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Prevalence of Elevated Blood Lead Level in Children of India

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ABSTRACT

Children are most susceptible to lead exposure. The most common lead exposure sources for children are leaded paint, leaded gasoline, lead-acid batteries, drinking water, food and toys, which should be considered for regular monitoring. Exposure to lead during pregnancy and blood lead levels (BLLs) in early childhood have also been associated with lead toxicity and lead associated adverse cognitive effects in children. Overall 47% children in India have elevated BLL (≥10µg/dL) and more than half of the children residing in metropolitan cities as well as in rural areas. The discrepancy in the mean distribution of elevated BLL in children was found. Prevalence of elevated BLL in children was also discrete. The low value of BLL (<5µg/dL) showed lead toxicity and longtime accumulation effect, which are associated with impaired intelligent quotient (IQ) of children. It is an alarming stage for the policy makers and health practitioners to monitor the BLL in regional and local areas of the country and find out the risk factors which are responsible for the elevation of BLL in children. Mass screening of elevated BLL in children is required by opting lower cut-off value of BLL (≥5µg/dL) to reduce its longer effect on neurobehavioural function. Awareness camps for general population regarding lead exposure and its adverse effects on children are also frequently needed to minimize the use of lead.

INTRODUCTION

Lead (Pb) is a highly toxic heavy metal occurring naturally in the Earth's crust. It is found in all parts of the environment and derived from human activities such as mining, manufacturing, and burning fossil fuels and from drinking water where lead pipes are used. Exposure at home may occur through ingestion of old leaded paint, and pigments and glazes used in pottery. Some healthcare products and folk remedies also contain lead (ATSDR 2000, 2004, 2006, 2017). It is a well-known non-biodegradable toxic metal in the environment and it has become a global health issue (Jaishankar et al. 2014, Patrick et al. 2006). Children are more likely to have elevated lead levels as compared to adults for several reasons. Some of these factors include increased hand-to-mouth behaviours, lead exposure from pica, an immature blood-brain barrier leading to greater neurotoxicity, increased lead absorption, and concomitant iron deficiency anaemia (Schnur et al. 2014, Chandran et al. 2010, Levin et al. 2008). Children appear to have approximately four to five times higher lead absorption, specifically water-soluble lead absorption, than adults (Wani et al. 2015, Cecil et al. 2011, Cleveland et al. 2008a). More than 15 million children in developing countries are suffering from permanent neurological damage due to lead poisoning (HEI 2004). In addition, an Egyptian population-based study reported that a total 113 out of 400 children had BLLs in the range of 10 to 20µg/dL (Moawad et al. 2016).

Moawad et al. (2016) reported that smoking fathers, housing conditions, playing outdoors, and exposure to lead in residential areas were significantly correlated with high BLLs. They also reported that the mean value of environmental lead in workshop areas exceeded the recommended levels. Also, the value of environmental lead measured in dust and paint samples of garbage city was found significantly higher. Moreover, the soil samples collected from urban schools were found with significantly higher mean lead levels than the soil samples collected from suburban schools (Moawad et al. 2016).

Similarly, lead paint and dust attributed up to 70% of elevation of BLL in U.S. children, while more than 30% of children estimated elevated BLL, which do not have an immediate leaded paint source exposure (Levin et al. 2008).

Lead affects almost every system in the body. It can damage the nervous system, the renal, and the reproductive systems, cause high blood pressure and affect growth and development, psychological behavior, and intelligence (Sanders et al. 2009, Choudhari et al. 2010, Reigurt et al. 1999). Evidence associating elevated lead levels in the body to the decline in early cognitive function (Bellinger et al.

2008, Rossi 2008, Canfield et al. 2005, Liu et al. 2013, Lanphear et al. 2000), delayed mental and physical development, hearing impairments (AACAP 2012, Gahyva et al. 2008) and intellectual impairment even at low levels (Jakubowski 2011, Canfield et al. 2003) have been reported. Jain et al. (2005) have also reported the association of elevated lead levels in the body with varying severity of anaemia in children. Moawad et al. (2016) also found that the mean values of haemoglobin were inversely correlated with BLLs. Children involved in pottery workshops had the highest BLLs (43.3µg/dL) and the lowest Hb values (8.6g/dL).

Lead pollution remains a public health concern in developing countries such as India. Previous studies based on regional data have estimated that more than half of the children in India have BLLs ≥10µg/dL (George Foundation 1999, Kaul 1999, Patel et al. 2001), which is higher as per the Centers for Disease Control and Prevention (CDC) definition of elevated BLL in children (CDC 2000). However, only a few studies with relatively small sample size have attempted to investigate factors associated with BLLs in Indian children (Kalra et al. 2003, Patel et al. 2001).

