Lead levels in children in Latin America and the Caribbean. Potential impact on human health

Dr. Kelly Polido Kaneshiro Olympio

Associate Professor

University of Sao Paulo, Brazil

Environment International 101 (2017) 46–58

Contents lists available at ScienceDirect

Environment International

journal homepage: www.elsevier.com/locate/envint

Review article

What are the blood lead levels of children living in Latin America and the Caribbean?

Kelly Polido Kaneshiro Olympio [a,*], Cláudia Gaudência Gonçalves [b], Fernanda Junqueira Salles [a], Ana Paula Sacone da Silva Ferreira [a], Agnes Silva Soares [c,1], Marília Afonso Rabelo Buzalaf [d], Maria Regina Alves Cardoso [e], Etelvino José Henriques Bechara [f]

[a] Departamento de Saúde Ambiental, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, SP, Brazil
[b] Departamento de Controle Ambiental/Grupo Técnico Permanente de Áreas Contaminadas – Secretaria do Verde e Meio Ambiente de São Paulo, Brazil
[c] Sustainable Development and Health Equity, Pan American Health Organization, Washington, DC, United States
[d] Departamento de Ciências Biológicas, Faculdade de Odontologia de Bauru, Universidade de São Paulo, Bauru, SP, Brazil
[e] Departamento de Epidemiologia, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, SP, Brazil
[f] Departamento de Química Fundamental, Instituto de Química, Universidade de São Paulo, São Paulo, SP, Brazil

ARTICLE INFO

Article history:
Received 17 August 2016
Received in revised form 21 December 2016
Accepted 21 December 2016
Available online 1 February 2017

Keywords:
Latin America
Caribbean
Lead
Children
Blood

ABSTRACT

Introduction: Information on the prevalence of lead exposure is essential to formulate efficient public health policies. Developed countries have implemented successful public policies for the prevention and control of lead poisoning. In the United States, Canada, Japan and the European Union, for instance, periodically repeated prevalence studies show that blood lead levels (BLLs) in children have decreased overall. Although BLL of Latino children in the U.S. have also dropped in recent years, the geometric mean remains higher than that of white children. Little is known about lead exposure in children in Latin America and the Caribbean (LAC). In this review, we responded to two questions: What is currently known about lead sources and levels in children in LAC? Are there public policies to prevent children's exposure to lead in LAC?

Method: We conducted a literature review covering the period from January 2000 to March 2014 in the PubMed and Lilacs databases to obtain English, Portuguese and Spanish language studies reporting the prevalence of BLLs in children aged 0–18 years living in LAC countries. No specific analytical method was selected, and given the scarcity of data, the study was highly inclusive.

Results: Fifty-six papers were selected from 16 different LAC countries. The children's BLLs found in this review are high (≥10 μg/dL) compared to BLLs for the same age group in the U. S. However, most studies reported an association with some type of "lead hot spot", in which children can be exposed to lead levels similar to those of occupational settings. Only Peru and Mexico reported BLLs in children from population-based studies.

Conclusions: Most BLLs prevalence studies carried out in LAC were in areas with known emission sources. The percentage of children at risk of lead poisoning in LAC is unknown, and probably underestimated. Thus, there is an urgent need to establish public health policies to quantify and prevent lead poisoning, specifically by prioritizing the identification and control of "hot spots".

Contents

1. Introduction . . . 47
2. Methods . . . 48
3. Results . . . 48
3.1. Argentina . . . 51
3.2. Brazil . . . 52
3.3. Belize . . . 52
3.4. Chile . . . 53
3.5. Colombia . . . 53

* Corresponding author.
E-mail address: kellypko@usp.br (K.P.K. Olympio).
[1] The author is a staff member of the Pan American Health Organization. The author alone is responsible for the views expressed in this publication, and they do not necessarily represent the decisions or policies of the Pan American Health Organization.

http://dx.doi.org/10.1016/j.envint.2016.12.022

- **Lead is a neurotoxin that causes serious damage to the human brain** (Toscano and Guilarte, 2005).

- **A large body of scientific evidence shows an association between lead exposure during childhood and impaired cognitive function in children** (Bellinger, 2004; Needleman, 2004; Lanphear et al., 2005; Hornung et al., 2009; Mazumdar et al., 2011; Dickerson et al., 2016; Blackwoicz et al., 2016; Wagner et al., 2016).

- **Early lead exposure may also be a risk factor for neurocognitive impairment in adulthood, adult mental retardation** (Carpenter and Nevin, 2010; Nevin, 2009), **low economic productivity** (Grosse et al., 2002; Schwartz, 1994), **delinquency and violent offences** (Needleman et al., 2002; Dietrich et al., 2001; Wright et al., 2008; Olympio et al., 2010; Mielke and Zahran, 2012).

- **An assessment of neurobehavioural outcomes showed no evidence of a threshold under which lead levels are not associated with harmful effects** (Chiodo et al., 2007); **no level of lead exposure is considered safe** (Canfield et al., 2003; Lanphear et al., 2005).

The levels of lead considered tolerable for children have dropped repeatedly over the last three decades. In 2012, the United States (U.S.) Advisory Committee on Childhood Lead Poisoning Prevention (ACCLPP) recommended eliminating the term "blood lead level of concern", based on evidence of the adverse health effects on children with levels <10 µg/dL. Instead, the ACCLPP recommended the adoption of a "reference value" based on the 97.5th percentile of the blood lead levels (BLLs) distribution in children aged 1–5 years in the U.S., which is currently 5 µg/dL.

Revisión bibliográfica / Literature review

Neurotoxicity and aggressiveness triggered by low-level lead in children: a review

Kelly Polido Kaneshiro Olympio,[1] Claudia Gonçalves,[2] Wanda Maria Risso Günther,[1] and Etelvino José Henriques Bechara[3]

Suggested citation Olympio KPK, Gonçalves C, Günther WMR, Bechara EJH. Neurotoxicity and aggressiveness triggered by low-level lead in children: a review. Pan Am J Public Health. 2009;26(3):266–75.

ABSTRACT *Lead-induced neurotoxicity acquired by low-level long-term exposure has special relevance for children. A plethora of recent reports has demonstrated a direct link between low-level lead exposure and deficits in the neurobehavioral-cognitive performance manifested from childhood through adolescence. In many studies, aggressiveness and delinquency have also been suggested as symptoms of lead poisoning. Several environmental, occupational and domestic sources of contaminant lead and consequent health risks are largely identified and understood, but the occurrences of lead poisoning remain numerous. There is an urgent need for public health policies to prevent lead poisoning so as to reduce individual and societal damages and losses. In this paper we describe unsuspected sources of contaminant lead, discuss the economic losses and urban violence possibly associated with lead contamination and review the molecular basis of lead-induced neurotoxicity, emphasizing its effects on the social behavior, delinquency and IQ of children and adolescents.*

Key words Lead poisoning; neurotoxicity syndromes; oxidative stress; juvenile delinquency.

Since ancient times, lead (Pb) has been known to be toxic to human health (1). Indeed, lead is now recognized as a devastating neurotoxin. The widespread contamination of the environment by lead, the wide range of toxic effects associated with this metal, and the millions of people affected worldwide, both in poor and developed nations, make this insidious and ubiquitous neurotoxicant a public health problem of global magnitude and concern (2).

