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Review article

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

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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".

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1. Introduction

Lead is a neurotoxin that causes serious damage to the human brain. 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. The ACCLPP also recommended that the Centres for Disease Control and Prevention (CDC) focus on implementing primary prevention strategies and providing guidance using the best available evidence to respond to children with BLL above the reference value.

The U.S. has implemented successful public policies for the prevention and control of lead contamination. Data on the ethnicity of children associated with BLLs is available from national surveys, which provides a useful overview of the situation of Latino children when compared to other ethnic groups. For example, Jones et al. (2009) assessed the trends in children's BLLs based on national surveys conducted during a 16-year period in the U.S. Data from 1- to 5-year-old children surveyed in Phase I (1988–1991) and Phase II (1991–1994) of the Third National Health and Nutrition Examination Survey (NHANES) were compared with those collected during the survey period from 1999 to 2004. A decline of 84% indicated that the prevalence of high BLLs (≥ 10 μg/dL) dropped from 8.6% in 1988–1991 to 1.4% in 1999–2004. Between 1988–1991 and 1999–2004, the BLLs geometric means (GM) declined among non-Hispanic blacks (5.2 to 2.8 μg/dL), Mexican Americans (3.9 to 1.9 μg/dL), and non-Hispanic whites (3.1 to 1.7 μg/dL). However, the BLLs found in non-Hispanic black children are still higher than in Mexican American and non-Hispanic white children. BLLs were distributed as follows: 92.6% were <5 μg/dL, 6% ranged from 5 to 10 μg/dL and 1.4% were ≥ 10 μg/dL. Multivariate analysis indicated that living in old houses, poverty, younger age and being non-Hispanic black are still major risk factors for elevated BLLs. The authors concluded that children's BLLs have decreased in the U.S., even among populations that historically face high risks of lead poisoning. To maintain the progress achieved and eliminate remaining disparities, efforts should be directed toward screening children at high risk to identify and control sources of lead (Laborde et al., 2015).

More recently, Raymond et al. (2014) evaluated the prevalence of BLLs in 1- to 2-year-old children using data from the 2002 to 2010 CDC's Child Blood Lead Surveillance (CBLS) System to determine the proportion of U.S. children 1 to 2 years of age who tested for lead and data from the 1999 to 2010 National Health and Nutrition Examination Survey (NHANES) to examine the prevalence of BLLs ≥ 5 μg/dL and ≥ 10 μg/dL. The NHANES data from the period between 2007 and 2010 showed that 3.1% of children aged 1 to 2 years had BLLs ≥ 5 μg/dL. BLLs higher than 5 μg/dL were found for 7.7% of the non-Hispanic black children and for 1.6% of the Mexican-American children aged 1 to 2 years (95%CI: 0.7–3.0). The poverty level influenced BLLs in those children: 6.0% of children living in a household with a poverty-to-income ratio of <1.3 had BLLs ≥ 5 μg/dL, while only 0.5% of children living in a household with poverty-to-income ratio of ≥ 1.3 presented BLLs ≥ 5 μg/dL. Children living in pre-1950s housing were 10 and 4 times more likely to show BLLs ≥ 5 μg/dL compared to children living in post-1978 housing during NHANES 1999–2002 and 2007–2010, respectively.

The largest minority group of children in the U.S. is Latino, representing >12 million, i.e., 1 out of every 6 children (Carter-Pokras et al., 2007; U.S. Census Bureau, 2006). Nearly one-third of all children living in poverty are Latinos living in inner city areas and agricultural/rural communities, where they are routinely exposed to environmental contaminants (Ramirez and De La Cruz, 2002).

Childhood lead poisoning remains a serious concern in the U.S., disproportionately affecting ethnic minorities. Deteriorating lead-based paint in homes is the most common source of lead exposure among children (CDC, 2000). According to a study by Carter-Pokras et al., 1990, Puerto Rican and Mexican American children may present a higher probability of elevated BLLs than non-Hispanic white children in the U.S. because of their greater likelihood of living in older housing and inner cities. The exposure of Mexican-American children may be higher than the general population because of the use lead-containing folk medicines and lead-glazed pottery, and consumption of lead-contaminated candy from Mexico.

Japan and several countries in Europe present additional examples of developed countries that have been required to address the exposure of the population to lead. Lead concentrations from different sources, such as air and food, have tremendously decreased in Japan since the 1970s (Yoshinaga, 2012). BLLs for Japanese children between 1 and 14 years are relatively low, with a GM of 1.07 μg/dL (Yoshinaga et al., 2012). Since 2011, the country's Ministry of the Environment has been conducting a large-scale birth cohort study called “Japan Environment and Children's Study” (JECS), in which mother-child pairs are followed and studied until the children reach the age of 13 years. The study registered >103.000 pregnant mothers. This study includes the monitoring of air, soil, water and indoor environments, as well as several chemicals, physical conditions, socioeconomic factors, psychological conditions, lifestyles and community situations (Nakayama, 2016).

European Union (EU) directives and resolutions have noted the importance of exposure to lead as a key public health issue. In 1977, the Council Directive committed the EU Member States to invest in a standard procedure to assess the population's exposure to lead outside the working environment. In 2004, the EU adopted the Children's Health and Environment Action Plan for Europe. One of the goals of this plan is reduce the risks of disease and disability induced by exposure to heavy metals. Specific action includes enacting legislation on the lead content in petrol, developing or enforcing regulations to minimise lead in building materials, and implementing lead biomonitoring in infants and mothers at risk (WHO, 2009). In addition, the Global Alliance to Eliminate Lead Paint was established in 2009, and campaign activities related to the International Lead Poisoning Prevention Week of Action were held in 2013 in Albania, Georgia, the Republic of Moldova, Kazakhstan, Kyrgyzstan and Serbia (WHO, 2014). In Europe, a significant decrease in children's BLLs was observed over the last two decades, largely a result of the phasing out of lead from petrol, a process that began in Western Europe and later spread to Central and Eastern Europe. However, in some European countries (Bulgaria, Poland, the Republic of Macedonia and Ukraine), industrial emissions are still important local sources of lead exposure (WHO, 2009).

Considering all this information, we have previously revised studies on neurotoxicity and aggressiveness, triggered by low-level lead in children, described unsuspected sources of contaminant lead, discussed the possible association of the economic losses and urban violence caused by lead contamination, and reviewed the molecular basis of lead-induced neurotoxicity, emphasizing its effects on social behaviour, delinquency and the IQs of children and adolescents (Olympio et al., 2009). However, data on BLLs among Latin American and Caribbean (LAC) children at that time was scarce. This study responds to the following points: 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 the Region?

2. Methods

We conducted a literature review of publications from January 2000 to March 2014 in the PubMed and Lilacs databases. The search was performed using the following 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] for PubMed and Lilacs respectively.

Criteria for inclusion were as follows: a) the study population included children 0–18 years of age living in any country in LAC; b) the study presented BLL results as an outcome; and c) the study described the method used for collecting and analysing blood. Studies that collected both capillary and venous blood, using any analysis methods, such as graphite furnace atomic absorption spectroscopy (GFAAS), electrothermal atomic absorption (ETAAS), anodic stripping voltammetry, and those that used or did not use reference materials or inter-laboratory validation were included. All types of sampling and analytical methods were included to maximise the number of published studies and to provide an overview of the status of the study of BLLs in children from LAC countries. Only original papers were considered. Reviews, commentaries and theses were excluded. Other criteria for exclusion were the inclusion of adults in the study population and the use of a biomarker other than blood. All other studies that fulfilled the described criteria and were published between January 2000 and March 2014 were included in this review.

Two of the authors selected the papers based on the criteria described above and reviewed the selections for any inconsistencies with regard to inclusion and exclusion criteria. In the case of disagreement, a third examiner, also an author of the paper was asked to assess the inclusion of the paper and a final decision was made based on consensus. We compiled the bibliographic references of each included paper from the manual search screening, and made additions when new studies were found.

3. Results

Using the search strategy described above, 136 papers in PubMed and 121 in the Lilacs databases were found. Duplicate papers and those that did not meet the inclusion criteria were excluded, leaving a total of 56 papers for review in this study. No other paper was annexed after searching for additional studies in the reference lists of the selected papers. All selected papers present studies conducted in LAC countries (Fig. 1).

An overview of the selected papers shows that blood samples were collected from 171,046 children; 42.9% of the studies were performed in urban areas, and the remaining studies included both urban and rural areas or did not clearly describe whether the area was urban or rural; and 80.4% of the studies were conducted in "hot spots areas" (areas of potential high exposure), described below. Twenty (35.7%) of the studies included in this review clearly presented two quality assurance (QA)/quality control (QC) procedures or indicators of analytical performance for analysis,22 (39.3%) of the studies described one procedure and 14 (25.0%) studies did not mention any QA/QC procedure. Those QA/QC procedures and indicators of analytical performances included interlaboratorial programs, use of validated methods, duplicated analysis, use of certified reference materials, electronic calibrations, calibration curves, background corrections, reference standards, analysis

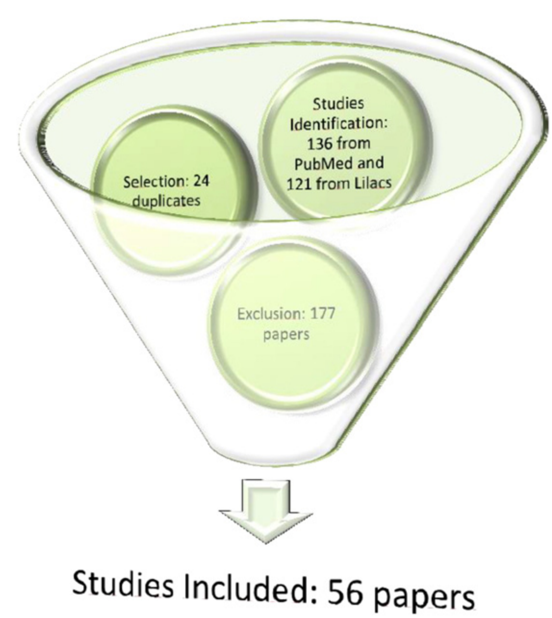

Fig. 1. Studies included in the review.

