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Status of children's blood lead levels in Pakistan: implications for research and policy

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Summary

Objectives—Data on blood lead levels, sources of lead and health effects were reviewed among children in Pakistan.

Methods—A systematic review was conducted of published studies found through PubMed, an index of Pakistani medical journals PakMediNet and unpublished reports from governmental and non-governmental agencies in Pakistan.

Results—With the exception of a few studies that had adequate sample sizes and population-based samples, most studies were small and used convenience sampling methods to select study subjects. Overall, blood lead levels declined from 38 µg/dl in 1989 to 15 µg/dl in 2002. The major sources of lead that directly or indirectly resulted in lead exposure of children included: leaded petrol; father's occupation in lead-based industry; leaded paint; traditional cosmetics; and remedies. Apart from leaded petrol, there was no information regarding the level of lead in other sources such as paints and the household environment. Very little information was available regarding the adverse health effects of lead among children.

Conclusion—The phasing out of leaded petrol was a commendable mitigation measure undertaken in July 2001 in Pakistan. A comprehensive assessment is now needed urgently to explore other sources of lead contributing to adverse health effects, and to plan intervention options with the ultimate goal of reducing the burden of disease due to lead exposure.

Introduction

Lead is a toxic, non-degradable heavy metal that was added to petrol in the early 20th Century to improve fuel efficiency. Lead in petrol has caused more environmental lead exposure than any other source. High blood lead levels (80–100 µg/dl), which are rare nowadays, result in encephalopathy and death, while lower chronic levels (10–80 µg/dl) result in neurotoxicity, hypertension, renal impairment and altered cognitive functions.¹ Chronic low-level exposure to environmental lead is of great concern to public health because of the large population being exposed. In any population, children are more vulnerable to lead exposure than adults for the

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following reasons: (a) hand-to-mouth activities of children; (b) child absorption is higher than adults; and (c) developing brains are more sensitive to insults resulting from lead exposure. It has been shown that low-level childhood lead exposure shifts the intelligence quotient (IQ) distribution of an entire population towards lower values, leading to a decrease in the overall intellectual level and productivity of that population.² A recent pooled analysis of seven cohort studies showed that the IQ declined by 6.9 points for an increase in blood lead level from 2.4 to 30 µg/dl. The lead-associated decline in IQ was greatest in the lower range of the lead exposure distribution (2.4–10 µg/dl).³ In most countries, lead has been phased out of petrol which has resulted in a strong decline in blood lead levels.^{4–8} In the USA, blood lead levels have declined to 1.6 µg/dl since lead was phased out in the 1970s. The impact of lead exposure could still be very high in countries where lead is still used in petrol or has only recently been phased out. Even if petrol is lead free, exposure from other sources, such as lead deposits in soil, food, industry and occupations, continues, especially in developing countries. Once exposure to lead occurs, lead is deposited in the bones and persists for decades.⁹

Lead is therefore an important public health problem in many countries of the world. A recent World Health Organization (WHO) global burden of disease estimate found that lead-induced mild mental retardation amounts to 9.8 million disability-adjusted life years (DALYs), while in comparison, the burden of cardiovascular disease results in 3.1 million DALYs each year.¹⁰ In Pakistan, environmental lead has been recognized as a public health problem since 1988. Since then, several small-scale studies have highlighted the existing high blood lead levels, and formed the basis of phasing out lead from petrol in 2001. This paper reviews the trends in lead over time in Pakistan, the factors associated with high lead levels, and identifies avenues for further reduction in lead exposure.

Methods

PubMed was searched in July 2006 using the keywords 'lead' and 'Pakistan'. The index of local journals, PakMediNet (www.pakmedinet.com), was also searched using the same keywords. In addition, non-indexed studies and reports pertaining to lead sources and levels in Pakistan by contacting governmental agencies, experts in the field and nongovernmental organizations (NGOs) were searched.