The 1998-1999 National Family Health Survey (NFHS) is the first to provide information on BLLs in children of < 3 years of age in two major Indian metropolitan cities (Mumbai and Delhi). The results of the NFHS indicated that approximately 50% of children of these metropolitan cities had BLLs ≥10µg/dL (NFHS 2000). In addition, more than 12% of the children tested had concentrations of 20µg/dL or more (Sharma 1999). However, it is reported that BLLs below 10µg/dL is also associated with harmful effects on the children's learning and behavior (Reigurt et al. 1999).

ENVIRONMENTAL SOURCES OF LEAD

Lead absorption pathways: An exposure pathway must have five components: (1) a source of contamination (such as deteriorating lead-based paint on the walls, doors and windows of a home, used car batteries, open burning of waste), (2) an environmental medium and transport mechanism (such as lead contaminated dust on the floor of a home, lead smoke from open burning, or lead exhaust from leaded gasoline), (3) a point of exposure (such as children's hands, the floor, or children's toys), (4) a route of exposure (such as eating the dust through hand-to-mouth behavior), and (5) an exposed population (such as children in the home environment or pregnant women in polluted environments or workplaces) (EPA 2002).

Inhalation of airborne lead may not typically be a major source of exposure for children, although very fine particles of airborne lead in particulate matter less than 10µm in diameter (PM10) are generated from car exhausts (using leaded gasoline) and smoke from the open burning of waste can be inhaled by children (Amitai et al. 1987, Amitai et al. 1991).

The most common sources of lead in children's environ-

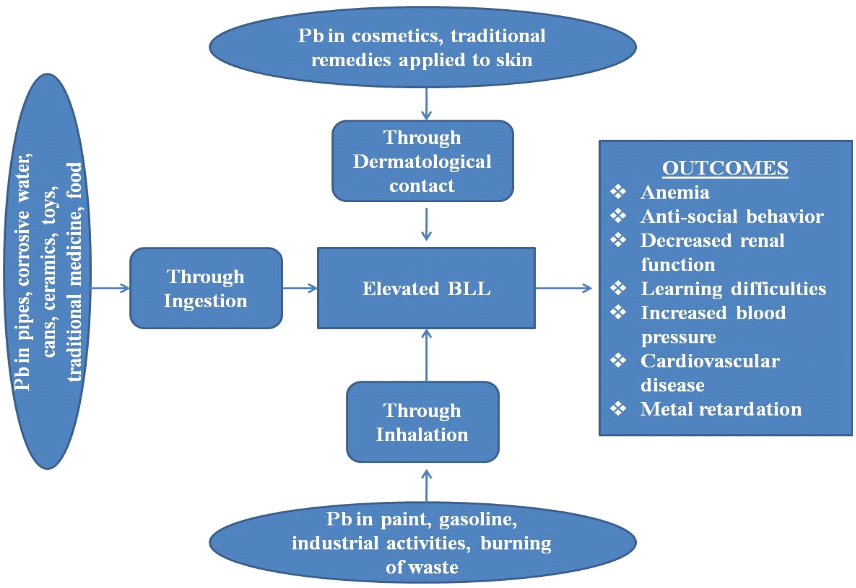

Fig. 1: Some routes by which lead moves from its primary source to reach the bodies of children (Source: Rojas-López et al. 1994).

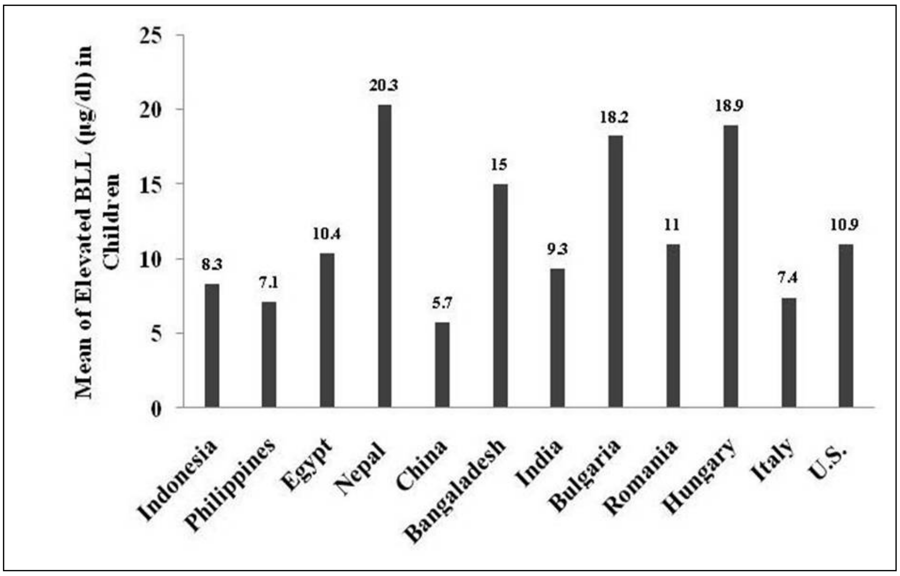

Fig. 2: Global distribution of mean BLL in children (age: 4-12 year).