Table 1
Studies describing BLLs in Latin children published from 2000 January to March 2014.

Locality	Number (n) and age of children (year of blood collection)	Descriptive characteristics of exposure or non-exposure	Sample type and laboratory method	Geometric or Arithmetic mean of BLLs (% BLL ≥ 10 μg/dL)	Bibliographic reference
Argentina (Abra Pampa)	N = 25 5–16 years (2004)	Children living in this city, where a smelter worked until the late 1980′s and the waste has not been removed from the place	VB/GF-ETAAS (Varian AA-840)	Mean: 12.7 μg/dL (40%)	Barberis et al., 2006.
Argentina (Tucumán)	N = 133 5–16 years (1991–1995)	Children living near lead smelter	VB/AAS	Mean: 22.9 μg/dL (98.5%)	Riera et al., 2006.
Argentina (La Plata)	N = 93 6 months–5 years (2006)	Children attended at Hospital de Niños Sor Maria Ludovica	VB/GF-ETAAS (Varian AA-840)	GM: 4.26 μg/dL (10.8%)	Disalvo et al., 2009.
Brazil (Salvador)	N = 129 2–39 months (1995)	Children attending a nursery school.	VB/GF-AAS	AM: 10.7 μg/dL (32.56%)	Carvalho et al., 2000.
Brazil (Ribeira do Iguape River)	N = 295 7–14 years (1999–2000)	Children living in three cities in the valley of upper river including a community close to a lead refinery	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)	Children residents in an area of 1 km from a lead smelter	VB/GF-AAS	GM: 17.1 μg/dL (87%)	Carvalho et al., 2003.
Brazil (Bauru)	N = 850 0–12 years (2002)	Children residents in an area of 1 km from a battery recycling plant, whose contamination was proven by the state environmental authority	VB/GF-AAS using a Zeeman background correction)	Median: 7.3 μg/dL (36.6%)	Freitas et al., 2007.
Brazil (Rio de Janeiro)	N = 64 0–16 years (NS)	Children residing in a sanitary bank area, between high traffic roads and close to other potential lead contamination sources	NS Blood/AAS (AAnalyst 800 PerkinElmer)	Mean: 5.5 μg/dL (5%)	Mattos et al., 2009
Brazil (Ribeirão Preto)	N = 444 6–8 years (2006)	Children attending 4 public schools	VB/ICP-MS	Median: 2.1 μg/dL (0%)	Almeida et al., 2010.
Brazil (Porto Alegre)	N = 97 0–5 years (2006)	Children highly exposed to solid waste, high traffic roads, close to the airport and to an area with mid-sized factories	VB/GF-AAS	Median: 5.5 μg/dL (16.5%)	Ferron et al., 2012.
Belize	N = 164 2–8 years (2002)	Children living and 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 and 75 unexposed under 7 years old (1997–1998)	Children living near lead storage places, and 75 children living far away from these sites	VB/AAS (Perkin-Elmer 2100)	GM: 8.7 μg/dL -exposed children and 4.22 μg/dL– non-exposed children. (48%)	Sepúlveda et al., 2000.
Chile (Santiago)	N = 2051 children 4–14 years (1998–1999)	Observational and transversal study in rural and urban areas	CB/LeadCare™	Mean: 3.33 μg/dL (1,32%)	Sánchez-Cortez et al., 2003.
Chile (Santiago)	N = 422 4–12 months (1995–1997)	Children exposed environmentally when leaded gasoline began to be replaced by unleaded gasoline in 1993	VB/ETAAS – Perkin-Elmer 1100B	GM: 6.6 μg/dL (21.3%)	Pino et al., 2004.
Chile (Antofagasta)	N = 192 7–16 years (2005)	Children living near a lead storage local	CB/LeadCare™	AM: 3.2 μg/dL (0%)	Iglesias et al., 2011.
Colombia (Cartagena)	N = 189 5–9 years (2004)	Urban schoolchildren without known lead exposure	VB/ETAAS with longitudinal Zeeman-effect background correction	AM: 5.49 μg/dL (7.4%)	Olivero-Verbel et al., 2007.
Colombia (Soacha)	N = 32 <12 years old (2004–2005)	Occupational exposure in recycling automobile batteries process	VB/GF-AAS	Median: 54 μg/dL (100%)	Hurtado et al., 2008.
Colombia (Cali)	N = 350 6–14 years (2004–2005)	156 children exposed to industrial lead sources and 144 children non-exposed	VB/GF-AAS	AM: 4.7 μg/dL for exposed group and 3.0 μg/dLfor non-exposed group. (0%)	Filigrana and Méndez, 2012.
Cuba (Centro Habana)	N = 85 3–8 years (2002)	Children living in houses built before 1928	VB/LeadCare™	Median: 9.6 μg/dL (41.2%)	Valdés et al., 2003.
Dominican Republic (Santo Domingo)	N = 63 2–10 years (2007)	85.7% of the homes where children lived and their parents worked stayed in a perimeter from 0 to 50 m of repairing/ painting shops for vehicles	VB/GF-AAS	Mean: 16.7 μg/dL (36.5%)	Rodríguez and Espinal, 2008.
Ecuador (Ecuadorian Andes)	N = 88 2–15 years (NS)	Chronic lead exposure, children living in a highly lead-contaminated Andean village	VB/ICP-MS and GF-AAS	Mean: 43.2 μg/dL (ICP-MS) and 42 μg/dL (GF-AAS). (NS)	Counter et al., 2000.
Ecuador (Pujilí)	N = 166 6–16 years	Exposed to lead in a local ceramic glazing cottage industry	VB/GF-AAS	Mean: 18 μg/dL (49%)	Counter et al., 2008.

(continued on next page)

Table 1 (*continued*)

Locality	Number (n) and age of children (year of blood collection)	Descriptive characteristics of exposure or non-exposure	Sample type and laboratory method	Geometric or Arithmetic mean of BLLs (% BLL ≥ 10 μg/dL)	Bibliographic reference
	(NS)				
Ecuador (Andes Mountains)	N = 53 6–16 years (NS)	Exposed to lead in a local ceramic glazing cottage industry	VB/GF-AAS	Mean: 37.7 μg/dL. (79.25%)	Buchanan et al., 2011.
Jamaica	N = 421 3–11 years (1994–1996)	242 children in rural areas, 90 children in urban areas, 61 children from Hope River Valley (contaminated area) and 28 children from contaminated area after remediation	CB/LeadCare™	Mean: Rural areas - 9.1 μg/dL (42%) Urban areas - 14.0 μg/dL (71%) Contaminated area before remediation – 35 μg/dL (100%) Contaminated area after remediation – 15 μg/dL (96%)	Lalor et al., 2001.
Jamaica (Mona Commons district – Kingston)	N = 107 2–12 years (2006)	Children residents in a district with a backyard lead smelting producing lead burdens in soils and indoor dust loadings in residents' home	CB/LeadCare™	Mean: 25.1 μg/dL (59%)	Lalor et al., 2006.
Jamaica	N = 1081 2–6 years (NS)	Children of 33 basic schools across Jamaica	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)	Oaxaca has a centuries-old tradition of lead-glazed ceramic ware used and manufactured mainly by small family businesses	VB/AAS	GM: 10.5 μg/dL (54.9%)	Azcona-Cruz et al., 2000.
Mexico (Lagunera)	N = 394 6–9 years (NS)	Children were attending 3 primary schools and living in the vicinity of the largest smelter complex	VB/AAS	Medians: Close school – 27.6 μg/dL (67.5%) Intermediate – 21.8 μg/dL (56.3%) Remote – 7.8 μg/dL (26.9%)	García Vargas et al., 2001.
Mexico (Mexico City)	N = 19 6 months–6 years (1999–2000)	19 exposed children of radiator repair workers and 29 non-exposed children	CB/LeadCare™	GM: 16.3 μg/dL - exposed children and 5.6 μg/dL - non-exposed children. (NS)	Aguilar-Garduño et al., 2003.
Mexico (Torreón)	N = 367 1–6 years (NS)	Children living in Torreón and risk factors for lead exposure in these children were assessed	CB/LeadCare™ and VB/AAS with Zeeman background correction	GM: 6.0 μg/dL. (20%)	Albalak et al., 2003.
Mexico (Morelos)	N = 232 1–12 years (1996)	Main risk factor was use of lead-glazed pottery and vehicle traffic intensity near the household	CB/Anodic stripping voltammetry (ESA)	GM: 6.7 μg/dL (29.7%)	Meneses-González et al., 2003.
Mexico (Mexico City)	N = 321 children born between (1987–1992)	BLL was measured every 6 months during a 10-year period in children of families who used lead-glazed ceramics	CB/LeadCare™	GM: Whole cohort - 8.4 μg/dL First year – 10.1 μg/dL End of the study – 6.4 μg/dL (26.7% to 12.9%).	Schnaas et al., 2004.
Mexico (Fresnillo)	N = 59 0–15 years (2004–2005)	Inhabitants of a place located 500 m from a recycling company of metals	CB/LeadCare™	Mean: 4.9 μg/dL (11% and 14% for 0–6 and 6–12 years old, respectively).	Manzanares-Acuña et al., 2006.
Mexico (Mexico City)	N = 715 7–14 years (1996)	Children who attended the outpatient units of five paediatric hospitals. The main source of exposure was the use of glazed pottery	VB/GF-AAS (Perkin-Elmer 3000)	AM: 8.6 μg/dL GM: 7.7 μg/dl (27.1%)	Leal-Escalante et al., 2007.
México (Torreon)	N = 232 6–8 years (2001–2005)	Children who started an elementary school located up to 3.5 km of a metallurgic smelter complex	VB/GF-AAS (Zeeman-Graphite Furnace-Analyst 800, PerkinElmer)	The mean at the beginning was 10.12 μg/dL and progressively diminished to 4.4 μg/dL after 5 years (The percentage decreased from 50.84% to 5.6%)	Rubio-Andrade et al., 2011.
Mexico (Torreón)	N = 34 2–17 years (2005–2006)	Living within a 113 km^2 area of a silver-zinc-lead smelting plant in Torreon	VB/MC-ICP-MS	GM: 9.8 μg/dL. (NS)	Soto-Jiménez and Flegal, 2011.
Mexico (1. Avalos Metallurgical, Chihuahua. 2. Morales Metallurgical, San Luis Potosi. 3. Cedral mine site. 4. Trinidad Poterry area, Tlaxcala)	N = 316 4–9 years, 67 in Avalos 58 in Morales 119 in Cedral 72 in Trinidad (2008–2009)	Living near contaminated sites	VB/GF-AAS	GM: Avalos - 11.3 μg/dL (57%) Morales - 7.1 μg/dL (22%) Cedral – 6.1 μg/dL (18%) Trinidad – 19.4 μg/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 effect background correction	GM (2010): 5.15 μg/dL (84.9% in 1999 and 10.4% in 2010)	Recio-Vega et al., 2012.
Mexico	N = 226	Children from public schools	VB/AAS	Mean: 7.23 μg/dL (18%)	Farías et al., 2014.