Results

Literature retrieval

Thirty-seven relevant articles were identified using PubMed between January 1988 and July 2006. Three additional articles were found in PakMediNet, and two unpublished reports and one NGO report were available.

Lead levels in children

Since 1989, studies conducted in different population groups including children in Pakistan have reported high levels of lead in blood.^{11–13} The mean blood lead levels among children ranged from 38.2 µg/dl in Karachi in 1989 to 2.3 µg/dl in Islamabad in 1994 (Table 1). Blood lead levels varied widely across and within cities, which may be at least partially explained by traffic density variation. Higher levels have been reported from cities that are highly populated and have high traffic density such as Karachi (range 38.2–7.2 µg/dl), whereas lower levels have been reported from cities that are sparsely populated and traffic density is low such as Islamabad (range 3.22–2.3 µg/dl). There is also marked variation within cities; a study in Karachi that selected various areas of the city based on traffic density reported an overall higher blood lead level among children in areas with high traffic density (16.46 µg/dl) compared with those in a suburban area (12.0 µg/dl).¹⁴ In Karachi, there has been a major decline in blood

lead levels from 38.2 µg/dl among school children in 1989 to 16.5 µg/dl among preschool children in 2000 and 10.8 µg/dl among newborns in 2005–2006 in the same area of the city with high traffic density (Figure 1). The level of lead in umbilical cord blood may be slightly lower than that in children of the same age, as in previous studies. Although a major decline has been noted, a large proportion of children still have a blood lead level above the allowable limit. In 1989, a study among school children in Karachi found that 93% of children had blood lead levels above the safety limit accepted for that time (40 µg/dl).^{11–13} In 2002, 80.5% of children in Karachi had blood lead levels above the current allowable limit of 10 µg/dl.¹⁴ A population of children aged 7–14 years working in automobile workshops in Peshawar had mean blood lead levels of 38.2 µg/dl (range 8.2–68.5 µg/dl).¹⁵

Sources of lead exposure

Identified sources of lead exposure in Pakistan include: leaded petrol; lead-based paints; occupational exposure; traditional remedies; and cosmetics.

Lead in petrol has been the major source of elevated blood lead levels among children. A study among children in Karachi identified various markers of leaded petrol, including: travel in open vehicles (vs closed vehicles); eating food from street vendors; and distance of house from the road. All were associated with high lead levels.¹⁴

Over the last few decades in Pakistan, there has been accelerated growth of vehicle use. During the 1980s and 1990s, the number of vehicles increased from 0.8 million to about 4.0 million, reflecting an increase of 400%.¹⁶ Fuel consumption for the transport sector has been estimated to be 40,000 tons of oil equivalent in 2050.¹⁷ In 1991, the concentration of lead reported in Pakistani petrol was the highest of all the Asian countries (1.5–2.0 g/l), and far exceeded the WHO guidelines of 0.15 g/l.¹⁸ During 1993–1996, the lead levels in petrol were >0.4 g/l. Samples of regular petrol and diesel collected in 1999 contained 0.36 g/l lead (range 0.33–0.39 g/l); a five-fold decrease since 1991 but still way above the recommended range (0.00–0.15 g/l). Figure 2 shows the trend in phasing out lead from petrol in Pakistan. In 2001, the Pakistani Government encouraged all the refineries in the country to phase out the lead in petrol. This began in October 2001 and was completed in July 2002.⁷ Currently, the permissible limit of lead in petrol is 0.02 g/l and all Pakistani refineries are following this standard.¹⁹ Blood lead levels in Pakistani children have declined in parallel with the reduction in lead content of petrol (Figures 1 and 2). However, blood lead levels are still comparatively high, and a large proportion of children have levels >10 µg/dl. Decreasing levels of lead in blood following the phasing out of lead from petrol have been reported from many countries including the USA, the UK and Mexico.²⁰ The decline in blood lead levels after the phasing out of lead from petrol will require more time,²¹ mainly because of exposure from lead that is deposited in the soil, gets suspended in dust, gets inhaled and contaminates food. Additionally, lead is deposited in bone and persists for decades. Therefore, interventions for the abatement of lead from soil are required to reduce the suspension and resuspension of lead into the environment. Furthermore, other sources of lead continue to exist. There is a need to quantify exposure from these sources and to institute interventions for remedial actions.