The levels of lead considered tolerable for children have been repeatedly lowered over the last three decades (3–5). In the early 1960s, the toxic threshold was established as venous blood lead levels (BLL) of 60 μg/dL, at which overt physical symptoms were observed (6). In 1970, after the recognition that even lower blood lead could cause brain damage (7), the threshold was reduced to 40 μg/dL; it was then reduced to 30 μg/dL in 1975, and to 25 μg/dL in 1985. Finally, in 1991, the Centers for Disease Control and Prevention (CDC) set the intervention level at 10 μg/dL. According to Bellinger (8), although this level only intends to serve as a risk guidance and management tool, it has been widely and incorrectly imbued with biological significance for the individual child. Indeed, the intervention level is often interpreted as a threshold, so that a level lower than 10 μg/dL would be "safe," and a higher level would be "toxic." There is not a safe level of lead exposure because factors such as the endpoint of interest, the age at exposure and at assessment, the duration of blood lead elevation, and characteristics of the child's rearing environment must also be considered (8). Recently, studies by Lanphear et al. (9) and Canfield et al. (10) have shown intellectual impairment in children with blood lead concentrations below 10 mg/dL, and Chiodo et al. (11) have demonstrated child neurobehavioral deficits linked to 3 μg/dL concentrations.

The goal of the present study was to discuss unexpected sources of contaminant lead and review the molecular basis of the neurotoxicity induced in children by low-level lead, emphasizing its effects

1 Universidade de São Paulo, Faculdade de Saúde Pública, Departamento de Saúde Ambiental, São Paulo, SP, Brazil. Send correspondence to: Kelly Polido Kaneshiro Olympio, Marcondes Salgado 17-71, bl. 13, apto. 24 – VI, CEP 17013-231, Antártica, Bauru, SP, Brazil. Tel: +55-14-3879.6884; e-mail: kellypko@usp.br
2 Centro de Extensão Universitária, São Paulo, SP, Brazil.
3 Universidade de São Paulo, Instituto de Química, Departamento de Bioquímica, São Paulo, SP, Brazil, and Universidade Federal de São Paulo, Departamento de Ciências Exatas e da Terra, São Paulo, SP, Brazil.

Neurotoxicology and Teratology 32 (2010) 273–279

Contents lists available at ScienceDirect

Neurotoxicology and Teratology

journal homepage: www.elsevier.com/locate/neutera

Surface dental enamel lead levels and antisocial behavior in Brazilian adolescents

Kelly P.K. Olympio [a], Pedro V. Oliveira [b], Juliana Naozuka [b], Maria R.A. Cardoso [c], Antonio F. Marques [d], Wanda M.R. Günther [a], Etelvino J.H. Bechara [e,f,*]

[a] *Faculdade de Saúde Pública, Departamento de Saúde Ambiental, Universidade de São Paulo, 01246-904 São Paulo, SP, Brazil*
[b] *Instituto de Química, Departamento de Química Fundamental, Universidade de São Paulo, 05508-900 São Paulo, SP, Brazil*
[c] *Faculdade de Saúde Pública, Departamento de Epidemiologia, Universidade de São Paulo, 01246-904 São Paulo, SP, Brazil*
[d] *Faculdade de Ciências, Departamento de Educação, Universidade Estadual Paulista, 17033-360 Bauru, SP, Brazil*
[e] *Instituto de Química, Departamento de Bioquímica, Universidade de São Paulo, 05508-900 São Paulo, Brazil*
[f] *Departamento de Ciências Exatas e da Terra, Universidade Federal de São Paulo, 09972-270 Diadema, SP, Brazil*

ARTICLE INFO

Article history:
Received 16 May 2009
Received in revised form 24 November 2009
Accepted 7 December 2009
Available online 18 December 2009

Keywords:
Lead poisoning
Dental enamel biopsy
Antisocial behavior
Juvenile delinquency
5-Aminolevulinic acid
Oxidative stress

ABSTRACT

Lead poisoning has been reportedly linked to a high risk of learning disabilities, aggression and criminal offenses. To study the association between lead exposure and antisocial/delinquent behavior, a cross-sectional study was conducted with 173 Brazilian youths aged 14–18 and their parents ($n=93$), living in impoverished neighborhoods of Bauru-SP, with high criminality indices. Self-Reported Delinquency (SRD) and Child Behavior Checklist (CBCL) questionnaires were used to evaluate delinquent/antisocial behavior. Body lead burdens were evaluated in surface dental enamel acid microbiopsies. The dental enamel lead levels (DELL) were quantified by graphite furnace atomic absorption spectrometry (GFAAS) and phosphorus content was measured using inductively coupled plasma optical emission spectrometry (ICP-OES). Logistic regression was used to identify associations between DELL and each scale defined by CBCL and SRD scores. Odd ratios adjusted for familial and social covariates, considering a group of youths exposed to high lead levels (≥75 percentile), indicated that high DELL is associated with increased risk of exceeding the clinical score for somatic complaints, social problems, rule-breaking behavior and externalizing problems (CI 95%). High DELL was not found to be associated with elevated SRD scores. In conclusion, our data support the hypothesis that high-level lead exposure can trigger antisocial behavior, which calls for public policies to prevent lead poisoning.

1. Introduction

Since ancient times, lead poisoning has afflicted millions of people, both in developed and poor nations. It is a ubiquitous and insidious toxicant present not only in air, dust, water, soil, food, paints, car batteries, and gasoline, but also hidden in ceramic dishes, crystal baby bottles, toys, herbal medicines and eye make-up.

Three meta-analyses confirmed that low-level lead exposure was associated with reduced IQ [49,55,57]. More recent data indicated cognition, attention and behavior disturbances in children presenting lead levels in the order of 3–5 μg/dL [16,17,40]. In recent years, ecological [27,52,53,59] and observational [28,50,51,66] studies have been carried out relating lead exposure to antisocial, aggressive, delinquent and criminal behavior. These studies showed an association between these disorders and lead intoxication.

Thus, considering evidence linking lead exposure to a higher risk for aggression and antisocial problems [28,48,51,54,66], the aim of this study was to determine lead concentrations in poverty-stricken Brazilian adolescents using a biomarker of chronic exposure (surface dental enamel) [5,6,13,14,19–22,31] to evaluate the association between lead exposure and antisocial/delinquent behavior in Brazilian youths.

2. Methods

2.1. Subjects

The volunteers were youths residing in a slum (Ferradura Mirim); in a housing complex built by an urban renovation project to remove shantytown squatters from the city (Fortunato Rocha Lima); and in the Fundação Casa (a unit for court-ordered juvenile delinquents). All these sites are located in the city of Bauru, southeastern Brazil, and were selected for this study due to their high crime rates. In Ferradura Mirim,

Abbreviations: ADM, assessment data manager; AIP, intermittent acute porphyria; ALA, 5-aminolevulinic acid; ALAD, 5-aminolevulinic acid dehydratase; CBCL, Child Behavior Checklist; CNS, central nervous system; DELL, dental enamel lead levels; GABA, γ-aminobutyric acid; GFAAS, graphite furnace atomic absorption spectrometry; ICP-OES, inductively coupled plasma optical emission spectrometry; PNS, peripheral nervous system; SRD, Self-Reported Delinquency.

* Corresponding author. Instituto de Química, Departamento de Bioquímica, Universidade de São Paulo, Av. Prof. Lineu Prestes, 748, 05508-000 São Paulo, SP, Brazil. Tel.: +55 11 30913869; fax: +55 11 38155579.
E-mail address: ebechara@iq.usp.br (E.J.H. Bechara).