Table 1 (*continued*)

Locality	Number (n) and age of children (year of blood collection)	Descriptive characteristics of exposure or non-exposure	Sample type and laboratory method	Geometric or Arithmetic mean of BLLs (% BLL ≥ 10 μg/dL)	Bibliographic reference
(Morelos)	6–13 years (2011)				
Paraguay (Asunción)	N = 52 7–16 years (June–July/2002)	20 children who worked and lived in the streets of Asunción (G1), and 32 children living in the suburban area, in Capiatá (G2).	VB/AAS	GM: 6.8 μg/dL. The GM were 7.2 and 6.6 μg/dL for G1 e G2, respectively. (NS)	Samaniego and Benítez-Leite, 2002.
Peru (Lima and Callao)	N = 2510 6 months–11 years (1998–1999)	Children from 15 schools from different districts in Lima and Callao with different vehicular traffic intensities	Anodic Striping Voltmeter	Mean: 9.9 μg/dL (29%)	Espinoza et al., 2003
Peru (Puerto Nuevo)	N = 70 8–12 years (1999)	Children from "Maria Reiche" school	CB/LeadCare™	Mean: 40.7 μg/dL (100%)	Vega et al., 2003.
Peru (El Callao: Puerto Nuevo and La Punta)	N = 134 6–8 years and 6 months. (NS)	Children living in a zone with high lead exposure (deposits of lead in the vicinity)	CB/LeadCare™	Mean: 10.33 μg/dL (44.6%)	Vega-Dienstmaier et al., 2006.
Peru (La Oroya)	N = 93 newborns <12-h of life (2004–2005)	Pregnant residents in La Oroya, one of the most contaminated cities in the world	VB/AAS (equipment Perkin Elmer 3110)	Mean: 8.84 μg/dL (24.7%). There were not newborns presenting BLL <5 μg/dL.	Pebe et al., 2008.
Peru (Quiulacocha and Champamarca)	N = 236 1–10 years (2005)	Residents of localities situated within 5 to 7 km from Pasco, where there is a metal waste area	VB/flame AAS (PerkinElmer 560)	Mean: 15.79 μg/dL for all children (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 – 9.5 μg/dL (25.7%) Non-exposed – 9.2 μg/dL (25.8%)	Anticona et al., 2011.
Peru (Peruvian Amazon basin)	N = 208 0–17 years (2009)	Communities exposed and non-exposed to oil activities	CB/GF-AAS	GM: 8.7 μg/dL (27.4%)	Anticona et al., 2012.
Puerto Rico (Brisas del Rosario)	N = 42–6 years old (2000)	Children living near contaminated sites	VB/Method 1080B by CDC.	AM: 2.52 μg/dL GM: 2.28 μg/dL (0%)	Sánches-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 = 2351 6 months–15 years (2001)	Children living near metal smelting plants and other industrial activities	VB/AAS	Mean: 11.7 μg/dL (61%)	Mañay et al., 2003.
Uruguay (Montevideo)	N = 112 children unexposed, 62 children exposed, and 4 siblings 0–14 years old. (NS)	Children living close to industrial areas, in old buildings, with lead pipelines for their water systems	VB/FAAS 283.3 nm, Perkin Elmer 306	Means: Unexposed - 9.4 μg/dL (0%), Exposed – 11.8 μg/dL (59%), and siblings 35.05 μg/dL (100%)	Cousillas et al., 2005.
Uruguay (Montevideo)	N = 180 0–15 years (2004)	2004 – Children living in Montevideo City and a rural area of Uruguay	VB/FAAS 283.3 nm, Perkin Elmer 306	Means: 2004–5.7 μg/dL (6.7%)	Cousillas et al., 2008.
	N = 47 2–11 years (1994)	1994 – Children attending a public care centre from different places of the country		1994–9.6 μg/dL (36%)	
Uruguay (Montevideo)	N = 222 6–37 months (2007)	Urban children without known lead exposure	CB/NS laboratory method	Mean: 9.3 μg/dL (33.9%)	Kordas et al., 2010.
Venezuela (Valencia)	N = 10 4–7 years (2000)	Children with BLL higher than 10 μg/dL attending a Centre for Infant Development	VB/AAS (Perkin Elmer 3110)	Means: Before treatment: 19.95 μg/dL. After treatment: 12.55 μg/dL (90%)	Squillante et al., 2002.
Venezuela (Valencia)	N = 60 4–9 years (2004)	Children living near potential sources of environmental lead	VB/AAS (Perkin-Elmer 3110)	Means Males — 11.1 μg/dL Females — 9.5 μg/dL (61.7%)	Espinosa et al., 2006.
Venezuela (Valencia)	60 children 4–9 years (2004)	Schoolchildren from Michelena, earlier classified as "critical" for lead exposure	NS Blood/AAS (Perkin-Elmer 3110)	Mean: 10.5 μg/dL (33.9%)	Seijas and Squillante, 2008.

by two different methods (ICP-MS (inductively coupled plasma mass spectrometry) and GFAAS or anodic stripping voltammetry) and the use of calibration kits. Very few papers reported the timeframe between the blood collection and the sample analysis.

Table 1 summarizes the detailed characteristics of the selected studies. Fig. 2 shows intervals of BLLs means or medians of children living in the LAC region.

3.1. Argentina

In Argentina, studies conducted in the cities of Cordoba and Buenos Aires revealed that approximately 10% to 40% of environmentally exposed children below the age of 15 presented BLLs > 10 μg/dL (Garcia and Mercer, 2003). More recently, children aged 6 months to 5 years old and residing in La Plata, Argentina, were examined between July

Fig. 2. Intervals of BLLs means or medians of children living in the LAC region. Lalor et al. (2001) is not included in the map due to the non-reported BLL mean or median for the whole studied population.

and October 2006 (Disalvo et al., 2009). The geometric mean of the BLLs for that population was 4.26 μg/dL (95% CI 3.60–5.03). Prevalence of BLL ≥ 10 μg/dL was 10.8%. One more study verified BLLs of populations with high risk of lead contamination. In Abra Pampa, Jujuy, a smelter worked until the end of the 1980′s, and the waste has not been removed from the place. Children (n = 25) aged 5 to 16 years had venous blood collected in 2004, and the mean BLL was 12.7 μg/dL, with 40% of the children presenting BLLs higher than 10 μg/dL (Barberis et al., 2006). Between 1991 and 1995, children residing in Tucumán, Argentina, were exposed to the environmental contamination of a lead smelter near their homes. Biological monitoring of 133 children aged 5 to 16 years reported that 98.5% had high BLLs, with a mean of 22.9 μg/dL (Riera et al., 2006).

3.2. Brazil

Carvalho et al. (2000) analysed 129 children aged 2 to 39 months attending a daycare centre in Salvador, Bahia. Their results indicated an arithmetic mean (AM) of 10.7 μg/dL for BLLs in 1995. Paoliello et al. (2002) examined 295 schoolchildren aged 7 to 14 years living in three cities in the valley of the upper Ribeira do Iguape River. The authors found BLLs with a mean of 11.25 μg/dL in a community close to a lead refinery (rural area) and a mean of 4.40 μg/dL for communities far from the same lead refinery (urban and rural). In this study, 59.6% of the children living near the lead refinery had BLLs ≥ 10 μg/dL, and only 8.5% of the children residing in the other communities presented BLLs higher that benchmark. Children living close to a primary lead-smelting plant in Santo Amaro, Bahia, presented mean BLLs of around 17 μg/dL, and 5 μg/dL higher in children with pica-habit, regardless of age, which they attributed to the visible presence of dirty surroundings, the householder employment status, familial history of lead-poisoning, and malnutrition (Carvalho et al., 2003).

Freitas et al. (2007) evaluated lead exposure in the city of Bauru, where a car battery recycling plant had contaminated the neighbouring residential area with lead oxides during the previous eight years. Environmental lead contamination was assessed by the São Paulo State Authority for Environmental Control (CETESB), and the plant was closed in 2002. In the same year, venous blood was collected from 0- to 12-year-old children. The BLLs data are presented in Table 1. Another Brazilian study conducted in the same city reported an association between high lead levels in surface dental enamel and antisocial behaviour in adolescents (Olympio et al., 2010).

In Rio de Janeiro, 64 children were evaluated for BLLs in an economically deprived community without a history of lead pollution, but located in an area with potential risk factors for contamination by the metal. The reported mean was 5.5 ± 3.34 μg/dL and 5% presented values higher than 10 μg/dL (Mattos et al., 2009). In Ribeirão Preto, São Paulo, all the examined children (n = 444) had levels below 10 μg/dL. Boys presented higher BLLs (2.3 μg/dL) than girls (2.0 μg/dL) (p = 0.0003), probably because boys are more prone to playing outdoors, and thus more exposed to soil dust (Almeida et al., 2010).