Maintenance of houses, especially in poor neighbourhoods in inner cities, is relatively poor. Housing stock is very old, and paint and plaster chipping off the walls and windows is common. Hand-to-mouth activity, especially among young children, is common. Paints containing lead are still being used in Pakistan.²² It is likely that the weathering or flaking of lead-based paint from buildings and houses contributes to high levels of lead exposure in Pakistani children. Studies in Pakistan have found that a history of pica (eating dirt and paint chips) was associated with higher blood lead levels among children.^{23,24} In Pakistan, no comprehensive study has been undertaken to date to determine the prevalence of lead-based paint on the market or the use of lead-based paint in dwellings such as schools, homes and other infrastructures. There is

a need to assess the availability and use of lead-based paint. Regulation of lead-based paint through policy can reduce lead exposure of children substantially.

Lead exposure from industrial sources is another problem. Paternal employment at radiator repair shops and other related occupations was identified as a risk factor for high blood lead levels among children.¹⁴ Children living or playing near these workshops are also at risk of higher lead exposure.¹⁴ Children working in automobile workshops had very high blood lead levels (38 µg/dl).¹⁵

The use of traditional and folk medicine is common in Pakistan. Traditional medicines prescribed and used under the name of 'kushtas' in Pakistan have been reported to contain heavy metals including lead.²⁵ Kushtas are prepared and distributed by the traditional Unani and Ayurvedic system of medicine and may contain minerals. Surma and kohl are eye cosmetics used in India, Pakistan and Middle Eastern countries that contain high levels of lead (up to 83%).²⁶ Surma is a black powder said to be made of antimony but it has been found to contain a high proportion of lead. Two studies from Karachi and one from Islamabad have found that the use of surma is associated with high blood lead levels in children.^{14,24,27} A study of children (aged 8 months to 6 years) of Indian and Pakistani descent living in California found average blood lead levels of 12.9 µg/dl for those using eye cosmetics compared with 4.3 µg/dl for those not using eye cosmetics ($P=0.03$).²⁸

Very few studies have explored lead levels in drinking water in Pakistan. A study conducted on drinking water in Karachi, the largest city of Pakistan, found high levels of lead in the three main sources of water tested: piped water (0.21 parts per million (PPM)); water from hand pumps (0.64 PPM); and water delivered through tankers (0.37 PPM). These levels are significantly higher than the WHO-recommended level of 0.01 PPM.²⁹ Another study estimated that the mean level of lead in water consumed by Karachi children is 0.95 µg/dl.²⁴ Another recent study from Karachi showed that the mean level of lead in water was in the range of 3.08–4.32 µg/dl.¹⁴ All of these studies point towards contamination of water with lead, the source of which could be underground water contamination or leaded pipes. This needs to be investigated for a comprehensive strategy for reducing lead exposure.

Health effects of high lead levels in children

Adverse neurological effects of lead on children, particularly in terms of impaired intellectual ability and behavioural problems, are well documented in the literature.^{3,30–35} A pooled analysis of seven cohort studies found a decline of 6.9 IQ points associated with an increase in concurrent blood lead levels from 2.4 to 30 µg/dl among children.³ To the authors' knowledge, only one study has assessed the effects of lead in children in Pakistan.³⁶ This study, conducted on primary school children (aged 6–10 years) in Karachi, demonstrated an association between impaired learning and adverse behaviour with increased lead levels.³⁶ Additionally, haemoglobin IQ, school score, behaviour score and height-for-age z-score were negatively associated with blood lead level.³⁶ The mean IQ was 8 points lower among children with a blood lead level in the upper quintile compared with those in the lower quintile.