0892-0362/$ – see front matter © 2009 Elsevier Inc. All rights reserved.
doi:10.1016/j.ntt.2009.12.003

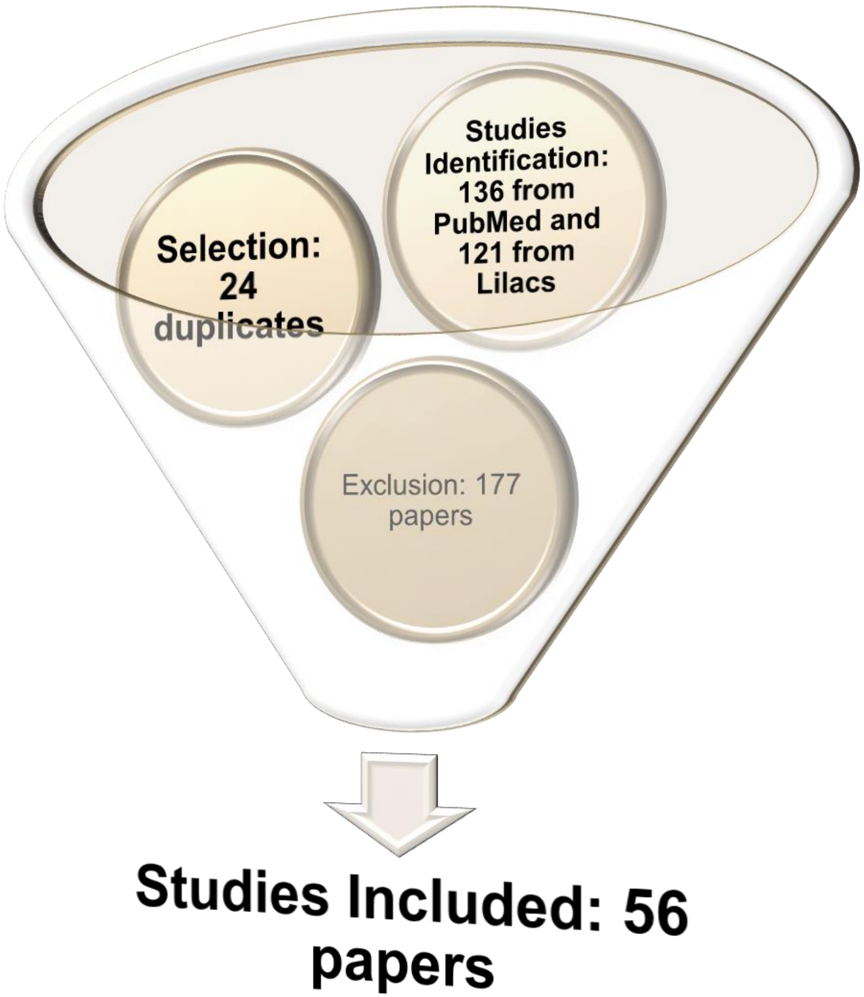
Methods

- Publications from January 2000 to March 2014 in PubMed and Lilacs databases;
- Terms: ("Lead/blood"[Mesh] OR "Lead Poisoning/blood"[Mesh]) OR (("Lead Poisoning"[Mesh] OR "Lead"[Mesh]) AND "Blood"[Mesh]) AND ("South America"[Mesh] OR "Central America"[Mesh] OR "Mexico"[Mesh] OR "Latin America"[Mesh] OR "Caribbean Region"[Mesh]) AND "humans"[MeSH Terms] AND ("infant"[MeSH Terms] OR "child"[MeSH Terms] OR "adolescent"[MeSH Terms]) AND ("2000/01/01"[PDAT] : "3000/12/31"[PDAT]) and (chumbo or plomo or lead) and (sangue or sangre or blood) [Palavras] and "2000" or "2001" or "2002" or "2003" or "2004" or "2005" or "2006" or "2007" or "2008" or "2009" or "2010" or "2011" or "2012" or "2013" or "2014" [País, ano de publicação] and ((("LACTENTE") or "pre-escolar") or "crianca") or "adolescente" [Descritor de assunto]
- Pubmed and Lilacs respectively.

Methods

Criteria for inclusion were:

a) the study population included children 0-18 years of age living in any country in LAC;
b) the study presented BLLs results as an outcome; and
c) the study described the method used for collecting and analyzing blood. Studies that collected both capillary and venous blood, using any analysis methods, such as GFAAS, ETAAS, Anodic Stripping Voltammetry, and that used or not reference materials or inter-laboratory validation were included. All types of sampling and analytical methods were included to maximize the number of published studies and to provide an overview of the status of the art regarding the study of BLLs in children from LAC countries.


Selection: 24 duplicates
Studies Identification: 136 from PubMed and 121 from Lilacs
Exclusion: 177 papers
Studies Included: 56 papers

Locality	Number (n) and age (year of blood collection)	Descriptive characters of exposure or non-exposure	Sample type and lab method	Geometric or Arithmetic mean of BLL (% BLL ≥10µg/dL)	Bibliographic reference
Argentina (Abra Pampa)	N=25 5-16 years (2004)	Smelter worked up to 80's end.	VB/GF-ETAAS (Varian AA-840)	Mean: 12.7µg/dL (40%)	Barberis et al., 2006.
Argentina (Tucumán)	N=133 5 – 16 years (1991 -1995)	Children living near lead smelter	VB/AAS	Mean: 22.9µg/dL (98.5%)	Riera et al., 2006.
Argentina (La Plata)	N=93 6 months - 5 years (2006)	Hospital de Niños Sor Maria Ludovica	VB/GF-ETAAS (Varian AA-840)	GM: 4.26µg/dL (10.8%)	Disalvo et al., 2009.
Brazil (Salvador)	N=129 2-39 months (1995)	Nursery school.	VB/ GF-AAS	AM: 10.7µg/dL (32.56%).	Carvalho et al., 2000.
Brazil (Ribeira do Iguape)	N=295 7-14 years (1999-2000)	Three cities in the valley of upper river.	VB/GF-AAS	Mean:11.25 µg/dL – exposed children and 4.4 µg/dL – non-exposed. children (59,6%)	Paoliello et al., 2002.
Brazil (Santo Amaro da Purificação)	N=47 1-4 years (1998)	1 km from a lead smelter.	VB/ GF-AAS	GM: 17.1µg/dL (87%)	Carvalho et al., 2003.
Brazil (Bauru)	N=850 0-12 years (2002)	Near a battery recycling plant.	VB/GF-AAS	Median: 7.3µg/dL (36.6%)	Freitas et al., 2007.
Brazil (Rio de Janeiro)	N=64 0-16 years (NS)	Between high traffic density roads.	NS Blood/AAS (AAnalyst 800 PerkinElmer)	Mean: 5.5µg/dL (5%)	Mattos et al., 2009
Brazil (Ribeirão Preto)	N=444 6 - 8 years (2006)	Children attending 4 public schools.	VB /ICP-MS	Median: 2.1µg/dl (0%).	Almeida et al., 2010.
Brazil (Porto Alegre)	N=97 0-5 years (2006)	Close to the airport and mid-sized factories.	VB/ GF-AAS	Median: 5.5µg/dL (16.5%)	Ferron et al., 2012.