ments are gasoline, active industry, such as mining, lead-based paints and pigments, food cans, ceramic glazes, drinking water systems used lead pipes, lead-containing traditional and folk remedies, cosmetics, toys, incineration of lead-containing waste such as electronic waste, and lead-contaminated food chain system through lead-contaminated soil etc. summarized in Fig. 1.

The relative importance of these various potential sources of exposure to lead varies both within and between countries and regions. In the United States (U.S.), for example, lead-based paint is an important source of exposure, while in Mexico, lead-glazed ceramics used for food storage and preparation are more important (Rojas-López et al. 1994).

MEASUREMENT OF BLOOD LEAD LEVELS

BLL is determined by whole blood lead measurement. Three assay methods are currently available: anodic stripping voltammetry (ASV), atomic absorption spectroscopy (AAS), inductively coupled plasma mass spectrometry (ICP-MS). Some companies provide a simple automated BLL measurement apparatus based on AAS, ICP-MS and ASV i.e. LeadCare® instrument (Magellan Biosciences, Chelmsford, MA, USA). ICP-MS offers a high degree of specificity, sensitivity and selectivity and the ability to analyse other toxic and essential metals simultaneously from a small sample (Mbughuni et al. 2016). This technique can also determine the isotope ratios of the lead in a set of samples, which helps determine if a particular source of lead is a possible contributor to the poisoning of an individual (Schutz et al. 1996, Clune et al. 2011).

BLL tests tell how many micrograms (µg) of lead are in each decilitre (dL) of blood. This is written as µg/dL. A blood lead test is mainly an estimate of recent exposure to lead. The public health action level for children is ≥5µg/dL and at risk of lead poisoning is ≥10µg/dL recommended by Centers for Disease Control and Prevention (CDC) (CDC, 2012). Classification of BLL in children is presented in Table 1.

DEMOGRAPHICAL DISTRIBUTION OF BLL IN CHILDREN

Several studies reported that BLL varied in different countries and ethnicity. It depends on localization, industrialization, and exposure to lead. The mean BLL was reported 10.99±4.63µg/dL in the U.S. (Reuben et al. 2017), 8.6±2.8µg/dL in Indonesia (Albalak et al. 2003), 7.1µg/dL in Philippines (Riddell et al. 2007), 20.33±9.36µg/dL in Nepal (Dhimal et al. 2017), 5.7µg/dL in China (Li et al. 2014), 15µg/dL in Bangladesh (Kaiser et al. 2001), 9.3µg/dL in India (Ahmed et al. 2010), 10.37±7.94µg/dL in Egypt (Abushady et al. 2017), 18.2µg/dL in Bulgaria, 11µg/dL in Romania, 18.9µg/dL in Hungary, and 7.4µg/dL in Italy (WHO 2009) (Fig. 2).

Developed countries have implemented various awareness and prevention programs to reduce the exposure of lead to children. Although, developing countries like India still have various ways of lead exposure to children. Mean of BLL varied in different cities of India from metropolitan to industrial and rural areas is as follows: Mean of BLL was reported to be 14.5µg/dL in Delhi (Kalra et al. 2013), 9.3µg/

Table 1: Centers for disease control and prevention (CDC) classification of whole blood lead levels (BLLs) in children.

CDC Class	BLLs (μg/dL)	Abbreviated Comments
I	5-9.9	Not considered to be lead poisoned. Treat iron deficiency as it increases lead absorption
IIA	10-14	Community action recommended if many children found; Rescreen
IIB	15-19	Nutritional and educational intervention; Rescreen
III	20-44	Environmental remediation and medical evaluation needed; Consider chelation therapy; Rescreen
IV	45-69	Environmental intervention; Chelation therapy; Rescreen
V	≥70	A medical emergency; Begin interventions immediately; Rescreen

(Source: CDC 2012).

dL in Lucknow (Ahmed et al. 2010), 18.4μg/dL in Nagpur (Patel et al. 2001), 13.0±6.7μg/dL in Mumbai (Jain et al. 2006), 4.55μg/dL in Kolkata (Roy 2017), 32.26±11.34μg/dL in Bangalore (Prashant et al. 2008), 16.6μg/dL in Karnataka (D'Souza et al. 2002) as shown in Fig. 3.