More recently, a cross-sectional study was performed in Porto Alegre with 0- to 5-year-old-children residing in a district whose dwellers are involved with recycling activities. Ninety-seven children participated in the study, and 16.5% had BLLs ≥ 10 μg/dL. The median value for BLLs was 5.2 μg/dL. More than 50% of the children had BLLs > 5 μg/dL. Factors associated with elevated BLLs included older age, father's low educational level and recycling-related chores in the household (Ferron et al., 2012).

3.3. Belize

Charalambous et al. (2009) performed a survey in 2002 with 164 children aged 2 to 8 years from 4 different cities: San Pedro, Benque

Viejo, Belize City and Orange Walk. Approximately 7% of the children had BLLs > 10 μg/dL. Analysis of variance (ANOVA) revealed no difference in BLLs between males and females.

3.4. Chile

Between 1997 and 1998, children living near lead storage sites in Antofagasta had a 24-fold higher risk of having lead in their blood. The venous blood of these children ($n = 486$) presented BLLs of 8.7 μg/dL, whereas unexposed children ($n = 75$) presented 4.22 μg/dL (Sepúlveda et al., 2000). Sánchez-Cortez et al. (2003) reported BLLs obtained from 2050 children with a mean of 3.33 μg/dL and 1.3% of children with BLLs ≥ 10 μg/dL. Considering that this survey was conducted between 1998 and 1999, the reported values are low, since a previously conducted study found 14.5% of children with BLLs ≥ 10 μg/dL. The authors attributed these results to the reduction of leaded gas use since 1992.

Pino et al. (2004) reported that leaded gasoline was an important source of exposure to lead before 1993, in Santiago. After this year, leaded gasoline began to be replaced for unleaded gasoline and lead emissions started to decline. According to their study, the BLLs of 422 infants fell following the decline of leaded gasoline sales between October 1995 and February 1997. The BLL mean was 6.6 μg/dL, whereas 21.3% of infants surpassed 10 μg/dL. In 2005, after the main source of lead exposure in Antofagasta was removed, Iglesias et al. (2011) performed a similar study with 192 children from the original study. The BLL mean was 3.2 μg/dL, and all children presented BLLs < 10.0 μg/dL.

3.5. Colombia

In Cartagena, 7.41% of children had BLLs > 10 μg/dL (Olivero-Verbel et al., 2007), which was lower than the levels reported in children from other LAC countries. In Soacha, 32 children younger than 12 years with relatives or neighbours involved in the recycling of automobile batteries reported a median BLL value of 60 μg/dL. The minimum BLL value was 2 times higher than 10 μg/dL (Hurtado et al., 2008). In Cali, 156 schoolchildren exposed to industrial sources presented BLLs means of 4.7 μg/dL, and 144 non-exposed schoolchildren presented means of 3.0 μg/dL. In this case, all children were under 5 μg/dL, which is the value recommended by the CDC standard (Filigrana and Méndez, 2012).

3.6. Cuba

Between April and December 2002, BLLs were analysed for 85 children (3 to 8 years old) residing in houses built before 1992 in Centro Habana. The factors associated with high BLLs were soil-eating habits, chewing toys and not washing hands (Valdés et al., 2003).

3.7. Dominican Republic

In 2007, 63 children were monitored in Santo Domingo. In 85% of homes where children lived and worked, there was a machine or automotive paint shop within 50 m. Results showed that 36% of children had elevated BLLs; the mean value was 16.7 μg/dL, and the highest value was 61.9 μg/dL (Rodríguez and Espinal, 2008).

3.8. Ecuador

Children who resided in Pujilí County, an Ecuadorian Andean village, had been exposed to lead as result of a local ceramic glazing cottage industry. Counter et al. (2000) found an extremely high BLLs mean value of 43.2 μg/dL measured by inductively coupled plasma mass spectrometry (ICP-MS) and 42 μg/dL measured by GF AAS. In 2008, children presented BLLs of 18 μg/dL, representing acute exposure (Counter et al., 2008). In 2011, 53 children had BLLs ranging from 4.2 to 94.3 μg/dL (Buchanan et al., 2011). Both these studies were conducted in Pujili County.

3.9. Jamaica

In 2001, the BLLs of 421 3- to 11-year-old-children from rural and urban areas were measured, including a highly contaminated community. Forty-two percent of the children from the rural area and 71% from the urban area had BLLs above 10 μg/dL (Lalor et al., 2001).

In the Mona Commons district, where long-term backyard smelting of lead occurs, 55% of the children presented BLLs ≥ 10 μg/dL. Five children had BLLs between 89 and 202 μg/dL, of which two had lead encephalopathy and one had epilepsy (Lalor et al., 2006).

Lalor et al. (2007) performed an island-wide survey of 1081 elementary school children (2 to 6 years). BLLs ranged from 1.4 to 202 μg/dL, with an AM and GM of 7.3 μg/dL and 4.35 μg/dL, respectively. The higher BLLs were found mainly in poor areas of urban Kingston, the St. Andrew Corporate Area and St. Catherine. The most important source of exposure was the recovery of lead from used automobile batteries.

3.10. Mexico

In 1999, there was a remediation process in Torreon concerning a smelting plant considered a contaminated area since 1977. Over 100 tons of dust containing high concentrations of metals was removed. Furthermore, >100 families were relocated to other places. The State Ministry of Health opened a multi-professional clinic to follow the lead contaminated population using a five-year cohort of children. The mean of the start age was 7.2 ± 0.33 years and the mean end of follow-up age was 12.2 ± 0.34 years. The mean BLL at the beginning was 10.2 μg/dL and progressively decreased to 4.4 μg/dL after 5 years (Rubio-Andrade et al., 2011). According to Albalak et al. (2003), 20% of the children from the Torreón region presented BLLs of 6.0 μg/dL and 20% had levels higher than 10 μg/dL.

In another case, BLLs of 34 children (2 to 17 years old) living in a 113 km^2 area of industrial growth and a silver-zinc-lead smelting plant in Torreón, were 9.8 μg/dL (Soto-Jiménez and Flegal, 2011). García Vargas et al. (2001) analysed the BLLs of 394 children living near the largest smelting complex. The mean was 7.8 μg/dL among children attending a school that was remote from the smelter (8100 m), and 21.8 μg/dL and 27.6 μg/dL at an intermediate (1750 m) and a closer distance (650 m), respectively. The percentages of children with BLLs > 15 μg/dL were 6.8%, 84.9% and 92.1%, respectively.

From 1998 to 2010, the database of the Coahuila Health Secretary's Childhood BLLs Surveillance Program was analysed. Data from 151,322 children aged 0 to 15 years old were used to compare BLLs values. When values were analysed by year, the highest mean was recorded in 1998 (20.05 μg/L). When the values were evaluated by age group, the highest mean was in children aged 3 to 5 years (8.24 μg/L) and boys presented BLLs higher than girls ($p < 0.03$). In 2010, the BLLs mean was 5.15 μg/dL (Recio-Vega et al., 2012).

In San Ignacio, located within 500 m of a metal recycler, BLLs were measured in 2530 15-year-old-children. The reported mean BLLs (4.9 μg/dL) was similar to that reported in other studies (Manzanares-Acuña et al., 2006). In Mexico City, 715 children, who attended the outpatient units of five paediatric hospitals in 1996 were examined. The main source of lead exposure was the use of glazed pottery (Leal-Escalante et al., 2007). According to this study, the risk of failing a school year between the first and fourth grade with a BLL ≥ 10.0 μg/dL was 44%. An additional study in Mexico City collected the capillary blood of 19 exposed children whose parents were radiator repair workers, and 29 children with parents not occupationally exposed to lead. BLLs were 16.3 μg/dL for the exposed children and 5.6 μg/dL for the non-exposed children (Aguilar-Garduño et al., 2003). Schnaas et al. (2004) collected capillary blood in Mexico City to measure BLLs every 6 months over a 10-year period in 321 children born between 1987 and 1992 whose families used lead-glazed ceramics. According to the authors, the Mexican government successfully reduced different lead sources during this period, mainly gasoline with lead. BLLs decreased to 6.4 μg/dL when these children reached their tenth birthday.

In Morelos (1996), the main risk factors were due to the use of lead-glazed pottery and the vehicle traffic intensity near the household (Meneses-González et al., 2003). In 2011, the mean value of BLLs was higher; however, 18% of the schoolchildren had BLLs > 10 μg/dL (Farías et al., 2014). Oaxaca, Mexico, has a centuries-old tradition of using lead-glazed ceramics manufactured mainly by small family businesses. The geometric mean of BLLs was 10.5 μg/dL and 54.9% were above 10 μg/dL (Azcona-Cruz et al., 2000).

Children living near Avalos Metallurgical, Chihuahua, and Trinidad Pottery area, Tlaxcala, presented BLLs above the established CDC “concern value” (Flores-Ramírez et al., 2012).

3.11. Paraguay

A cross-sectional and exploratory study measured BLLs during 2002. Twenty children who worked and lived in the streets of Asunción, and 32 children living in the suburban area in Capiatá, were studied. BLLs values were 5.5 to 10.9 μg/dL in Asunción and 5 to 17.4 μg/dL in Capiatá (Samaniego and Benítez-Leite, 2002).

3.12. Peru

Puerto Nuevo, in the district of Callao, is Peru's main port and a place where mineral ore is stored for export. In the district's slums, 44.6% of 6- to 8-year-old children presented BLLs > 10 μg/dL. A likely explanation for this is the very unsafe environment of the warehouses in which the mineral ore is stored (Vega-Dienstmaier et al., 2006). In an earlier study (1998–1999), 2510 Peruvian children had capillary blood samples collected and analysed by LeadCare™. The results showed means of 7.1 μg/dL and 9.6 μg/dL for Lima and Callao respectively. In Puerto Nuevo, two schools and a health unit presented excessive BLLs of 40.7 μg/dL, 15.8 μg/dL and 26.6 μg/dL, depicting the location's severe contamination (Espinoza et al., 2003). In 1999, 8- to 12-year-old schoolchildren from Puerto Nuevo presented a BLL mean of 40.7 μg/dL (Vega et al., 2003).