Belize	N=164 2-8 years (2002)	Children attending school in the spring.	CB/Anodic stripping voltammetry with LeadCare	Mean: 4.94 µg/dL (7%)	Charalambous et al. 2009.
Chile (Antofagasta)	N=486 exposed + 75 unexposed; < 7 years (1997-1998)	Children living near lead storage places.	VB/AAS (Perkin-Elmer 2100)	GM: 8.7µg/dL - exposed and 4.22µg/dL – non - exposed. (48%).	Sepúvelda et al., 2000.
Chile (Santiago)	N=2051 children 4-14 years (1998-1999)	Rural and urban area.	CB/ LeadCare™	Mean: 3.33µg/dL (1,32%)	Sánchez-Cortez et al., 2003.
Chile (Santiago)	N=422 4-12 months (1995-1997)	Environmental exposure (leaded gasoline).	VB/ ETAAS Perkin-Elmer 1100B	GM: 6.6µg/dL (21.3%).	Pino et al., 2004.
Chile (Antofagasta)	N=192 7-16 years. (2005)	Near to a lead storage local	CB/ LeadCare™	AM: 3.2µg/dL (0%).	Iglesias et al., 2011.
Colombia (Cartagena)	N=189 5-9 years (2004)	Urban schoolchildren without lead exposure.	VB / ETAAS	AM: 5.49µg/dL (7.4%).	Olivero-Verbel et al., 2007.
Colombia (Soacha)	N=32 <12 years old (2004-2005)	Occupational exposure in recycling automobile batteries.	VB/ GF-AAS	Median: 54µg/dL (100%)	Hurtado et al., 2008.
Colombia (Cali)	N=350 6-14 years (2004-2005)	Children exposed to industrial lead sources.	VB/ GF-AAS	AM: 4.7µg/dL for exposed group and 3.0µg/dL for non-exposed. (0%).	Filigrana and Méndez, 2012.
Cuba (Centro Habana)	N=85 3-8 years (2002)	Children living in houses built before 1928	VB/ LeadCare™	Median: 9.6µg/dL. (41.2%)	Valdés et al., 2003.
Dominican Republic San Domingo)	N=63 2-10 years (2007)	0 to 50 m of repairing/ painting shops for vehicles.	VB/ GF-AAS	Mean: 16.7µg/dL (36.5%)	Rodríguez and Espinal, 2008.
Ecuador (Ecuadorian Andes)	N=88 2-15 years (NS)	Highly Pb-contaminated Andean village.	VB/ICP-MS and GF-AAS	Mean: 43.2µg/dL (ICP-MS) and 42µg/dL (GF-AAS). (NS)	Counter et al., 2000.
Ecuador (Pujilí)	N=166 6-16 years (NS)	Ceramic glazing cottage industry.	VB/ GF-AAS	Mean: 18µg/dL. (49%).	Counter et al., 2008.
Ecuador (Andes	N=53 6-16 years (NS)	Ceramic glazing cottage industry	VB/ GF-AAS	Mean: 37.7µg/dL. (79.25%)	Buchanan et al., 2011

Jamaica	N=421 3-11 years old. (1994-1996)	Rural and Urban areas, Hope River Valley (contaminated area).	CB/ LeadCare™	Mean: Rural: 9.1µg/dL (42%) Urban: 14.0µg/dL (71%) Contaminated: 35µg/dL (100%) After remediation: 15µg/dL (96%)	Lalor et al., 2001.
Jamaica (Kingston)	N=107 2-12 years. (2006).	District with a backyard lead smelting.	CB/ LeadCare™	Mean: 25.1 µg/dL (59%).	Lalor et al., 2006.
Jamaica	N=1081 2-6 years (NS)	33 basic schools.	CB/ LeadCare™	AM: 7.3 µg/dL GM: 4.35 µg/dL (21%).	Lalor et al., 2007.
Mexico (Oaxaca)	N=220 8-10 years (NS)	Family working with lead-glazed ceramic.	VB/AAS	GM: 10.5µg/dL. (54.9%)	Azcona-Cruz et al., 2000.
Mexico (Lagunera)	N=394 6-9 years (NS)	3 primary schools in the vicinity of the largest smelter complex.	VB/AAS	Mean: Close school: 27.6µg/dL (67.5%) Intermediate: 21.8µg/dL (56.3%) Remote: 7.8µg/dL (26.9%).	García Vargas et al., 2001.
Mexico (Mexico City)	N=19 6months - 6years (1999-2000)	Exposed children of radiator repair workers.	CB/ LeadCare™	GM: 16.3µg/dL - exposed 5.6µg/dL - non-exposed. (NS)	Aguilar-Garduño et al., 2003.
Mexico (Torreón)	N=367 1-6 years (NS)	Risk factors for lead exposure.	CB/LeadCare™ and VB/AAS with Zeeman	GM: 6.0µg/dL. (20%)	Albalak et al., 2003.

Mexico (Morelos)	N=232 1-12 years (1996)	Lead-glazed pottery and vehicle traffic intensity near the household.	CB/Anodic stripping voltammetry (ESA)	GM: 6.7µg/dL. (29.7%)	Meneses-González et al., 2003.
Mexico (Mexico City)	N=321 children born between (1987 – 1992)	10 years cohort (families who used lead-glazed ceramics).	CB/ LeadCare™	GM: Whole cohort- 8.4µg/dL First year – 10.1µg/dL End – 6.4µg/dL (26.7% to 12.9%).	Schnaas, et al., 2004.
Mexico (Fresnillo)	N=59 0-15 years (2004-2005)	500m from a recycling company of metals.	CB/LeadCare™	Mean: 4.9µg/dL. (11% for 0-6; 14% for 6-12 years)	Manzanares-Acuña et al., 2006.
Mexico (Mexico City)	N=715 7-14 years (1996)	5 pediatric hospitals; (exposure = glazed pottery).	VB/GF-AAS (Perkin-Elmer 3000)	AM: 8.6µg/dL GM: 7.7µg/dl (27.1%).	Leal - Escalante et al., 2007.
México (Torreon)	N=232 6-8 years (2001-2005)	3.5 km of a metallurgic smelter complex.	VB/GF-AAS	Mean:10.2µg/dL 4.4µg/dL after 5 years. (50.84% to 5.6 %) (NS)	Rubio-Andrade et al., 2011.
Mexico (Torreón)	N=34 2-17 years (2005-2006).	113 km² area of a silver-zinc-lead smelter plant.	VB/ MC-ICP-MS	GM: 9.8µg/dL. (NS)	Soto-Jiménez and Flegal 2011.
Mexico (Metallurgicals, Cedral mine site, Trinidad Pottery area)	N=316 4-9 years (2008-2009)	Living near contaminated sites.	VB/GF-AAS	GM: Avalos: 11.3µg/dL (57%) Morales: 7.1µg/dL (22%) Cedral: 6.1µg/dL (18%) Trinidad: 19.4µg/dL (93%).	Flores-Ramírez et al., 2012.
Mexico (Torreon)	N=151,322 0-15 years (1998-2010)	Residents located within 2 km of the smelter.	VB/ GF-AAS with Zeeman	GM (2010): 5.15µg/dL (84.9% in 1999 and 10.4% in 2010)	Recio-Vega et al., 2012.
Mexico (Morelos)	N=226 6-13 years (2011)	Children from public schools.	VB/ AAS	Mean: 7.23µg/dL. (18%).	Farias et al., 2014.
Paraguay (Asunción)	N=52 7-16 years (2002)	Streets of Asunción (G1), and suburban area, Capiatá (G2).	VB/AAS	GM: 6.8µg/dL. 7.2 for G1 and 6.6µg/dL for G2. (NS)	Samaniego and Benítez-Leite 2002.
Peru (Lima and Callao)	N=2510 6months-11years (1998-1999)	15 schools with different vehicular traffic intensity.	Anodic Striping Voltmeters	Mean: 9.9µg/dL (29%)	Espinoza et al., 2003
Peru (Puerto Nuevo)	N=70 8-12 years (1999)	Children from “Maria Reiche” school.	CB/LeadCare™	Mean: 40.7µg/dL (100%)	Vega et al., 2003.