As per the guidelines of CDC (2012), children having BLL ≥10μg/dL are at risk of lead poisoning. In India, almost 47% children having BLL ≥10 μg/dL and greater risk of lead poisoning (Jain et al. 2005). In addition, various regional studies found the discrepancy in the population distribution of BLL ≥10μg/dL. In India, 45% children in Delhi (IIPS 2000), 37% in Lucknow (Ahmed et. al. 2010), 44.2% in Aligarh (Chaudhary et al. 2017), 67% in Nagpur (Patel et al. 2001), 50% in Mumbai (IIPS 2000), 87% in Kolkata (George Foundation 1999), 43% in Hyderabad (George Foundation 1999), 69.2% in Vellore (Mohan et al. 2014), 81% in Bangalore (Prashant et al. 2008), 96% in Chennai (George Foundation 1999), and overall 47% children in India have BLL ≥10μg/dL (Jain et al. 2005) as shown in Fig. 4.

PREVENTION AND TREATMENT STRATEGY

In developed countries, various international lead poisoning awareness prevention programs have been conducted to reduce the exposure of lead to children. World Health Organization (WHO) launched the international lead poisoning awareness prevention week theme based on lead-free kids for a healthy future-underscores the importance of avoiding the use of lead paint and using safe alternatives in order to prevent children from lead poisoning (WHO 2013).

In developed countries, the various advisory committees are active in evaluating and responding to elevated lead levels and conduct the Educational Interventions for Lead-Exposed Children Work Group (CDC 2015). The National Health and Medical Research Council (NHMRC) currently recommends that, if a person has a BLL ≥ 5μg/dL, the source of exposure should be investigated and reduced, particularly if the person is a child or a pregnant woman (NHMRC 2015).

Keller et al. (2017) reviewed that national and local policies have led to large reductions in the prevalence of lead poisoning. Two national surveys of children aged 1-5 years showed a decline in the prevalence of BLLs ≥10mg/dL from 88.2% in 1976-1980 to 0.8% in 2007-2010 (Pirkle et al. 1994, MMWR 2013). Children in New York City (NYC) newly identified with BLLs ≥10mg/dL declined from 92% in 1995 to 7.6% in 2009 (NYCDHMH 2010). The incidences of BLLs ≥10mg/dL have declined and evidence of health effects at lower BLLs have accumulated (Lanphear et al. 2005). Similarly, it was reported that after the measures to control lead pollution were implemented in the United States, beginning in 1970, BLLs in children have declined by > 80% (ATSDR 2000).

Several studies suggested that nutritional supplements such as calcium, iron, vitamin C, zinc and protein can specifically decrease absorption of ingested lead in children (ACCLPP 2012, Cecil et al. 2011, Chandran et al. 2010, Cleveland et al. 2008b). Higher levels of dietary intake such as zinc, iron, vitamin C, and calcium have been associated with lower BLLs during childhood (ACCLPP 2012). In addition, chelation therapy is recommended if the patient has a BLL of ≥45μg/dL. Succimer (dimercaptosuccinic acid) is a water-soluble, oral chelating agent and calcium disodium edetate ($CaNa_2$ EDTA) is given by continuous intravenous infusion (Hon et al. 2017, Lawry et al. 2017). But these chelation therapies have limitations and symptomatic diagnosis must be required at various interventions.

Similar to developed countries, prevention and awareness programs should be implemented in developing countries like India and carry out strict monitoring and environmental survey at regular intervals because low-level exposures can result in long-term, irreversible cognitive deficits and greater exposures can lead to organ damage and death in children. Exposure to lead during pregnancy and BLLs in early childhood should be monitored at the regular time intervals to prevent the lead toxicity and lead associated adverse cognitive effects in children. Lin et al. (2010) reported that chronic exposure to Indian spices, foodstuff products, and cultural powders may cause elevated BLLs. A majority of cultural products contained >1μg/g lead, and some sindoor contained extremely high bioaccessible lead levels. They suggested that clinicians should routinely