La Oroya has long been known as one of the most polluted cities in the world. The BLLs mean of the newborns (12 h of life) was 8.84 μg/dL (95% CI: 8.40–9.28). Of the 93 babies who participated in the study, none had BLLs < 5 μg/dL (range: 6–15 μg/dL). Surprisingly, 93% of the newborns' mothers had received secondary or college degrees, yet all ignored the harmful effects of lead contamination both for themselves and their children's health (Pebe et al., 2008).

BLLs were also measured in Quiulacocha and Champamarca in 2005, where mineral waste is deposited. Of the 236 Peruvian children evaluated, 85.8% in Quiulacocha and 82.8% in Champamarca had BLLs > 10 μg/dL (Astete et al., 2009).

In 2006, a governmental study showed 66.2% of children residing along the Corrientes River in Peru's Amazon Basin with BLLs ≥ 10 μg/dL. The elevated BLLs in these remote communities were surprising due to the absence of known sources of lead exposure (Anticona et al., 2011). In 2008, BLLs were measured to compare communities exposed and non-exposed to oil exploitation activities. Analyses of 361 capillary blood samples resulted in a mean BLLs of approximately 9.4 μg/dL (range: 3–31.6 μg/dL). There was no significant difference in mean BLLs between communities exposed (9.5 μg/dL) and non-exposed (9.2 μg/dL) to the oil activity. These results did not allow for identification of the lead exposure sources (Anticona et al., 2011). Later, Anticona et al. (2012) studied the potential risk factors associated with high BLLs in these communities. The data indicated that the exposure could be linked to specific activities in which lead-containing devices (hooks, bullets) are used, such as in fishing and hunting.

3.13. Puerto Rico

Children living near contaminated sites in “Brisas do Rosário” were below the CDC standard BLL. Venous blood of 42 children was analysed, and the highest value was 7.79 μg/dL. The obtained BLL results suggested statistically significant associations with lead in the windowsills of children's bedrooms ($p = 0.034$), toy-chewing habits ($p = 0.007$) and soil-eating habits ($p = 0.031$) (Sánches-Nazario et al., 2003).

3.14. Trinidad and Tobago

The first national baseline survey of BLLs conducted on primary schoolchildren in Trinidad and Tobago was performed by Rajkumar et al. (2006). A total of 1761 students from 61 schools participated in the study. The mean was 2.8 μg/dL, and 0.9% of the children had BLLs ≥ 10 μg/dL.

3.15. Uruguay

In early 2001, Mañay et al. (2003) detected BLLs > 25 μg/dL in children from Montevideo living near several metal smelting plants and other industrial activities that had been in operation for the past 50 years. The Ministry of Public Health commissioned a second study, in which 61% of the 2351 children presented BLLs > 10 μg/dL. Higher BLLs were found in younger children (<4 years). Maximum BLLs were found in children aged approximately 2 years old, which is consistent with the results of other studies (ATSDR, 2003; IPCS, 1995). Mañay et al. (2008) reported a comparison between BLLs of children examined in 1994 and in 2004. The two populations were sampled at the same healthcare centre. The mean of 9.9 μg/dL found in 1994 declined to 5.7 μg/dL in 2004 ($p < 0.0001$). A possible reason for the decline in Uruguayan BLLs is the increasing concern about lead pollution, which started in 2001. This raised the population's awareness of the possible harmful effects of lead pollution on children's health and led to important changes in their nutritional and hygiene habits. The phase-out of leaded petrol, and the substitution of lead water pipes with plastic pipes in many households may have also contributed to this decline. Cousillas et al. (2005) collected venous blood of 178 children residing in Montevideo city and in a rural area of Uruguay. Mean BLLs for exposed children (living in old buildings with lead water pipelines) was 11.8 μg/dL and 9.4 μg/dL for unexposed children. Four siblings whose father recovered batteries at their home presented levels of 35.05 μg/dL. Another comparative study performed in 2004 in the same area with 0- to 15-year-old-children showed significantly lower BLLs (5.7 μg/dL) than those sampled in 1994 (9.6 μg/dL, $p < 0.001$). Furthermore, in 1994, 36% of the BLLs were higher than the CDC recommended value, while only 6.7% were above this value in 2004 (Cousillas et al., 2008).

This reduction in Montevideo notwithstanding, a sample of preschool children and their mothers participated in a study in 2007 when children had their non-fasting capillary blood analysed by LeadCare™ (Kordas et al., 2010). They presented elevated BLLs. The authors also collected hair samples and found that higher capillary blood lead was a significant predictor for lead in children's hair.

3.16. Venezuela

Squillante et al. (2002) evaluated the contribution of clinical and psychological treatments in children with BLLs over 10 μg/dL, who attended a centre for infant development in Valencia. The BLLs were measured for ten 4- to 7-year-old children. Before *N*-acetylcysteine treatment, BLLs displayed a mean of approximately 19.9 μg/dL and 12.55 μg/dL after. Espinosa et al. (2006) described a significant difference between the BLLs of males (11.1 μg/dL) and females (9.5 μg/dL). In 2004, venous blood was collected from 60 children aged 4 to 9 years. This study also reported that children living near a mechanical workshop had elevated BLLs.

BLLs were measured in sixty 4- to 9-year-old-children in Valencia in 2004 (Seijas and Squillante, 2008). The mean was 10.5 μg/dL, which was lower than the mean found in 2003 (11.6 μg/dL) (Rojas et al., 2003). However, in 2003, the studied population was 1 to 12 years old and included residents of Naguanagua City, a less polluted town.

4. Discussion and conclusions

So…What is the situation of Latin American and Caribbean children?

The present study showed the scarcity of data on BLLs in LAC children. Using the same search strategy without limiting the research for LAC, we found 1161 and 934 papers from PubMed and Lilacs, respectively. By including only the studies carried out in the U.S., Canada, Europe, Australia and Japan, we found 232 papers reporting the prevalence of BLLs in children and adolescents from their countries. As previously reviewed, the majority of BLLs studies carried out in LAC are point-source exposures that include only a small number of children exposed to “hot spots”. In some developed countries, this situation is much better. For example, in 2013 the Canadian Government published a Risk Management Strategy to reduce and mitigate lead exposure. Federal initiatives were implemented as part the strategy by applying limits for lead in different sources, including consumer products, such as glazed ceramics and glassware, jewellery for children, cosmetics, food, health products and water and soil quality (Canada, 2013). According to the Canadian Health Measures Survey (CHMS), the geometric BLLs mean of 6- to 79-year-old Canadians was 1.34 μg/dL (Bushnik et al., 2010), showing more than a 70% decline in BLLs since the 1970s (Canada, 2013). Further actions to reduce lead exposure are being proposed by the Canadian government, such as updating the tolerance levels for lead in foods in the Food and Drug Regulations, reviewing the Guidelines for Canadian Drinking Water Quality and Consumer Products, and introducing new lead content restrictions for products destined for children (Canada, 2013). In the same way, the U.S. has continuously invested a great deal of money and research to dramatically reduce lead contamination across the entire population.

On the other hand, developing countries have achieved little progress on this front. Lead poisoning remains a critical issue in many low-income countries, with an estimated 99% of all children exposed to excessive amounts of lead residing in low-income countries (WHO, 2009). 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 for environmentally exposed children. A more recent population study was performed in Brazil ($n = 2463$) on the BLLs prevalence among 1- to 4 year-old children residing in Sao Paulo (Olympio et al., 2015).

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 WHO, only ten of the 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. However, the levels allowed in these regulations are much higher than those currently in place in Canada and the United States (90 mg/Kg). Moreover, the levels differ across the countries, ranging from 600 mg/Kg in Argentina, Brazil, Chile, Costa Rica, Dominica, Guyana, Mexico, Panama, and Uruguay, to 20,000 mg/Kg in Cuba. Chile also limits the bioavailability of lead in products for children to 0.7 μg/day, and Costa Rica establishes that no lead should be found in furniture and toys for children.

In seven LAC countries, there are no regulations on the content of lead in paint and other potential sources of exposure of children to lead: Colombia, Ecuador, El Salvador, Guatemala, Haiti, Honduras and Suriname. In three LAC countries, there are other types of regulations on lead: Paraguay only regulates lead content in toys, with a maximum limit of 0.7 μg; Peru establishes limits for lead in toys and modelling clay to 90 mg/Kg; and Saint Lucia requires a caution label when the amount of lead in paint or any material exceeds 5000 mg/Kg. For thirteen countries, no information was found: Antigua and Barbuda, Bahamas, Barbados, Belize, Bolivia, Dominican Republic, Grenada, Jamaica, Nicaragua, Saint Kitts and Nevis, Saint Vincent and the Grenadines, Trinidad and Tobago, and Venezuela (WHO, 2016a).

In relation to lead production, there are 40 countries worldwide producing lead in the mining industry, and among them, are eight LAC countries: Peru (the fourth largest producer in 2010), Mexico, Brazil, Bolivia, Argentina, Honduras, Chile and Guatemala. Besides mining production, secondary (recycled) lead makes up a significant portion of the global lead supply (USGS, 2011). Most of the recovered lead comes from lead-acid car batteries, but sources may also include electro-electronic waste. Although highly regulated and enforced control on recycling activities occurs in the U.S. and other developed countries, scavenging unregulated dumpsites and recycling sites remains informal and poorly controlled in low- and middle-income LAC countries. It has been estimated that 500,000 people in the Americas live on or close by a hazardous waste site (PAHO, 2011).

Important progress has been made in some LAC countries with regard to establishing and enforcing regulations to reduce children's exposure to lead. The region has also witnessed positive advances toward establishing protocols to reduce and monitor lead exposure in some countries (Laborde et al., 2015). However, tracking children's BLLs remains limited, particularly in areas of potential high exposure (“hot spots”), such as active and old mining areas, recycling sites, and industrial dumpsites (Table 1).

Lead paint control has improved, especially in recent years, but more needs to be done if we are to meet the 2020 global goal of achieving chemical safety. In fact, the World Health Assembly has approved a resolution on the “Role of the health sector in the sound management of chemicals,” in which it urged health ministries to support identified priority actions for the sound management of chemicals and to achieve the chemical-related goals and targets included in the 2030 Agenda for Sustainable Development (WHO, 2016b). A roadmap is now being prepared in consultation with WHO Member States, which will guide countries on future activities.

