NeuroToxicology 45 (2014) 220–223

Contents lists available at ScienceDirect

NeuroToxicology

Towards the prevention of lead exposure in South Africa: Contemporary and emerging challenges

Angela Mathee [a,b,c,*]

[a] Environment & Health Research Unit, South African Medical Research Council, South Africa
[b] Faculty of Health Sciences, University of Johannesburg, South Africa
[c] School of Public Health, University of the Witwatersrand, South Africa

ARTICLE INFO

Article history:
Received 7 July 2014
Received in revised form 18 July 2014Accepted 19 July 2014
Available online 30 July 2014

Keywords:
Lead
Exposure
Informal sector
Cottage industries
South Africa

ABSTRACT

The prevention of lead exposure continues to constitute a major public health challenge in developed countries. In well-resourced countries major lead exposure reduction interventions have resulted in significant improvements in childhood blood lead distributions. In developing countries on the other hand, while lead exposure and poisoning remain serious public health concerns, a range of prevailing factors and circumstances, such as poverty, a large informal sector, competing public health challenges, low levels of awareness of lead hazards and weak capacity to enforce legislation, contribute to an increase in the scale and intensity of the challenge, and limit the prospects of comparable success in the foreseeable future.

This paper collates available information to illustrate that despite some progress, a wide range of sources of lead exist in South Africa, and that certain settings and groups continue to be at high risk of lead exposure. Lead exposure in relation to paint, mining, lead melting in subsistence fishing communities, the consumption of Ayurvedic medicines and food production is described, and discussed with regard to the key factors hindering efforts to prevent lead poisoning and exposure in South Africa and many other developing countries.

1. Introduction

The role of lead as a neurological toxin is well established. Lead exposure has been associated with reductions in intelligence scores, hearing loss, hyperactivity, shortened concentration spans and poor school performance in children, as well as lowered lifetime earnings (Tong et al., 2000). In recent years a growing number of studies have also pointed to links between lead exposure and aggression or violent behaviour (Needleman et al., 2002, 1996; Nevin, 2007; Wright et al., 2008). In the light of growing evidence of the lack of a threshold of safety for lead in blood, there have been calls for a lowering of the blood lead "action" level (Gilbert and Weiss, 2006; Tong et al., 2000), and in 2012 the Centers for Disease Control in the United States of America lowered their blood lead reference level for children from 10 μg/dl to a reference range set at the 97.5th percentile of their blood lead distribution, which is currently equal to 5 μg/dl (Betts, 2012).

African children have been identified as a group at particular risk of exposure, often simultaneously, to multiple sources of environmental lead (Nriagu et al., 1996). Two recent incidents of large scale lead poisoning in Zamfara, Nigeria from informal gold mining (Lo et al., 2012) and Dakar, Senegal from the dismantling of batteries (Haefliger et al., 2009) have highlighted the vulnerability of African children in this regard. Notwithstanding the available evidence of serious lead exposure in African settings, few, if any, African countries have comprehensive lead poisoning prevention, or even national blood lead surveillance, programmes in place (Tong et al., 2000). Instead, what is known about the sources and pathways of lead exposure, as well as blood lead distributions in African children, is derived mainly from *ad hoc* and often relatively small scale, localised environmental and epidemiological studies. For example, papers published on lead exposure from gasoline, paint (Gottesfeld et al., 2013; Mathee et al., 2007; Montgomery and Mathee, 2005), landfill sites (Graber et al., 2010), lead mining in the informal (Dooyema et al., 2012) and formal (von Schirnding et al., 2003) sectors, and the dismantling of batteries (Haefliger et al.,

* Correspondence to: PO Box 87373, Houghton, 2041, South Africa. Tel.: +27 824647038; fax: +27 11 642 6832.
E-mail address: amathee@mrc.ac.za

http://dx.doi.org/10.1016/j.neuro.2014.07.007

2009) have all highlighted the extent of the risk of lead exposure or poisoning in African children.

