLL among their children. The relationship between lead poisoning and solid waste recycling activities was also identified in another study that evaluated an asymptomatic population of children in La Plata, Argentina.[5]

The environmental analysis found higher concentrations of lead in the soil and few indications of lead deposition through atmospheric emissions. This analysis was conceived as a preliminary assessment of possible local sources. Other potential sources such as leaded pigments used in wall paints and lead in drinking water were not directly verified.

Lead in paints could be relevant in the area of Vila Dique, since there are a large number of houses in precarious states of conservation, and the regulation that forbids the use of lead in house paints was enforced in Brazil in 2008.[e] The water supply of Vila Dique comes from the city's official water supply department, lowering the possibility of contamination.

The tree's leaves exhibited low concentrations of lead and no statistical difference among the different collection spots, suggesting that lead deposition by atmospheric emissions was not important to explain the contamination of children in the area.

The concentration of lead in the bark samples, although varying among the collection spots, showed low amounts of lead compared to studies in places with high levels of environmental lead contamination due to industrial activities.[13] The lead concentration in barks suggest a relationship with vehicular emissions. Similar values were found by Martins (2009),[f] who analyzed bark from trees in parks in São Paulo city, Southeastern Brazil, and attributed the lead deposition to vehicular emissions.

The gasoline used in aviation in Brazil contains lead, and the area of Vila Dique is close to the local airport; so the contamination of children might be also due to this exposure. However, we did not find indications of this problem based on the analyses of tree leaves and bark, and the wind direction blows from the study area towards the airport and not the opposite, ruling out this possibility (Figure).

The soil analyses showed an important amount of lead in the samples from Vila Dique, more specifically at sites C (118.2 μg/g) and D (601.7 μg/g). The maximum recommended level for residential areas according to the *Companhia de Tecnologia e Saneamento Ambiental* de São Paulo (CETESB – State Environmental Agency) is 300 μg/g.[g] However, values of metal concentration can be affected by the mineral composition of the soil, by the sample collection protocol and the analytical methodology applied. There is no reference level for soil lead concentration in Porto Alegre, and the methodology used in this study is different than the one recommended by the CETESB, making direct comparison difficult.

The possible causes of soil contamination can be related to the process of land use. There is no report of industrial activity of any kind inside Vila Dique. According to local residents, the area with the highest concentration of lead was formerly used as an informal garbage dump, which no longer exists. Some environmental contaminations resulting from this garbage dump could be responsible for the high level of lead found in the soil. Vila Dique is located close to a region of industrial plants, including some secondary metal processing industries; they might have contributed to previous deposition of lead in the soil.

Although we found high lead concentrations in soil from some collection spots, the distribution of BLL of children from Vila Dique were not related to their micro area of residence (Table 3). The source of lead contamination for these children can be an arrangement of soil contamination, waste recycling at the home, and dust due to precarious housing conditions.

We used information on prevalence of lead poisoning among the population of US children for the calculation of sample size. This was necessary since the prevalence among Brazilian children is not available. However, the prevalence of BLL $\geq$ 10μg/dL among American children is expected to be lower than among Brazilian children, since the US has been adopting control measures for many years. The estimated sample is expected to have enough power to estimate the prevalence of lead poisoning in children from Vila Dique. The distribution of the geographic and socioeconomic characteristics of the selected children was similar to those of the general population of children from Vila Dique, indicating that the sample was representative of this population.

We did not evaluate other risk factors for environmental lead poisoning, such as parents' occupational activities, tobacco smoking and nutritional aspects.

Despite these limitations, this study was able to find a high prevalence of lead poisoning in children living in an area without previous reports of environmental lead contamination, but with important risk factors. The children of the studied area will be relocated due to the planned expansion of the local airport, thus reducing the possibility of continued contamination through local environmental lead concentrations. Nevertheless, the associations and the preliminary environmental analysis suggest unregulated recycling activities, an important source of income for this community and others across the country, can be an important cause of childhood lead poisoning.

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