Childhood exposure to lead is estimated to contribute to approximately 600,000 new cases of children developing intellectual disabilities every year (WHO, 2016b). Given the slow advances in LAC countries, the engagement of the health sector in the development of public policies to protect children's exposure to lead and to monitor progress by tracking BLL in children will be critical. Guaranteeing that mapping and controlling potential and confirming “lead hot spots” becomes a priority agenda in the sustainable development era will only be possible with the support of the health sector.

Brazil, for example, has no public policies that establish an official procedure for sampling and analysing lead in human tissues, or for screening lead in schoolchildren, even in the presence of psychomotor and learning disabilities. A law establishing the maximum allowable lead content in materials for children in educational settings, as well as in varnishes and furniture was not signed until 2008. Law no. 11762 sets the upper lead limit at 600 ppm (Brazil, 2008). However, this threshold was already outdated when compared to U.S. legislation that came into effect in August 2009, which established the limit at 90 ppm (PL 110-314, Section 101. 2008).

Lead intoxication must be urgently recognized as a public health issue in LAC by governmental agencies. Since January 2011, exogenous intoxications in Brazil must be reported to the Information System for Reporting Injuries, given that the Centres for Toxicological Information and Assistance form part of Brazil's Unified Health System (SUS). This action is of the utmost important among Brazilian public health policies, as it subsidizes the establishment of strategies aimed at ensuring the health of exposed people through the development of standardised clinical protocols. In conformity with the Brazilian Ministry of Health's Ministerial Ordinance No. 104/GM/MS in January 2011, all suspected poisoning cases should be reported, including individuals who have been exposed to chemicals (pesticides, medicines, household products, heavy metals, cosmetics and personal hygiene, chemical products for industrial use, drugs) and show clinical signs and symptoms of poisoning and/or laboratory abnormalities. This was communicated through the Notifiable Diseases Information System (SINAN), exogenous intoxication template, CID10 code 65.9 (Brazil, 2011).

According to Laborde (2004), the primary mission of poison control centres has always been to improve the care of poisoned patients and to prevent poisoning. However, many other functions and roles must be undertaken. Centres in both developed and developing countries must be multifunctional to provide comprehensive and useful toxicological information services. The main challenges of poison centres in developing countries are therapy information and formal training on metal contamination. Moreover, these centres should render their public health actions more effective by strengthening and expanding several well-defined roles, such as toxic surveillance and environmental health monitoring, according to prevalent and potential future toxicological problems. Furthermore, evidence-based medicine and research are essential, and toxicological surveillance has become increasingly relevant, considering the numerous cases registered daily at poison centres.

Stakeholders must consider 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 as well as in informal working environments quickly and reliably.

A recently published systematic review of interventions that facilitate sustainable development by preventing toxic exposure to chemicals concluded that reduction in lead-contaminated house dust through cleaning and education interventions is not sufficient to eliminate children's exposure to lead (Haby et al., 2016). A recently updated version of a Cochrane review concluded that "dust control interventions may lead to little or no difference in blood lead levels" and that "there is currently insufficient evidence to draw conclusions about the effectiveness of soil abatement or combination interventions" (Nussbaumer-Streit et al., 2016). The only study showing a sustained reduction in blood lead levels in children is a retrospective cohort study that evaluated the economic benefits of strict enforcement of housing policies in preventing childhood lead poisoning (Brown, 2002). All studies were based on interventions in developed countries, revealing a knowledge gap in the existing literature. This also indicates the need to strengthen and enforce regulations to eliminate children's exposure to lead, and not focus solely on individual and on-site interventions.

The fact that lead poisoning threatens the healthy social dynamic of LAC cannot be underestimated. The learning disabilities and anti-social behaviour of many children may be linked to contamination by lead in the region. The blood lead figures highlighted by this review are cause for concern when compared to BLLs for the same age group in the U.S., Canada, Japan and the European Union, where prevention/control programs were well-designed and implemented. It is extremely important to establish public policies against lead contamination and ensure an adult population that is socially well balanced, peaceful and productive (Olympio et al., 2009). As Needleman (2009) stated, "*We do not know how smart our children might be*". It is essential that health policies emphasize the importance of preventing lead poisoning for the protection of both individuals and society. We conclude with a plea for the establishment of public health policies in LAC to prevent lead poisoning in underdeveloped and developing countries, modelled after policies that have long been adopted in developed countries and considering the context of each country in the region.

References

Agency for Toxic Substances and Disease Registry ATSDR, 2003. The Nature and Extent of Lead Poisoning in Children in the United States. A Report to the Congress. U.S. Department of Health and Human Services, Atlanta, GA.

Aguilar-Garduño, C., Lacasaña, M., Tellez-Rojo, M.M., Aguilar-Madrid, G., et al., 2003. Indirect lead exposure among children of radiator repair workers. Am. J. Ind. Med. 43, 662–667.

Albalak, R., McElroy, R.H., Noonam, G., Buchanan, S., Jones, R.L., et al., 2003. Blood lead levels and risk factors for lead poisoning among children in a Mexican smelting community. Arch. Environ. Health 58, 172–183.

Almeida, G.R.C., Tavares, C.F.F., Souza, A.M., Sousa, T.S., et al., 2010. Whole blood, serum, and saliva lead concentrations in 6- to 8-years-old children. Sci. Total Environ. 408, 1551–1556.

Anticona, C., Bergdahl, I.A., Lundh, T., Alegre, Y., Sebastian, M.S., 2011. Lead exposure in indigenous communities of the Amazon basin, Peru. Int. J. Hyg. Environ. Health 215, 59–63.

Anticona, C., Bergdahl, I.A., San, S.M., 2012. Lead exposure among children from native communities of the Peruvian Amazon basin. Rev. Panam. Salud Publica 31, 296–302.

Astete, J., Cáceres, W., Gastañaga, M.C., Lucero, M., Sabastizagal, I., Oblitas, T., et al., 2009. Intoxicación por plomo y otros problemas de salud em niños de poblaciones aledañas a relaves mineros [in Spanish]. Rev. Peru Med. Exp. Salud Publica 26, 15–19.

Azcona-Cruz, M.I., Rothenberg, S.J., Schnaas, L., Zamora-Muñoz, J.S., Romero-Placeres, M., 2000. Lead-glazed ceramic ware and blood lead levels of children in the city of Oaxaca, Mexico. Arch. Environ. Health 55, 217–222.

Barberis, S., Piñero, A., Lopes, C.M., 2006. Estudio sobre contaminación ambiental por plomo em niños de La Localidad de Abra Pampa (Jujuy-Argentina) [in Spanish]. Acta Toxicol. Argent 14, 2–6.

Bellinger, D.C., 2004. Lead. Pediatrics 113, 1016–1022.

Blackwoicz, M.J., Hryhorczuk, D.O., Rankin, K.M., et al., 2016. The impact of low-level lead toxicity on school performance among hispanic subgroups in the Chicago public schools. Int. J. Environ. 13, 774.

Brazil, 2008. Law 11.762. Sets the upper lead limit authorized in the manufacture of paints for use in child and school settings, varnishes and similar materials and other dispositions, of 1st August 2008. [in Portuguese]. (Available at:http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2008/lei/l11762.htm (consulted: January 2015)).

Brazil, 2011. Ordinance No. 104/GM/MS, of January 25, 2011. It Defines the Terminologies Adopted in National Legislation, in Accordance with the Provisions of the International Health Regulations 2005 (IHR 2005), the List of Diseases, Throughout the National Territory and Establishes Flow, Criteria, Responsibilities and Attributions to Health Professionals and Services. Ministry of Health, Brasília [in Portuguese].

Brown, M.J., 2002. Costs and benefits of enforcing housing policies to prevent childhood lead poisoning. Med. Decis. Mak. 22, 482–492.

Buchanan, L.H., Counter, S.A., Ortega, F., 2011. Environmental lead exposure and Oto-acoustic emissions in Andean children. J. Toxic. Environ. Health A 74, 1280–1293.

Bushnik, T., Haines, D., Levallos, P., Levesque, J., Van Oostdam, J., Viau, C., 2010. Lead and bisphenol A concentrations in the Canadian population. Health Rep. 21 (3).

Canada, 2013. Risk Management Strategy for Lead. Publications Health Canada. Minister of Health of Canada (Available at: http://www.hc-sc.gc.ca/ewhsemt/alt_formats/pdf/pubs/contaminants/prms_lead-psgr_plomb/prms_lead-psgr_plomb-eng.pdf (consulted: October 2016)).

Canfield, R.L., Henderson Jr., C.R., Cory-Slechta, D.A., Cox, C., Jusko, T.A., Lanphear, B.P., 2003. Intellectual impairment in children with blood lead concentrations below 10 micrograms per deciliter. N. Engl. J. Med. 348, 1517–1526.

Carpenter, D.O., Nevin, R., 2010. Environmental causes of violence. Physiol. Behav. 99, 260–268.

Carter-Pokras, O., Pirkle, J., Chavez, G., Gunter, E., 1990. Blood lead levels of 4-11 year old Mexican American, Puerto Rican, and Cuban children. Public Health Rep. 105, 388–393.

Carter-Pokras, O., Zambrana, R.E., Poppell, C.F., Logie, L.A., Gerreo-Preston, R., 2007. The environmental health of Latino children. J. Pediatr. Health Care 21, 307–314.

Carvalho, F.M., Aguiar, A.S., Vieira, L.A., Gonçalves, H.R., Costa, A.C.A., Tavares, T.M., 2000. Anemia, deficiência de ferro e intoxicação pelo chumbo em crianças de uma creche de Salvador, Bahia. Rev. Baiana Saude Publica 24, 32–41.

Carvalho, F.M., Silvany Neto, A.M., Tavares, T.M., Costa, A.C.A., Chaves, C.E.R., Nascimento, L.D., et al., 2003. Chumbo no sangue de crianças e passivo ambiental de uma fundição de chumbo no Brasil. Rev. Panam. Salud Publica 13, 19–23.