Peru (El Callao**:** Puerto Nuevo and La Punta)	N=134 6-8 years and 6 months. (NS)	Deposits of lead in the vicinity).	CB/ LeadCare™	Mean: 10.33µg/dL (44.6%)	Vega-Dienstmaier et al., 2006.
Peru (La Oroya)	N=93 newborns <12-hours of life (2004-2005)	One of the most contaminated cities in the world.	VB/AAS (equipment Perkin Elmer 3110)	Mean: 8.84µg/dL. (24.7%). There were not newborns presenting BLL <5µg/dL	Pebe et al., 2008.
Peru (Quiulacocha; Champamarca)	N=236 1-10 years (2005)	5 to 7 km from Pasco, (metal waste).	VB/ flame AAS (PerkinElmer 560)	Mean: 15.79 µg/dL (85.8% in Quiulacocha and 82.8% in Champamarca).	Astete et al., 2009.
Peru (Peruvian Amazon basin)	N=361 0-17 years (2008)	Communities exposed and non-exposed to oil activities.	CB/LeadCare Analyzer II™	Mean:Exposed-9.5µg/dL(25.7%) Non-exposed–9.2µg/dL(25.8%)	Anticona et al., 2011.
Puerto Rico (Brisas del Rosario)	N=42 > 6 years old (2000)	Children living near contaminated sites.	VB/ Method 1080B by CDC.	AM: 2.52µg/dL GM: 2.28µg/dL (0%).	Sánchez-Nazario et al., 2003.
Trinidad and Tobago	N=1761 5-7 years (2004)	Students from 61 primary schools	CB/LeadCare™	GM: 2.8 µg/dL (0.9%)	Rajkumar et al., 2006.
Uruguay (Montevideo)	N= 112 unexposed 62 exposed and 4 siblings 0-14 years old. (NS)	Close to industrial area (lead pipelines in water systems).	VB/ FAAS 283.3 nm Perkin Elmer 306	Means:Unexposed: 9.4µg/dL (0%), Exposed: 11.8µg/dL (59%) Siblings 35.05µg/dL (100%).	Cousillas et al., 2005.
Uruguay (Montevideo)	N=180 0-15 years (2004) N=47 2-11 years (1994)	2004 Montevideo City and a rural area. 1994 Public care center from different places.	VB/ FAAS 283.3 nm Perkin Elmer 306	Means:2004 –5.7µg/dL (6.7%) 1994 –9.6µg/dL (36%)	Cousillas et al., 2008.
Uruguay (Montevideo)	N=222 6-37 months (2007)	Urban children without known lead exposure.	CB/NS laboratory method	Mean: 9.3µg/dL (33.9%)	Kordas et al., 2010.
Venezuela (Valencia)	N=10 4-7 years (2000)	Children with BLL higher than 10 µg/dL.	VB/AAS (Perkin Elmer 3110)	Means: Before treatment: 19.95µg/dL. After treatment: 12.55µg/dL (90%).	Squillante et al., 2002.
Venezuela (Valencia)	N=60 4-9 years (2004)	Near potential sources of environmental lead.	VB/AAS (Perkin Elmer 3110)	Males: 11.1µg/dL Females: 9.5µg/dL (61.7%).	Espinosa et al., 2006.
Venezuela (Valencia)	N=60 4-9 years (2004)	Michelena school (“critical” for lead exposure).	NS Blood/AAS (Perkin Elmer 3110)	Mean: 10.5µg/dL (33.9%)	Seijas and Squillante 2008.


N
Mexico
Belize
Cuba
Jamaica
Dominican Republic
Puerto Rico
Trinidad and Tobago
Venezuela
Colombia
Ecuador
Peru
Brazil
Paraguay
Chile
Argentina
Uruguay
BLL mean of children living in Latin America
0.0 - 5.0 µg/dL
5.1 - 10.0 µg/dL
10.1 - 25.0 µg/dL
25.1 - 40.0 µg/dL
40.1 - 60.0 µg/dL
0
500
1000
1500 km

So...

- Scarcity of data on BLLs in LAC children;
- Using the same search strategy without limiting the research for LAC, we found 1,161 and 934 papers from PubMed and Lilacs, respectively.
- Lead poisoning remains a critical issue in many low-income countries; an estimated 99% of all children exposed to excessive amounts of lead reside in low-income countries (Prüss-Ustün et al, 2011). In LAC, the majority of the population is unaware of the dangers of lead poisoning, and the fraction of the population that is at risk of lead exposure is unknown. According to literature on lead exposure up to March 2015, Peru and Mexico were the only Latin American countries who had developed studies with environmentally exposed children.

- The fact that lead poisoning threatens the healthy social tissue of LAC cannot be underestimated. The learning disabilities and anti-social behavior of many children may be linked to contamination by lead in the Region. The blood lead figures highlighted by this review and is cause for concern when compared to BLLs for the same age group in the U.S., Canada, Japan and E.U. where prevention/control programs were well-designed and implemented.

- In LAC, there is limited information available on legal instruments to control children’s exposure to lead. According to the WHO database, which contains information provided by governments to the United Nations Environment Programme (UNEP) and the World Health Organization (WHO), only ten of 33 LAC countries had legally-binding regulations for lead in paint as of June 2016: Argentina, Brazil, Chile, Costa Rica, Cuba, Dominica, Guyana, Mexico, Panama, and Uruguay (Dr. Agnes Soares tomorrow).

- Stakeholders must take into account the particularities and infrastructure of individual countries before implementing public health policies for lead contamination prevention. In Brazil, the “Programa Saúde da Família” (Family Health Program) could be a useful model for primary prevention strategies. This program engages trained community health workers who routinely visit families in their homes and can identify possible domestic sources of exposure, provide suitable guidance to families, and report the risks to the health authorities. The routine could include the establishment of a standard and official flow for health risk assessment. Portable X-ray fluorescence equipment could be taken to specific locations after confirmation of contamination by blood test. This portable equipment can check probable sources of exposure within the home, but also within informal working environments in a fast and reliable way.

Conclusions

The establishment of public health policies to quantify and prevent lead poisoning is urgent. Priority should be given to identifying and control “hot spots” once children can be exposed to lead levels in these places similarly to those of occupational settings.

BRAZIL

Environmental Pollution 240 (2018) 831–838

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

ELSEVIER

Blood lead and cadmium levels in preschool children and associated risk factors in São Paulo, Brazil☆

Check for updates

Kelly Polido Kaneshiro Olympio [a, *], Júlia Prestes da Rocha Silva [a], Agnes Soares da Silva [b, 1], Vanessa Cristina de Oliveira Souza [c], Marília Afonso Rabelo Buzalaf [d], Fernando Barbosa Jr. [c], Maria Regina Alves Cardoso [e]

[a] Departamento de Saúde Ambiental, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, SP, Brazil
[b] Communicable Diseases and Environmental Determinants of Health (CDE), Pan American Health Organization, PAHO/WHO, Washington, DC, USA
[c] Departamento de Análises Clínicas, Toxicológicas e Bromatológicas, Faculdade de Ciências Farmacêuticas de Ribeirão Preto, Universidade de São Paulo, São Paulo, SP, Brazil
[d] Departamento de Ciências Biológicas, Faculdade de Odontologia de Bauru, Universidade de São Paulo, São Paulo, SP, Brazil
[e] Departamento de Epidemiologia, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, SP, Brazil

ARTICLE INFO

Article history:
Received 18 January 2017
Received in revised form
24 April 2018
Accepted 25 April 2018

Keywords:
Latin America
Brazilian children
Lead
Children
Blood lead levels
Risk factors
Lead exposure
Blood cadmium levels
Cadmium exposure
Cadmium