Epidemiological studies undertaken in South Africa provide clear evidence that while blood lead distributions in South African children have started to decline following the introduction of unleaded petrol (Mathee et al., 2006b), certain groups continue to be exposed to environmental lead (Mathee et al., 2007) from multiple sources. Lead is widely used in both the formal and informal sectors (including cottage industries) in South Africa, as well as in some traditional practices. This paper aims to collate the findings of some of the key South African studies in order to paint a picture of the range of sources and the settings or groups at risk of exposure to lead, and the complexity of addressing the challenge of lead exposure in a context of poverty.

2. Methodology

The paper is based on a review of the literature on lead exposure in South Africa, and also draws on media articles, and unpublished reports and data from the Environment and Health Research Unit of the South African Medical Research Council.

3. Key sources of lead

3.1. Lead in petrol

Leaded petrol was phased out in South Africa in January 2006. Until 1984, at 0.84 g/L, South Africa had amongst the highest levels of lead in petrol that had ever been used anywhere in the world (Thomas et al., 1999). Lead levels in soil alongside busy roads were shown to be significantly elevated relative to that alongside less heavily trafficked roads (von Schirnding and Fuggle, 1996). At the time, more than 90% of children living in urban areas had blood lead levels above 10 μg/dl (von Schirnding et al., 1991b). Over time, as the maximum permissible lead level in petrol was incrementally lowered, children's blood lead levels slowly started to decline (Mathee et al., 2006b; von Schirnding et al., 2001). The most recent studies however, show that elevated blood lead distributions in urban areas in South Africa continue to constitute an important public health problem (Naicker et al., 2013).

3.2. Lead in paint

In 2002, during a survey of the blood lead levels of first grade school children in Johannesburg, a 7 year old girl was found to have a blood lead level of 44 μg/dl. A few weeks later a repeat test confirmed the high blood lead, with a reading of 52 μg/dl (Mathee et al., 2003). Interviews with the girl's parents revealed a strong pica habit: she regularly ingested paint in particular. The walls of her home showed large areas from which paint had been removed and ingested (Mathee et al., 2003). Subsequent environmental sampling and analysis pointed to high lead levels in the paint on the walls of her home, as well as her school.

A range of investigations of the lead content of paint in South Africa followed, revealing widespread use of lead in paint, and the absence of suitable legislative controls. For example a survey of the lead content of residential paint collected from 239 homes in sixty randomly selected suburbs across the City of Johannesburg showed the presence of lead based paint (defined as paint that contained lead levels equal to or greater than 0.5% by weight) on both interior and exterior surfaces, and in old as well as recently promulgated suburbs. The percentage of lead by weight in the samples ranged from 0.01% to 29.00%, and lead paint was found in one-fifth of homes studied (Montgomery and Mathee, 2005).

A survey of children's playground equipment in 49 public parks in and around Johannesburg also demonstrated widespread use of lead paint. Lead based paint was found in 96% of the parks studied, and in 83% of the parks there was clear evidence of paint chipping from playground equipment (Mathee et al., 2009). Lead paint was also shown to be widely applied to children's toys (Mathee et al., 2007): lead concentrations up to 145,000 μg/g were found in paint removed from popular children's toys, such as building blocks, purchased from major toy retailers and supermarket chains. Evidence of the widespread use of lead in paint in South Africa, especially the presence of lead in painted toys, prompted the South African Department of Health to promulgate legislation declaring paint with a lead content of 600 ppm or higher as a hazardous substance. The regulations were promulgated in 2009, with the paint industry given a year to reach compliance. It is uncertain however as to the current level of compliance with the new regulations amongst paint manufacturers.

3.3. Melting of lead to make sinkers in subsistence fishing communities

Prompted by anecdotal reports of lead melting to craft fishing sinkers, cross-sectional surveys of the blood lead levels of young school children were undertaken in two remote coastal South African fishing villages in 2012. The results showed that blood lead levels ranged from 2.2 to 22.4 μg/dl, with the mean blood lead level equalling 7.4 μg/dl. Around 74% of the children had blood lead levels ≥5 μg/dl (the current CDC reference level (Betts, 2012) and 16% had blood lead levels ≥10 μg/dl (Mathee et al., 2013). The study showed that local fisher folk were collecting waste lead (for example from wheel balancing and alignment centres) and lost fishing sinkers, which were melted down (usually in the home environment) to craft new sinkers.