CDC, 2000. Blood lead levels in young children—the United States and selected states, 1996–1999. Morbidity and Mortality Weekly Report 49. Centre for Disease Control and Prevention, pp. 1133–1137.

Charalambous, A., Demoliou, K., Mendez, M., et al., 2009. Screening for lead exposure in children in Belize. Pan Am. J. Public Health 25, 47–50.

Chiodo, L.M., Covington, C., Sokol, R.J., Hannigan, J.H., Jannise, J., Ager, J., Greennwald, M., Delaney-Black, V., 2007. Blood lead levels and specific attention effects in young children. Neurotoxicol. Teratol. 29, 538–546.

Counter, S.A., Buchanan, L.H., Ortega, F., 2008. Zinc protoporphyrin levels, blood lead levels and neurocognitive deficits in Andean children with chronic lead exposure. Clin. Biochem. 41, 41–47.
Counter, S.A., Buchanan, L.H., Ortega, F., Rifai, N., 2000. Blood lead and hemoglobin levels in Andean children with chronic lead intoxication. Neurotoxicology 21, 301–308.
Cousillas, A., Mañay, N., Pereira, L., Alvarez, C., Coppes, Z., 2005. Evaluation of lead exposure in Uruguayan children. Bull. Environ. Contam. Toxicol. 75, 629–636.
Cousillas, A., Pereira, L., Alvarez, C., Heller, T., De Mattos, B., Piastra, C., Viapiana, P., Rampoldi, O., Mañay, N., 2008. Comparative study of blood lead levels in Uruguayan children (1994–2004). Biol. Trace Elem. Res. 122, 19–25.
Dickerson, A.S., Rahbar, M.H., Bakian, A.V., et al., 2016. Autism spectrum disorder prevalence and associations with air concentrations of lead, mercury, and arsenic. Environ. Monit. Assess. 188, 407.
Dietrich, K.N., Ris, M.D., Succop, P.A., Berger, O.G., Bornschein, R.L., 2001. Early exposure to lead and juvenile delinquency. Neurotoxicol. Teratol. 23, 511–518.
Disalvo, L., Aab, C., Pereyras, S., Pattín, J., Apezteguía, M., Iannicelli, J.C., et al., 2009. Plumbemiaem niños de La ciudad de La Plata, Argentina y su relación com La deficiência de hierro y lós factores de exposición al plomo [in Spanish]. Arch. Argent. Pediatr. 107, 300–306.
Espinosa, C., Rojas, M., Seijas, D., 2006. El Sistema geográfico de información y las concentraciones de plomo en sangre en una población infantil venezolana [in Spanish]. Rev. Chile Salud Publica 48, 84–93.
Espinoza, R., Hernández-Avila, M., Narciso, J., Castañaga, C., et al., 2003. Determinants of blood-lead levels in children in Callao and lima metropolitan area. Salud Publica Mex. 45, 103–121.
Farías, P., Álamo-Hernández, U., Mancilla-Sánchez, L., et al., 2014. Lead in school children from Morelos, México: levels, sources and feasible interventions. Int. J. Environ. Res. Public Health 11, 12668–12682.
Ferron, M.M., Lima, A.K., Saldiva, P.H.N., Gouveia, N., 2012. Environmental lead poisoning among children in Porto Alegre state, Southern Brazil. Rev. Saude Publica 46, 226–233.
Filigrana, P.A., Méndez, F., 2012. Blood lead levels in schoolchildren living near an industrial zone in Cali, Colombia: the role of socioeconomic condition. Biol. Trace Elem. Res. 149, 299–306.
Flores-Ramírez, R., Rico-Escobar, E., Nuñez-Monreal, J.E., Garcia-Neto, E., et al., 2012. Exposición infantile al plomo en sitios contaminados [in Spanish]. Salud Publica Mex. 54, 383–392.
Freitas, C.U., Capitani, E.M., Gouveia, N., Simonetti, M.H., Paula e Silva, M.R., Kira, C.S., et al., 2007. Lead exposure in an urban community: investigation of risk factors and assessment of the impact of lead abatement measures. Environ. Res. 103, 338–344.
Garcia, S.I., Mercer, R., 2003. Salud infantil y plomo en Argentina [in Spanish]. Salud Publica Mex. 45, S252–S255.
García Vargas, G.G., Rubio Andrade, M., Del Razo, L.M., Borja Aburto, V., et al., 2001. Lead exposure in children living in a smelter community in region Lagunera, Mexico. J. Toxic. Environ. Health A 62, 417–429.
Grosse, S.D., Matte, T.D., Schwartz, J., Jackson, R.J., 2002. Economic gains resulting from the reduction in children's exposure to lead in the United States. Environ. Health Perspect. 110, 563–569.
Haby, M.M., Soares, A., Chapman, E., Clark, R., Korc, M., Galvão, L.A.C., 2016. Interventions that facilitate sustainable development by preventing toxic exposure to chemicals: an overview of systematic reviews. Rev. Panam. Salud Publica 39, 378–386.
Hornung, R.W., Lanphear, B.P., Dietrich, K.N., 2009. Age of greatest susceptibility to childhood lead exposure: a new statistical approach. Environ. Health Perspect. 117, 1309–1312.
Hurtado, C.M., Gutiérrez, M., Echeverry, J., 2008. Aspectos clínicos y niveles de plomo en niños expuestos de manera paraocupacional en el processo de reciclage de baterías de automóviles en las localidades de Soacha y Bogotá, D.C. Biomedica 28, 116–125.
Iglesias, V., Steenland, K., Maisonet, M., Pino, P., 2011. Exposure to lead from a storage site associated with intellectual impairment in Chilean children living nearby. Int. J. Occup. Environ. Health 17, 315–322.
IPCS, 1995. Environmental Health Criteria No 165: Inorganic Lead. International Programme on Chemical Safety, Geneva, Switzerland.
Jones, R.L., Homa, D.M., Meyer, P.A., Brody, D.J., Caldwell, K.L., Pirkle, J.L., et al., 2009. Trends in blood lead levels and blood lead testing among US children aged 1 to 5 years, 1988-2004. Pediatrics 123, 376–385.
Kordas, K., Queirolo, E.I., Ettinger, A.S., Wright, R.O., Stoltzfus, R.J., 2010. Prevalence and predictors of exposure to multiple metals in preschool children from Montevideo, Uruguay. Sci. Total Environ. 408, 4488–4494.
Laborde, A., 2004. New roles for poison control centres in the developing countries. Toxicology 198, 273–277.
Laborde, A., Tomasina, F., Bianchi, F., Bruné, M.N., Buka, I., Comba, P., Corra, L., Cori, L., Duffert, M.C., Harari, R., Iavarone, I., McDiarmid, M.A., Gray, K.A., Sly, P.D., Soares, A., Suk, W.A., Landrigan, P.J., 2015. Children's health in Latin America: the influence of environmental exposures. Environ. Health Perspect. 123, 201–209.
Lalor, G.C., Rattray, R., Vutchkov, M., et al., 2001. Blood lead levels in Jamaican school children. Sci. Total Environ. 269, 171–181.
Lalor, G.C., Vutchkov, M., Bryan, S.T., 2007. Blood lead levels of Jamaican children islandwide. Sci. Total Environ. 374, 235–241.
Lalor, G.C., Vutchkov, M., Bryan, S.T., et al., 2006. Acute lead poisoning associated with backyard lead smelting in Jamaica. West Indian Med. J. 55, 394–398.
Lanphear, B.P., Hornung, R., Khoury, J., Yolton, K., Baghurst, P., Bellinger, D.C., et al., 2005. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. Environ. Health Perspect. 113, 894–899.
Leal-Escalante, C.R., Baltazar-Reyes, M.C., Lino-González, M., Palazuelos-Rendón, E., Meneses-González, F., 2007. Concentraciones de plomo en sangue y reprobación de escolares en la ciudad de México. Gac. Med. Mex. 143, 377–381.
Mañay, N., Alonzo, C., Dol, I., 2003. Contaminación por plomo en el bairro La Teja; Montevideo, Uruguay [in Spanish]. Salud Publica Mex. 45, 268–275.
Mañay, N., Cousillas, A.Z., Alvarez, C., Heller, T., 2008. Lead contamination in Uruguay: the "La Teja" neighborhood case. Rev. Environ. Contam. Toxicol. 195, 93–115.
Manzanares-Acuña, E., Vega-Carrilo, H.R., Salas-Luévano, M.A., Hernándes-Dávilla, V.M., Letechipía-de Léon, C., Bañuelos-Valenzuela, R., 2006. Niveles de plomo em La población de alto riesgo y su entorno em San Ignacio, fresnillo, Zacatecas, México [in Spanish]. Salud Publica Mex. 48, 212–219.
Mattos, R.C.O.C., Carvalho, M.A.R., Mainenti, H.R.D., Xavier Junior, E.C., Sarcinelli, P.N., Carvalho, L.B.V., 2009. Avaliação dos fatores de risco relacionados à exposição à chumbo em crianças e adolescentes do rio de Janeiro/Evaluation of risk factors related to lead exposure in children and adolescentes from Rio de Janeiro [in Portuguese]. Cien. Saude Colet. 14, 2039–2048.
Mazumdar, M., Bellinger, D.C., Gregas, M., Abanilla, K., Bacic, J., Needleman, H.L., 2011. Low-level environmental lead exposure in childhood and adult intellectual function: a follow-up study. Environ. Health 10, 24.
Meneses-González, F., Richardson, V., Lino-González, M., Vidal, M.T., 2003. Niveles de plomo en sangre y factores de exposición en niños del estado de Morelos [in Spanish], México. Salud Publica Mex. 45, 203–208.
Mielke, H.W., Zahran, S., 2012. The urban rise and fall of air lead (Pb) and the latent surge and retreat of societal violence. Environ. Int. 43, 48–55.
Nakayama, S., 2016. Exposure measurements in Japan environment and children's study. Pharm. Soc. Jpn. Symp. Rev. Yakugaku Zasshi 136, 795–798.
Needleman, H., 2004. Lead poisoning. Annu. Rev. Med. 55, 209–222.
Needleman, H., 2009. Low level exposure: history and discovery. Ann. Epidemiol. 19, 235–238.
Needleman, H.L., McFarland, C., Ness, R.B., Fienberg, S.E., Tobin, M.J., 2002. Bone lead levels in adjudicated delinquents. A case control study. Neurotoxicol. Teratol. 24, 711–717.
Nevin, R., 2009. Trends in preschool lead exposure, mental retardation, and scholastic achievement: association or causation? Environ. Res. 109, 301–310.
Nussbaumer-Streit, B., Yeoh, B., Griebler, U., Pfadenhauer, L.M., Busert, L.K., Lhachimi, S.K., Lohner, S., Gartlehner, G., 2016. Household interventions for preventing domestic lead exposure in children. Cochrane Database Syst. Rev. 2016 (Issue 10). http://dx.doi.org/10.1002/14651858.CD006047.pub5 (Art. No.: CD006047).
Olivero-Verbel, J., Duarte, D., Echenique, M., Guette, J., Johnson-Restrepo, B., Parsons, P.J., 2007. Blood lead levels in children aged 5–9 years living in Cartagena, Colombia. Sci. Total Environ. 372, 707–716.
Olympio, K.P.K., Barbosa, F., Silva, A.S., Cardoso, M.R.A., 2015. Lead exposure in São Paulo, Brazil: blood levels and risk factors associated. 54th Annual Meeting and ToxExpo, San Diego, Califórnia, EUA. The Toxicologist - Supplement to Toxicological Sciences 144. Oxford University Press, pp. 104–105.
Olympio, K.P.K., Gonçalves, C.G., Günther, W.M.R., Bechara, E.J.H., 2009. Neurotoxicity and aggressiveness triggered by low-level lead in children: a review. Pan Am. J. Public Health 26, 266–275.
Olympio, K.P.K., Oliveira, P.V., Naozuka, J., Cardoso, M.R., Marques, A.F., Günther, W.M., et al., 2010. Surface dental enamel lead levels and antisocial behavior in Brazilian adolescents. Neurotoxicol. Teratol. 32, 273–279.
PAHO, 2011. The Atlas of Children's Health and Environment in the Americas. Pan American Health Organization (Available at: http://www.paho.org/hq/index.php?option=com_docman&task=doc_view&gid=20365&Itemid=721 (consulted: November 2016)).
Paoliello, M.M.B., Capitani, E.M., Cunha, F.G., Matsuo, T., Carvalho, M.F., Sakuma, A., 2002. Exposure of children to lead and cadmium from a mining area of Brazil. Environ. Res. 88, 120–128.
Pebe, G., Villa, H., Escate, L., Cervantes, G., 2008. Niveles de plomo sanguíneo en recién nacidos de La Oroya, 2004-2005 [in Spanish]. Rev. Med. Exp. Salud Publica 25, 355–360.
Pino, P., Walter, T., Oyarzún, M.J., Burden, M.J., Lozoff, B., 2004. Rapid drop in infant blood levels during the transition to unleaded gasoline use in Santiago, Chile. Arch. Environ. Health 59, 182–187.
Rajkumar, W.S., Manohar, J., Doon, R., et al., 2006. Blood lead levels in primary school children in Trinidad and Tobago. Sci. Total Environ. 361, 81–87.
Ramirez, R.R., de la Cruz, G.P., 2002. The Hispanic Population in the United States: 2002 Current Population Reports. 2002. U.S. Census Bureau, Washington, DC:pp. 20–545 [November 3, 2016]. (Available: http://www.census.gov/prod/2003pubs/p20-545.pdf).
Raymond, J., Wheeler, W., Brown, M.J., 2014. Lead screening and prevalence of blood lead levels in children aged 1–2 years — Child Blood Lead Surveillance System, United States, 2002–2010 and National Health and Nutrition Examination Survey, United States, 1999–2010. Morbidity and Mortality Weekly Report 63. CDC, pp. 36–42.
Recio-Vega, R., Valdez-Abrego, C., Adame-Lopez, B., Gurrola-Mendez, A., 2012. Surveillance of elevated blood lead levels in children in Torreon, Coahuila, Mexico, 1998–2010. Int. J. Hyg. Environ. Health 215, 507–513.
Riera, N.M., Soria, N., Feldman, G., Riera, N., 2006. Niveles de Plombemia y otros marcadores, en niños expuestos a una fundición de plomo en Lastenia, Tucumán, Argentina. Rev. Toxicol. línea 11, 12–22.
Rodríguez, A., Espinal, G., 2008. Niveles de plomo en sangre y factores de riesgo asociados en niños de 2 a 10 años en el barrio Villa Francisca, Santo Domingo, República Dominicana. Rev. Cienc. Soc. 33, 595–609.
Rojas, M., Espinoza, C., Seijas, D., 2003. Asociación entre plomo en sangre y parámetros sociodemográficos en población infantil [in Spanish]. Rev. Saude Publica 37, 503–509.
Rubio-Andrade, M., Valdés-Pérezgasga, F., Alonso, J., Rosado, J.L., Cabrián, M.E., Garcia-Vargas, G.G., 2011. Follow-up study on lead exposure in children living in a smelter community in Northern Mexico. Environ. Health 10, 78.
Samaniego, E., Benítez-Leite, S., 2002. Niveles de plomo en sangre en niños de áreas urbana y sub-urbana [in Spanish]. Pediatr. Py. 29, 92–121.