Discussion

Limited information on the status of lead exposure and its effects on children has made it difficult to formulate a complete picture of the extent of this problem in Pakistan. Most studies to date stem from small convenience samples that are limited by the possibility of selection bias and imprecise results. Current available data suggest that there has been a decline in blood lead levels since 1989, but a large proportion of children (>50%) are still exposed to lead, which translates to blood lead levels of more than 10 µg/dl. Continued high lead exposure has huge implications for the health of children and economic growth of Pakistan. Lead exposure

has the potential to shift the IQ distribution of an entire cohort of children to lower levels, resulting in reduced productivity. Further exposure to lead also results in increased healthcare costs from the associated diseases. Therefore, investments in the reduction of lead exposure will yield enormous benefits. In the USA, it has been estimated that due to a decline in lead exposure from 1970 to 1999, the estimated economic benefit for each year's cohort of 3.8 million 2-year-old children ranges from \$110 billion to \$319 billion.²

The major sources of lead exposure in Pakistan include lead emissions to ambient air, lead-based paints, cosmetics and remedies, drinking water and industrial sources. Most previous studies have focused primarily on leaded petrol. Although leaded petrol has been a major source of environmental lead pollution, and thus of lead exposure to children, other sources also play a significant role. Since 2001, unleaded formulations of petrol have been introduced in Pakistan. As of today, petrol is no longer the main source of lead pollution; however, lead deposited in soil near roads during the leaded petrol era will continue to expose the population unless remedial actions are taken. Other important sources of lead exposure in children include lead-based paint, eye cosmetics, water, occupational exposure, batteries and traditional medicines. As the paints produced in Pakistan still contain lead, this appears to be one of the major sources of lead exposure for children, especially younger children. No information is available about the extent of lead use in paints as a source of exposure. There is an urgent need to investigate the availability of lead-based paint on the market, as well as the current standards and directions for use. Furthermore, there is a need to assess the old housing stock that were painted with leaded paint and are now exposing residents. Experience from the UK, the USA and Europe could be valuable in reducing lead exposure. In the UK, blood lead levels have reduced dramatically since the 1980s as a result of removal of lead solder from tins containing food, and removal of lead from paint and petrol.³⁷ Lead use in various occupations, including use of lead paint, was restricted through legislation.³⁸ Further reduction in lead exposure occurred because of a gradual reduction in the lead content of petrol.^{39,40} The UK and other European governments reduced the tax on unleaded petrol as an incentive for its use.³⁹ In 1999, lead in petrol was banned through the Motor Fuel Regulations 1999.⁴¹ Lead phased out from lead reduced lead concentration of dust in and around houses.^{40,42} Although petrol containing lead has been phased out in Pakistan, regulatory measures are needed to reduce lead exposure from other sources.

Eye cosmetics, such as surma and kohl, are commonly used throughout Pakistan among young children of both sexes, although more by girls as they grow older, especially in the rural areas. There are no standards or registration requirements for these products. They have repeatedly been found to contain high levels of lead and have been associated with high lead levels in children.^{43,44} A laboratory analysis found that the concentration of lead in different types of surma available in Pakistan ranged from 0.03% to 81.37%.⁴⁴

Leaded pipes and contamination with industrial waste are apparent contributors to lead in drinking water. Here, again, scant information is available about the extent of this pollution and its implication for the general population. The high lead contents in river water due to industrial effluents could be a significant source of lead exposure to rural populations who are not exposed to traffic pollution but use river water for irrigation, drinking and other needs. A 1991 study of water from the Indus River in Pakistan reported an elevated lead concentration (range 13–160 µg/l, mean 73 µg/l, $n=10$).⁴⁵ However, it is noteworthy to point out that this study was conducted before lead was phased out of petrol in Pakistan, and that some of the water pollution could have been due to high levels of lead in the environment due to leaded petrol. The introduction of unleaded petrol was a major public health success in the fight against lead pollution in Pakistan. There is a high likelihood that this measure will reduce environmental lead levels considerably and will also affect the levels of lead exposure in children.