3.4. Pica in pregnancy

Studies have shown a high prevalence of geophagia (the intentional ingestion of soil, clay or stones) during pregnancy in many African communities, including South Africa (George and Ndip, 2011; Woywodt and Kiss, 2000). In rural areas geophagic soils are obtained from a variety of sources, such as residential gardens, or favoured hilltops and streams, while in urban areas in South Africa geophagic soil is usually obtained from street-side vendors. A recent study at an ante-natal clinic in Johannesburg showed that one fifth of the sample were geophagic (Mathee et al., 2014). Studies in New York have shown elevated lead exposure in pregnant women with geophagia (Thihalolipavan et al., 2012), and further investigation is needed in this regard among South African women.

3.5. Ayurvedic medicines

In September 2012, the media reported that around eight young people were being treated for lead poisoning in Durban. All those affected had ingested an Ayurvedic treatment for acne, which was confirmed by laboratory analyses to have a very high lead content (http://www.iol.co.za/news/south-africa/kwazulu-natal/hunt-for-toxic-acne-treatment-1.1377343, accessed 17.07.14). The product had been imported into South Africa from India and sold to the general public from health shops as well as through a direct sales network. The case raises serious concerns about public health risks from contaminated "traditional" or "natural" medicines, and the limitations of public health protection mechanisms in place in South Africa in this regard.

3.6. Recreational shooters

Preliminary results from a study currently underway at several shooting rangers and archery centres in Johannesburg is pointing to elevated lead exposure in those using lead ammunition. Amongst users of guns, blood lead levels were more than three times higher than amongst those who only practiced archery. The highest blood lead levels however, were found in staff at the indoor shooting ranges studied (de Jager et al., 2014, unpublished data).

3.7. Lead mining

The town of Aggeneys, located in the far northwestern part of South Africa, near the border with Namibia, was developed to support the operation of a lead mine. A survey of the blood lead levels of school children with a mean age of 8 years (ages ranged from 6 to 10 years) in Aggeneys, and in the comparison non-mining town of Pella, around 40 km away, showed that despite a higher socio-economic status (usually a protective factor), blood lead levels in Aggeneys children were significantly elevated relative to their Pella counterparts. The mean blood lead level in Aggeneys was 16 μg/dl (n = 86; range = 9.0–27.5 μg/dl and SD = 3.68 μg/dl), compared to 13 μg/dl in Pella (n = 68; range = 6.0–22.0 μg/dl; SD = 3.52 μg/dl). In Aggeneys and Pella respectively, 98% and 85% of children had blood lead levels ≥10 μg/dl. Elevated blood lead levels were associated with having a father who worked in the mine (von Schirnding et al., 2003).

4. Discussion

The phase-out of leaded petrol in South Africa in 2006, and the promulgation in 2010 of legislation to control the use of lead in paint constitute two major steps in the prevention of lead exposure in South Africa. Epidemiological studies have demonstrated the public health benefits of these actions, in terms of lowered blood lead distributions in South African school children (Mathee et al., 2006b), and the associated neurodevelopmental gains. In respect of paint, further work remains to be done to ensure compliance amongst manufacturers and retailers with recently promulgated legislation to control the lead content. There is also little clarity over how the enormous and costly challenge of removing toxic lead-based paint from, and soil remediation in, homes, schools, playgrounds and other settings is to be met, especially in the light of constrained resources and wide-ranging public health concerns in the country.

Notwithstanding the progress made in removing lead from petrol and paint in South Africa, as this paper has shown, numerous sources of lead continue to exist in the country. Lead exposure and toxicity has been demonstrated in occupational settings such as battery plant workers (Ehrlich et al., 1998), and para-occupational exposure has been shown in the children of lead mine workers (von Schirnding et al., 2003). Many other worker groups, such as those in the paint and construction industries, as well as employees in rifle ranges, are yet to be investigated for lead exposure.