ABSTRACT

In Brazil, there are scarce data on lead (Pb) and cadmium (Cd) contamination, especially for more vulnerable populations such as preschool children. In this paper, we answer two questions: (1) What are the exposure levels of lead and cadmium in preschool children, in Sao Paulo, Brazil? and (2) What are the risk factors associated with this exposure? This cross-sectional study included 50 day care centers (DCCs), totaling 2463 children aged 1–4 years. Venous blood samples were analyzed by ICP-MS. Questionnaires were administered to the parents. Multiple logistic regression models were used to identify associations between blood lead levels (BLLs) and blood cadmium levels (BCLs) and potential risk factors. The geometric mean for BLLs was 2.16 µg/dL (95% CI: 2.10–2.22 µg/dL), and the 97.5th percentile was 13.9 µg/dL (95% CI: 10.0–17.3 µg/dL). For cadmium exposure, the geometric mean for BCLs was 0.48 µg/L (95% CI: 0.47–0.50 µg/L), and the 95th percentile was 2.57 µg/L (95% CI: 2.26–2.75 µg/L). The DCCs' geographic region was associated with high BLLs and BCLs, indicating hot spots for lead and cadmium exposures. In addition, it was found that the higher the vehicles flow, the higher were the BLLs in children. Red lead in household gates was also an important risk factor for lead exposure. Comparing these results with the findings of the Fourth National Report on Human Exposure to Environmental Chemicals by CDC-2013, it was found that in Brazilian preschool children the BLLs are almost three times higher (97.5th percentile) and the BCLs are almost twelve times higher (95th percentile) than those in U.S. children. This information is essential to formulate public health policies.

Environmental Pollution 239 (2018) 681–688

Contents lists available at ScienceDirect

Environmental Pollution

journal homepage: www.elsevier.com/locate/envpol

High blood lead levels are associated with lead concentrations in households and day care centers attended by Brazilian preschool children☆,☆☆

Júlia Prestes da Rocha Silva [a, 1], Fernanda Junqueira Salles [a, 1], Isabelle Nogueira Leroux [a], Ana Paula Sacone da Silva Ferreira [a], Agnes Soares da Silva [b], Nilson Antonio Assunção [c], Adelaide Cassia Nardocci [a], Ana Paula Sayuri Sato [d], Fernando Barbosa Jr. [e], Maria Regina Alves Cardoso [d], Kelly Polido Kaneshiro Olympio [a, *]

[a] Departamento de Saúde Ambiental, Faculdade de Saúde Pública, Universidade de São Paulo, Av. Dr. Arnaldo, 715, Cerqueira César, CEP 01246-904, São Paulo, SP, Brazil
[b] Sustainable Development and Health Equity, Pan American Health Organization, Washington, DC, United States
[c] Departamento de Química, Instituto de Ciências Ambientais, Químicas e Farmacêuticas. Universidade Federal de São Paulo, Diadema, SP, Brazil
[d] Departamento de Epidemiologia, Faculdade de Saúde Pública, Universidade de São Paulo, São Paulo, SP, Brazil
[e] Departamento de Análises Clínicas, Toxicológicas e Bromatológicas, Faculdade de Ciências Farmacêuticas de Ribeirão Preto, Universidade de São Paulo, São Paulo, SP, Brazil

ARTICLE INFO

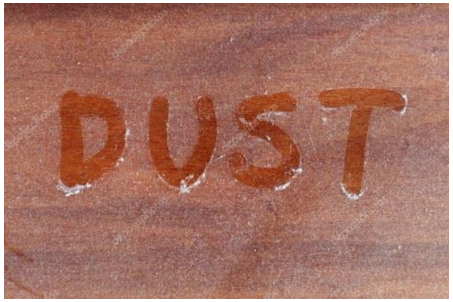
Article history:
Received 22 August 2017
Received in revised form
26 February 2018
Accepted 18 April 2018
Available online 28 April 2018

ABSTRACT

Background: A previous study observed high blood lead levels (BLL) in preschool children attending 50 day care centers (DCC) in São Paulo, Brazil.
Objective: To identify whether lead levels found in both homes and DCC environments are associated with high blood lead levels.
Methods: Children attending 4 DCCs, quoted here as NR, VA, PS and PF, were divided into two groups according to BLL: high exposure (HE: ≥13.9 µg/dL; 97.5 percentile of the 2013 year sample) and low exposure (LE: <5 µg/dL). For *in situ* lead measurements (lead paint mode: mg/cm^2 and ROHS mode: µg/g) in the children's households and in the DCC environments, a field portable X-ray-fluorescence analyzer was used. Multiple logistic regressions were performed to control for confounding factors. Odds ratios were adjusted for age, sex, day care center's measured lead, and tobacco.
Results: In an NR DCC building, 33.8% of the measurements had lead levels >600 µg/g, whereas such levels were observed in 77.1% of NR playground measurements. In VA DCC, 22% and 23% of the measurements in the building and in the playgrounds had levels higher than 600 µg/g, respectively. The percentage of high lead levels in the children's houses of the LE group was 5.9% (95% CI: 4.3–7.6%) and 13.2 (95% CI: 8.3–18.0%) in the HE group. Moreover, a significant association was found between high BLLs and lead levels found both in households and DCCs ($p < 0.001$). Most of the high lead measurements were found in tiles and playground equipment.
Conclusions: Lead exposure estimated from the DCCs, where children spend about 10 h/day, can be as relevant as their household exposure. Therefore, public authorities should render efforts to provide a rigorous surveillance for lead-free painting supplies and for all objects offered to children.

Introduction

<u>Household exposure sources</u>



<u>Playgrounds and recreational areas</u>

Objectives

General:

- **Study the lead exposure of preschool children and the risk factors.**

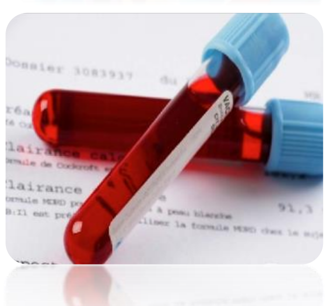
Specifics:

- **Determine the blood lead levels in preschool children of São Paulo, and the risk factors associated with this exposure;**
- **Analyze the main sources of lead exposure, considering children's home and school environments *in situ*;**
- **Investigate the association between blood lead levels (BLL) and lead exposure from children's diet and home and school environments.**

UNIVERSIDADE DE SÃO PAULO
FACULDADE DE SAÚDE PÚBLICA

Methods

- 50 DCCs – blood collections and questionnaires (2013 - 2014).
- 4 DCCs – 24-hour diets, blood and environmental screening using portable X-Ray (2015 - 2016).