Sánches-Nazario, E.E., Mansilla-Rivera, I., Derieux-Cortés, J.C., Pérez, C.M., Rodríguez-Sierra, C.J., 2003. The association of lead-contaminated house dust and blood lead levels of children living on a former landfill in Puerto Rico. Environ. Health 22, 107–121.

Sánchez-Cortez, J., Itabaca-Marileo, M., Martín, M.A., Viñas, M.A., Bravo-Méndes, R., 2003. Prevalencia de plomo en sangre, en niños escolares de Santiago de Chile [in Spanish]. Salud Publica Mex. 45, S264–S268.

Schnaas, L., Rothenberg, S.J., Flores, M.F., Martínez, S., et al., 2004. Blood lead secular trend in a cohort of children in Mexico City (1987–2002). Environ. Health Perspect. 112, 1110–1115.

Schwartz, J., 1994. Societal benefits of reducing lead exposure. Environ. Res. 66, 105–124.

Seijas, D., Squillante, G., 2008. Plomo en sangre, estado nutricional y estratificación socioeconómica, en niños de una comunidad de Valencia [in Spanish]. An. Venez. Nutr. 21, 14–19.

Sepúlveda, V.A., Vega, J.M., Delgado, I.B., 2000. Exposición severa a plomo ambiental en una población infantile de Antofagasta, Chile [in Spanish]. Rev. Med. Chil. 128.

Soto-Jiménez, M., Flegal, A.R., 2011. Childhood lead poisoning from the smelter in Torreón, México. Environ. Res. 111, 590–596.

Squillante, G., Rojas, M., Medina, E., De Rojas, O.T., 2002. Evolución conductual y de aprendizaje en niños con déficit en su desarrollo, posterior a tratamiento para plumbemia [in Spanish]. Gac. Med. Caracas 110, 96–121.

USGS, United States Geological Survey. Lead—Soft and Easy to Cast, 2011. Mineral Resources Program. Available at: http://pubs.usgs.gov/fs/2011/3045/pdf/fs2011-3045.pdf (consulted: October, 2016).

Valdés, J.A., Bermejo, P.M., Placeres, M.R., Roche, R.G., Peña, O.S., Orris, P., 2003. Niveles de plomo en sangre y factores asociados, en niños del municipio de Centro Habana [in Spanish]. Rev. Cuba. Hig. Epidemiol. 41, 104–121.

Vega, J., Coll, J., Katekaru, D., Lermo, J., Escobar, J., et al., 2003. Intoxicación plúmbica crónica y alteraciones del crecimiento y desarrollo cognitive-emocional en niños. An. Fac. Med. 64, 94–100.

Vega-Dienstmaier, J.M., Salinas-Piélago, J.E., Gutiérrez-Campos, M.R., Mandamiento-Ayquipa, R.D., Yara-Hokama, M.C., Ponce-Canchihuamán, J., et al., 2006. Lead levels and cognitive abilities in Peruvian children. Rev. Bras. Psiquiatr. 28, 33–39.

Wagner, P.J., Park, H.-R., Wang, Z., et al., 2016. In vitro effects of lead on gene expression in neural stem cells and associations between Upregulated genes and cognitive scores in children. Environ. Health Perspect. http://dx.doi.org/10.1289/EHP265.

WHO, 2009. Levels of lead in children's blood. European Environment and Health Information System. World Health Organization, Budapest, Hungry.

WHO, 2014. World Health Organization. International Lead Poisoning Prevention Week of Action in the WHO European Region. World Health Organization, Copenhagen, Denmark.

WHO, 2016a. Global Health Observatory data repository. Lead: Control Legislation. Full Country Database. The Americas Region (AMRO). World Health Organization (Available at: http://apps.who.int/gho/data/view.main.LEADCONTROLFULLv?lang=en (consulted: October 2016)).

WHO, 2016b. Role of the Health Sector in the Sound Management of Chemicals. Report by the Secretariat. World Health Organization (Available at: http://apps.who.int/gb/ebwha/pdf_files/WHA69/A69_19-en.pdf (consulted: October 2016)).

Wright, J.P., Dietrich, K.N., Ris, M.D., Hornung, R.W., Wessel, S.D., Lanphear, B.P., et al., 2008. Association of prenatal and childhood blood lead concentrations with criminal arrests in early adulthood. PLoS Med. 7, 732–740.

Yoshinaga, J., 2012. Lead in the Japanese living environment. Environ. Health Prev. Med. 17, 433–443.

Yoshinaga, J., et al., 2012. Blood lead levels of contemporary Japanese children. Environ. Health Prev. Med. 17, 27–33.