There is a particular dearth of information available in respect of lead exposure in the growing informal occupational sector in South Africa, for example small-scale motor vehicle repair and spray-painting businesses. Research is especially needed in "cottages industries" in which lead is used in residential settings where all household members may be exposed to elevated levels of environmental lead on a daily basis. For example, the study of lead melting in subsistence fishing communities shows how children are exposed to lead in their home settings because of lead melting to make fishing sinkers (Mathee et al., 2013).

The risk of maternal and foetal lead exposure in geophagic women has been demonstrated (Thihalolipavan et al., 2012), and requires further investigation in South Africa and other African countries where the practice is widespread, especially in the light of the risk of foetal neurotoxicity. The lead poisoning outbreak in Durban in 2012 associated with the consumption of Indian Ayurvedic medicines has raised concerns over the public health risks of certain traditional medicines. In this regard, there is a need for investigation and assessment of possible risks to public health from the widespread use of African traditional medicines in South Africa. In 2013 regulations were promulgated to bring complementary medicines under the umbrella of oversight mechanisms for all medicines in the country. However, there are questions over capacity to implement the legislation, and there is also strong resistance from the complementary medicines industry to the new legislation. The preparation of low cost alcoholic beverages (often referred to in South Africa as "concoctions") using the contents of lead batteries has also been reported, and similarly requires further investigation.

A particularly daunting challenge in South Africa, and in many other African or developing countries, is the prevention of lead exposure in the informal sector, in cottage industries and from traditional practices. A key concern in this regard is the limited capacity and resources available to enforce existing occupational health and safety legislation. Informal sector businesses, and cottage industries, are often unregistered and unregulated, and concealed in backyards and residential settings. Given the setting, lead use in cottage industries translates to lead exposure to the broader community, including young children and pregnant women. The upshot of low levels of awareness of lead hazards (Mathee et al., 2006a) in cottage industries and the informal sector is a cavalier approach to the use, handling and disposal of lead. Notwithstanding the challenges, the need to act in respect of the informal sector and cottage industries is particularly pressing, given the marginalisation and impoverishment in the affected communities, predisposing them to simultaneous exposure to multiple sources of lead (Tong et al., 2000).

To effectively address the issue, lead exposure in the informal sector in South Africa needs to be placed much higher on the public health and political agendas than is the case at present. Currently there is limited information on the extent of this important public health problem, and consequently a comprehensive national lead poisoning prevention strategy is lacking, as are effective surveillance and screening programmes and research to identify high-risk groups and settings. While currently competing health and developmental challenges in South Africa may render costly lead abatement programmes such as lead paint removal from homes and public buildings, and soil remediation, unlikely, lead hazard awareness ought to be a much higher priority in the country. A particular concern is the limited appropriate information for, and low levels of awareness of lead hazards amongst high risk groups (such as those practising geophagia, ingesting Ayurvedic medicines, melting lead to craft fishing sinkers or using ammunition), those caring for children (Mathee et al., 2006a), and in key sectors such as health and education. To date public awareness campaigns have been isolated and piecemeal, and have lacked the holistic and integrated approach needed to make an effective impact, which is regrettable given the absence of costlier lead abatement programmes.

Lead exposure has serious health, social and economic consequences, including compromised educational attainment (Ernhart, 2006; Lanphear et al., 2005) and aggressive or violent behaviour (Needleman et al., 2002; Nevin, 2007). For example, studies in the USA indicate that childhood lead exposure reduction in the 1990s contributed to a subsequent reduction in violent crime of around 56% (Reyes, 2007). It has also been estimated that ongoing lead exposure in the USA is costing their economy billions of dollars on an annual basis, and that the benefits of acting to

reduce childhood lead exposure exceeds that of other public health programmes such as immunizations (Gould, 2009). In this light, strong action on lead exposure prevention in South Africa, a country beset by major socio-political concerns such as poor school performance and high levels of crime and violence, would seem particularly prudent and cost-effective. Exposure to lead has also been shown to exacerbate the detrimental impact of social stressors such as poverty and violence, and the socio-economic cost of inaction is high (Gould, 2009). Furthermore, as a consequence of the former apartheid system of government in South Africa, which contrived the population's socio-economic well-being and environmental health status according to skin colour, levels of poverty and inequality (South Africa is amongst the most unequal societies in the world) continue to a large extent to be similarly defined, despite two decades of democratic government and progress. Blood lead levels also continue to be highest in Black children (Mathee et al., 2006b; von Schirnding et al., 1991a). Action on lead exposure prevention in South Africa therefore, in addition to the socio-economic imperatives, may constitute an act of socio-environmental justice, necessary to allow all to reach their full potential, and to decrease the inequality gap in the country.