1 – 4 years old

Low -exposure group

BLL <5 ug/dL

High-exposure group

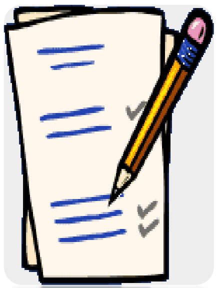
BLL ≥13.9 µg/dL

UNIVERSIDADE DE SÃO PAULO
FACULDADE DE SAÚDE PÚBLICA

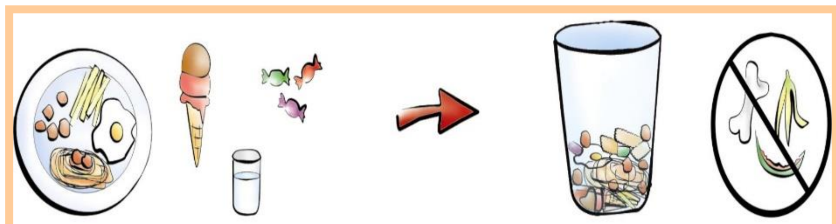
Methods

Diet and blood collection

- **124 preschool children with blood collected;**
- **64 24-hours duplicate diets.**



Food Recall



24-hour Duplicate Diets

Storage -24° C

Blood Collection

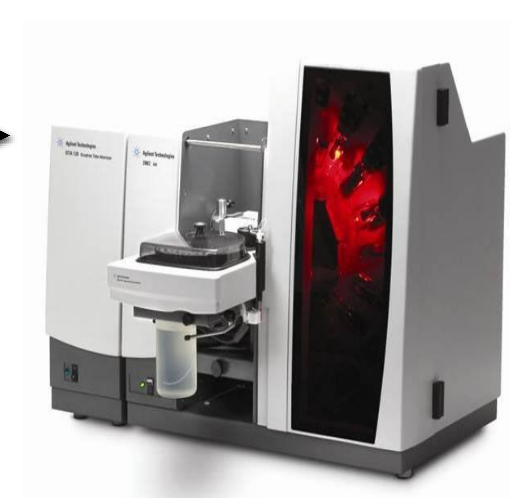
Diet and blood collection

Lead determination

24-hour Duplicate Diets

Homogenization and Lyophilization

1g Diet +
Open system digestion



ICP-MS (2013 study)

GF-AAS (2015 study)

5 mL of venous blood

500 µL venous blood +
3ml Triton™ X-100 0,2% with HNO_3 5%

Day Care Centers Results

Table 1. Comparison of geometric means and percentiles of concentrations of lead found in the blood sample between children aged 1 to 4 years old in Brazil (*n* = 2,397) and the United States (*n* = 836)

Blood lead levels per country	Geometric Mean (µg/dL) (95% CI)	Percentiles (95% CI)	Sample Size
BRAZIL	2.16 (2.10-2.22)	97.5^{th}: 13.9 (10.0-17.3)	2,397
UNITED STATES	1.17 (1.08-1.26)	97.5^{th}: 5.0	836

Day Care Centers Results

Table 2. Associations (adjusted *odds ratio* [OR_{adj}]) with their 95% confidence interval [95% CI] between blood lead levels (BLL) higher than 5 and 10 µg/dL and risk factors.

Risk Factor	BLL > 5 µg/dL		BLL > 10 µg/dL	
	OR_{adj}* 95% CI	*p*	OR_{adj}* 95% CI	*p*
Uncovered red lead at the household gates	1.57 (1.01-2.45)	0.046	1.84 (1.02-3.31)	0.044
High vehicle flow in the street of the DCC	1.70 (1.14-2.53)	0.009	2.42 (1.37-4.25)	0.002
DCC located in south region of Sao Paulo**	4.44 (1.83-10.74)	0.001	3.53 (1.00-12.45)	0.050
DCC located in east region of Sao Paulo**	7.22 (3.06-17.02)	<0.001	8.26 (2,50-27.36)	0.001

*OR adjusted for age and the others variables included in the table; **Reference category: DCC located in northwest region of Sao Paulo

Households Results

Table 3. Associations (adjusted *odds ratio* [OR_{adj}]) with their 95% confidence interval [CI 95%] for BLL groups and children's characteristics (n=204) and day care centers (n=4), 2013

	BLL (µg/dL) LE group		HE group			OR_{adj}.*	CI 95%
Variables	n	%	n	%	p		
Age group**					0.390		
1–3 years old	74	57.4	55	42.6		1	
4–5 years old	47	63.5	27	36.5		0.8	0.42, 1.51
Sex					0.055		
Feminine	69	65.7	36	34.3		1	
Masculine	52	52.5	47	47.5		1.91	1.04, 3.48
Day Care Centers					<0.001		
NR	8	32.0	17	68.0		1	
PS	49	79.0	13	21.0		0.12	0.04, 0.36
PF	43	55.1	35	44.9		0.39	0.14, 1.04
VA	21	53.9	18	46.1		0.45	0.15, 1.31
Tobacco use at home					0.206		
No	86	62.3	52	37.7		1	
Yes	35	53.0	31	47.0		1.57	0.82, 2.99

*Adjusted for age, sex, day care center's measured lead, and tobacco

** Missing age information for one child

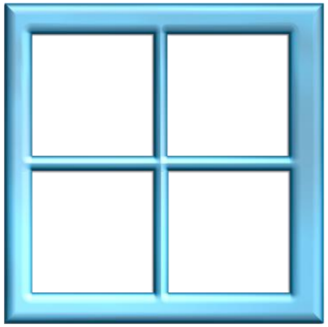
Day Care Centers Results

Table 4. Mean concentrations (μg/g) and percentage (> 600 μg/g) of high lead measurements, minimum and maximum values according to the day care center (DCC)

	Structure				Playground				Total	
DCC	Mean	% High lead	Min	Max	Mean	% High lead	Min	Max	Mean	% High lead
NR	2,836.2	33.8%	0	34,735	23,123	77.1%	0	170,406	10,443.8	50%
PS	1,293.7	32%	0	11,482	6,995.5	50%	0	144,900	4,563.3	42.3%
PF	3,138.7	30%	0	59,769	2,922.5	37.4%	0	28,863	3,015.9	34.2%
VA	2,158.9	21.6%	0	16,219	1,280.4	23.1%	0	25,122	1,678.6	22.4%

Structure

59,769 µg/g



34,735 µg/g

11,482 µg/g

16,219 µg/g

Playgrounds

170,406 µg/g

144,900 µg/g

28,863 µg/g

Households Results

Table 5. Associations (adjusted *odds ratio* [OR_{adj}]) with their 95% confidence interval [CI 95%] for BLL groups and children's characteristics, day care centers, and households (n=54)

Variables	BLL (µg/dL)						
	LE group		HE group		P	OR_{adj}[a].	CI95%
	n	%	N	%s			
Age group					0.014[b]		
1–3 years old	16	51.6	15	48.4		1	
4–5 years old	20	87.0	3	13.0		0.23	0.04, 1.34
Sex					0.081		
Feminine	23	76.7	7	23.3		1	
Masculine	13	54.2	11	45.8		4.61	0.82, 25.8
Day Care Centers					0.012[b]		
NR	1	14.3	6	85.7		1	
PS	10	83.3	2	16.7		0.03	0.01, 0.85
PF	19	67.9	9	32.1		0.07	0.01, 1.45
VA	6	85.7	1	14.3		0.02	0.01, 0.82
Households[c]							
High % of lead measurements (SD)	6.1 (4.8)		13.2 (9.7)		0.004	1.2	1.04, 1.39

[a] Adjusted for age, sex, day care center's measured lead.
[b] Fisher exact test.
[c] Continuous variable (SD = Standard deviation).