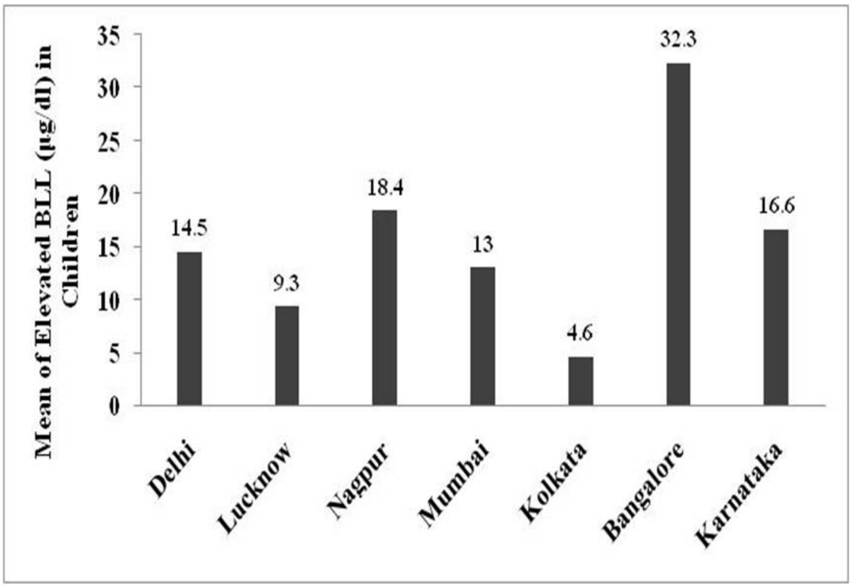

Fig. 3: Distribution of mean BLL in children of India.

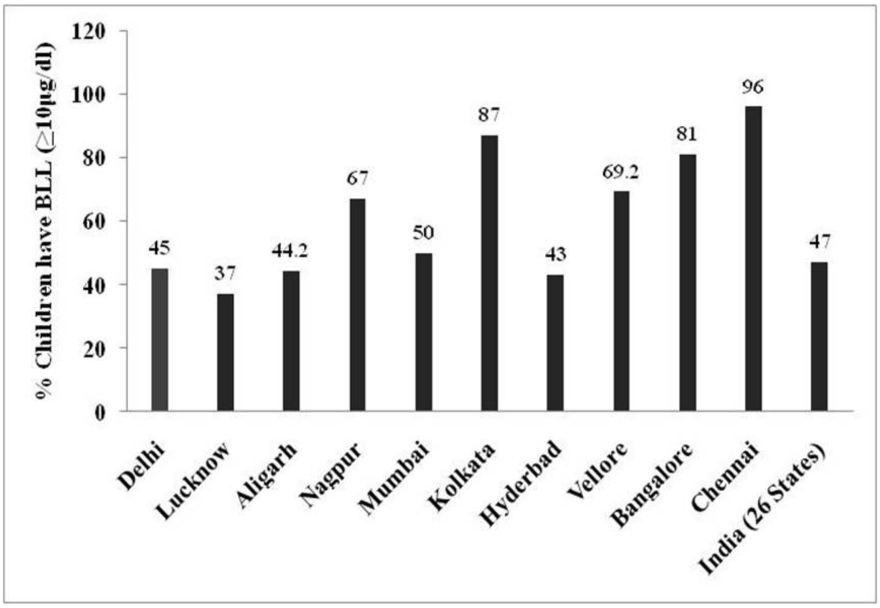

Fig. 4: Prevalence of elevated BLL in children of India.

screen for exposure to these products. Prevalence of elevated BLL is high in children of Indian southern and coastal cities; this may be due to the presence of high amount of lead-containing electronic waste (e-waste) (Mittal 2011). This should be properly handled, decomposed and children be kept away from dumping or recycling sites. Guo et al. (2014) reported that Guiyu children living around the e-waste cycling or workshops areas have significant elevated BLLs. In addition, elevated BLLs are associated with decreased olfactory memory in Guiyu children (Zhang et al. 2017).

Overall 47% children in India have elevated BLL (≥10µg/dL) and more than half of the children residing in metropolitan cities as well as in rural areas. It is the alarming stage for the policy maker and health practitioners to monitor the BLL in regional and local areas of the country and find out the risk factors which are responsible for the increase of BLL in children. Lower cut-off value of BLL (≥5µg/dL) should be considered as a risk factor to counsel the general population regarding the lead toxicity and long-time accumulation effects which are associated with impaired IQ of children.

CONCLUSION

More than half of the children residing in metropolitan cities as well as in rural areas of India have elevated BLL (≥10µg/dL). It is an alarming stage for the policy makers and health practitioners to monitor the BLL in regional and local areas of the country and find out the risk factors which are responsible for the elevation of BLL in children. Mass screening of elevated BLL in children is required by opting lower cut-off value of BLL (≥5µg/dL) to reduce its longer effect on neurobehavioural function.

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