In summary, current indications from the few studies carried out on Pakistani children are that most of these children still have high blood lead levels. Although lead has been removed from petrol, it will take a long time for these children to eliminate the lead from their bodies, and being get exposed from mothers during gestation and breast feeding. Soil and water close to roads may have been contaminated by leaded petrol. Although petrol is now lead-free in Pakistan, there is still a need to assess the blood lead levels of Pakistani children by undertaking studies using appropriate sample sizes and methodology. In particular, there is a need to gather information about the extent of lead exposure from lead-based paint, traditional cosmetics, ceramics, occupational exposure to adults resulting in child exposure, and children working in the automobile industry. At policy level, a comprehensive strategy is needed to reduce the children's exposure to lead to reduce future economic and disease burden. This includes, but is not limited to, lead abatement from dust, regulations for use of lead-based paints, work of children in hazardous occupations, appropriate recycling of automobile batteries, and educational campaigns in urban areas to reduce household lead exposures.

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Figure 1.
Blood lead levels (BLL) among children in Karachi, Pakistan 1989–2005. Source: Table 1.

Figure 2.
Lead contents of petrol in Pakistan, 1990–2002.

Table 1
Studies of blood lead levels among children in major cities of Pakistan 1989–2005

Authors	Study population	Year conducted	Year published	Sample	n	Mean(μ g/dl)	SD
Karachi							
Manser et al. ¹³	Children	1989	1990	School children		38.2	—
Khan et al. ²⁴	Children <12years	1997	2001	Population based	119	8.2	4.50
Khan et al. ²⁴	Children <6years	1997	2001	Population based	62	7.2	
Rahbar et al. ¹⁴	Children (30–60 months)	2000	2002	Population based ^b	83	16.46	15.72
Rahbar et al. ¹⁴	Children (30–60 months)	2000	2002	Population based ^c	52	12	4.50
Rahbar et al. ¹⁴	Children (30–60 months)	2000	2002	Population based ^d	107	14.3	5.30
Rahbar et al. ¹⁴	Children (30–60 months)	2000	2002	Population based ^d	105	14.9	5.76
Rahman et al. ³⁶	Children 6–10years	— ^a	2002	School children	138	16.8	6.29
Rahman and Hakeem ⁴⁶	Pregnant women	— ^a	2003	OPD patients	73	9.91	4.44
Janju	Unbilical cord blood lead	2005	Unpublished	OPD patients	534	10.84	5.76
Peshawar							
Aftab	6–17 years (mean: 13 $\pm$ 2.03)	2002	Unpublished	Population based	60	4.33	5.79
Zakir et al. ¹⁵	Children (7–14 years) working in automobile workshops	2001	2002	workers	60	38.2	—
Rawalpindi							
Hafeez and Malik ⁴⁷	Children <5years	— ^a	1996	Population based	92	18.8	
Malik and Hafeez ²⁷	Children 1–5years, surma users	— ^a	1999	OPD patients	30	21.2	—
Malik and Hafeez ²⁷	Children 1–5years, pica eating	— ^a	1999	OPD patients	29	21.2	—
Malik and Hafeez ²⁷	Children 1–5years, none	— ^a	1999	OPD patients	33	14.55	—
Islamabad							
Sadaruddin et al. ⁴⁸	Adolescents 13–19 years	1994	1995	School children	170	2.38	—
Agha et al. ⁴⁹	Adolescents 13–19 years	— ^a	2005	Population-based	88	3.22	0.20
Lahore							
Khalil et al. ²³	Children 1–6	— ^a	2004	OPD patients	50	9.95	5.77

SD, standard deviation.

^aData not available.

^bKarachi Sadar inner city with high traffic density.

^cKarachi suburban area with low traffic density.

^dKarachi City with moderate traffic density.