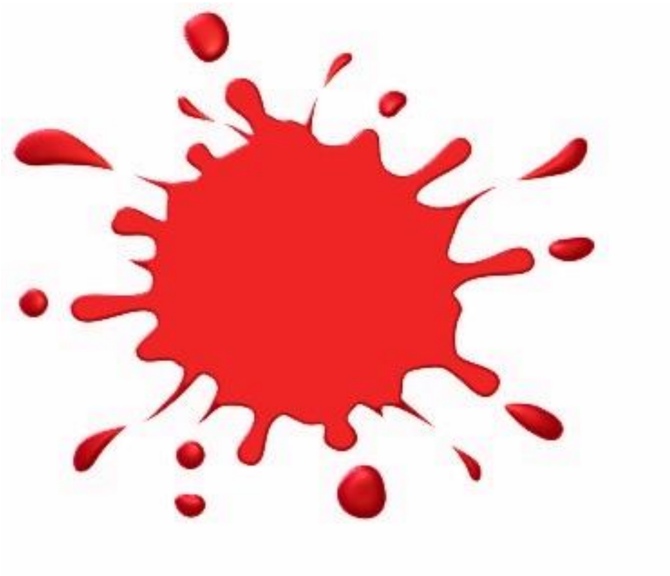
Households Results

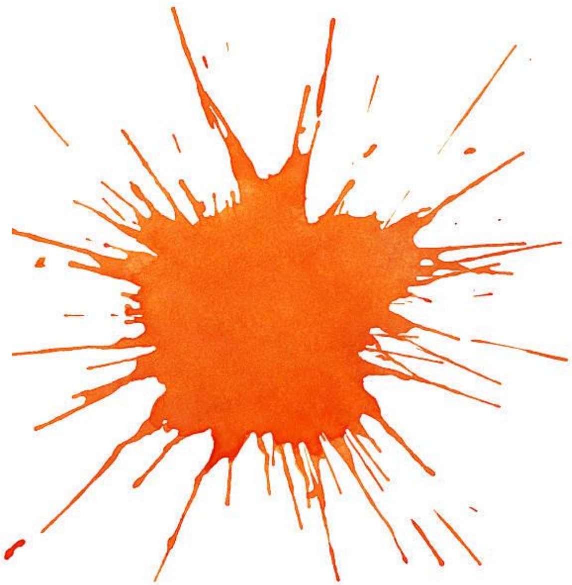
Table 6. Counting of measured objects both by lead paint mode (LPM: higher than 1 mg/cm^2) and by *Restriction of Certain Hazardous Substances* mode (ROHS: higher than 600 µg/g) in the children's houses according to day care center (DCC) attended

Children's households by DCC attended (*n*)	Tiles		Toys		Tableware		Doors, windows, and handrails		Walls		Bed (iron structure)		Folding Door	
	LPM	ROHS	LPM	ROHS	LPM	ROHS	LPM	ROHS	LPM	ROHS	LPM	ROHS	LPM	ROHS
PF (28)	45	32	12	31	1	2	16	144	1	1	0	0	8	8
PS (11)	20	6	4	8	0	1	2	23	0	2	0	3	2	6
VA (7)	8	4	2	9	2	0	3	39	0	0	0	0	1	5
NR (7)	58	42	5	2	2	0	3	16	0	0	0	0	1	3

Non-certified toys

Colors with the higher lead concentrations





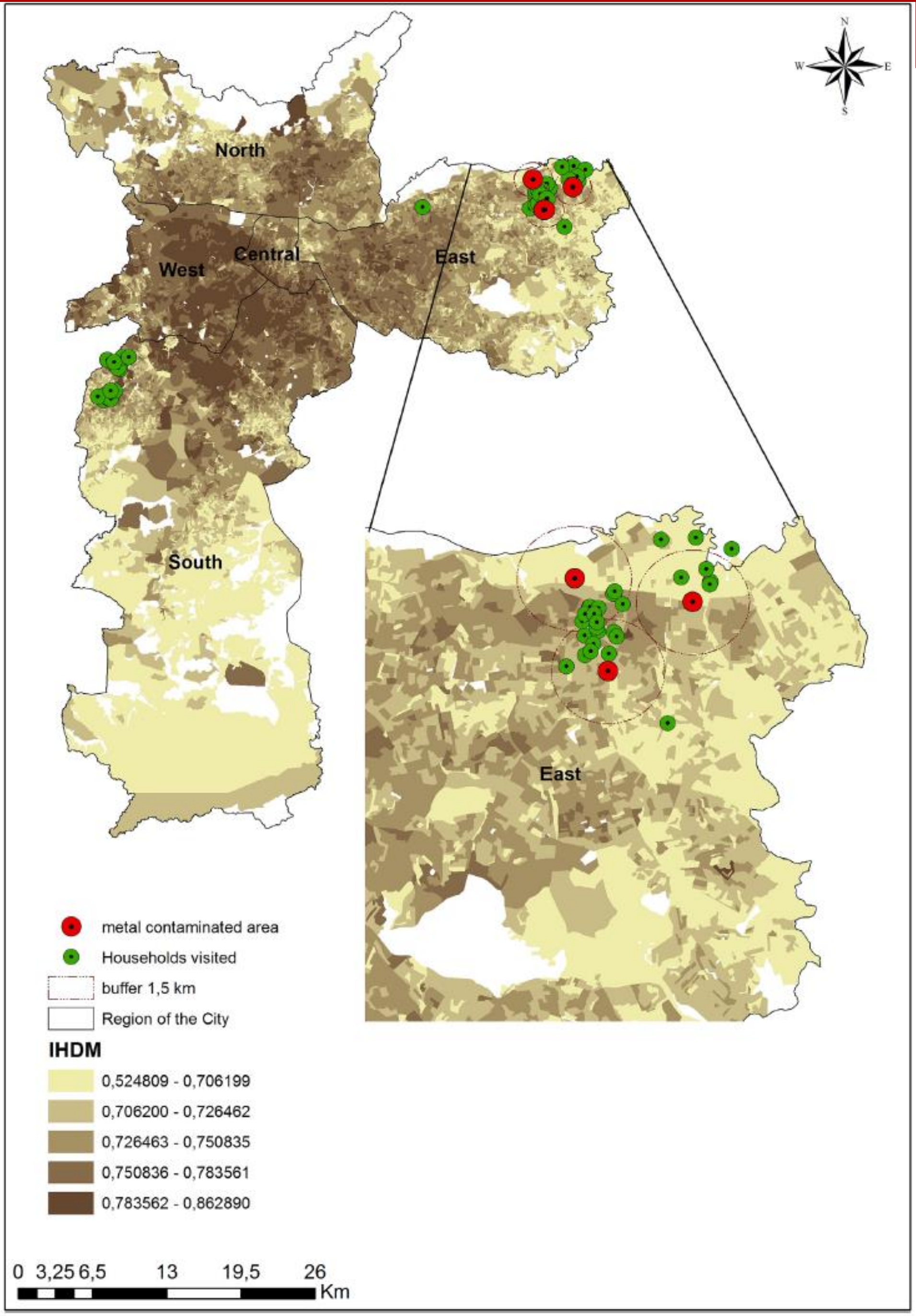


Fig. 1. Municipal Human Development Index (MHDI) of Sao Paulo city with the location of households visite.

Results of diets

- The diet have not found to be a risk factor to lead exposure

(p = 0,40).

Leroux et al. 2018. Manuscript submitted for Environmental Science and Pollution Research.

Conclusions

- The lead exposure estimated in DCCs, where children spend about 10 hours/day is relevant, as well as lead exposure in the households;
- Environmental and BLL screenings and regulation to reduce hazards from households and DCC compel urgent action;
- Public managers should promote efforts to acquire Pb-free supplies, toys and, equipments, beyond maintaining the structures in good conditions in order to prevent children's contact with paint chips and accidental intake and consequent poisoning.

As Needleman stated in 2009, “*We do not know how smart our children might be*”.

UNIVERSIDADE DE SÃO PAULO
FACULDADE DE SAÚDE PÚBLICA

exsat
The Human Exposome Research Group
Expossoma e Saúde do Trabalhador

Agradecimentos

UNIVERSIDADE DE SÃO PAULO
FACULDADE DE SAÚDE PÚBLICA

USP
Universidade de São Paulo

exsat
The Human Exposome Research Group
Expossoma e Saúde do Trabalhador

FAPESP

CNPq
Conselho Nacional de Desenvolvimento Científico e Tecnológico