5. Conclusions

While the issue of leaded petrol has been addressed, and some steps have been taken to reducing exposure to lead-based paint, many sources of exposure to lead continue to exist in South Africa, in both the formal sector, as well as in the growing informal occupational sector. Large numbers of people are therefore at risk of lead exposure and the concomitant health, neuro-developmental and social effects. There is particular concern about cottage industries in which lead is used, and where entire families or households may be exposed to lead on a continuous basis. Lead exposure prevention needs to be placed much higher on the political agenda in South Africa to address the associated health, educational attainment, violence and other social concerns.

Funding source

This work was funded by the South African Medical Research Council.

Conflicts of interest

The authors declare that there are no conflicts of interest.

Transparency document

The Transparency document associated with this article can be found in the online version.

References

Betts KS. CDC updates guidelines for children's lead exposure. Environ Health Perspect 2012;120:a268.
Dooyema CA, Neri A, Lo YC, Durant J, Dargan PI, Swarthout T, et al. Outbreak of fatal childhood lead poisoning related to artisanal gold mining in northwestern Nigeria, 2010. Environ Health Perspect 2012;120:601–7.
Ehrlich R, Robins T, Jordaan E, Miller S, Mbuli S, Selby P, et al. Lead absorption and renal dysfunction in a South African battery factory. Occup Environ Med 1998;55:453–60.
Ernhart CB. Effects of lead on IQ in children. Environ Health Perspect 2006;114:A85–6 author reply A86–7.
George G, Ndip E. Prevalence of geophagia and its possible implications to health – a study in rural South Africa. In: Second International Conference on Environmental Science and Development, vol. 4. Singapore; 2011;166–9.
Gilbert SG, Weiss B. A rationale for lowering the blood lead action level from 10 to 2 μg/dL. Neurotoxicology 2006;27:693–701.
Gottesfeld P, Kuepouo G, Tetsopgang S, Durand K. Lead concentrations and labeling of new paint in Cameroon. J Occup Environ Hyg 2013;10:243–9.
Gould E. Childhood lead poisoning: conservative estimates of the social and economic benefits of lead hazard control. Environ Health Perspect 2009;117:1162–7.
Graber LK, Asher D, Anandaraja N, Bopp RF, Merrill K, Cullen MR, et al. Childhood lead exposure after the phaseout of leaded gasoline: an ecological study of school-age children in Kampala, Uganda. Environ Health Perspect 2010;118:884–9.
Haefliger P, Mathieu-Nolf M, Lociciro S, Ndiaye C, Coly M, Diouf A, et al. Mass lead intoxication from informal used lead-acid battery recycling in Dakar, Senegal. Environ Health Perspect 2009;117:1535–40.
Lanphear BP, Hornung R, Khoury J, Yolton K, Baghurst P, Bellinger DC, et al. Low-level environmental lead exposure and children's intellectual function: an international pooled analysis. Environ Health Perspect 2005;113:894–9.
Lo YC, Dooyema CA, Neri A, Durant J, Jefferies T, Medina-Marino A, et al. Childhood lead poisoning associated with gold ore processing: a village-level investigation – Zamfara State, Nigeria, October–November 2010. Environ Health Perspect 2012;120:1450–5.
Mathee A, Barnes B, Haman T, Swart A. Limited awareness of lead hazards among pregnant women in South Africa. In: Conference of the International Society for Environmental Epidemiology, vol. 17. Paris, France: Lipincott, Williams & Wilkins; 2006S196S196.
Mathee A, Khan T, Naicker N, Kootbodien T, Naidoo S, Becker P. Lead exposure in young school children in South African subsistence fishing communities. Environ Res 2013;126:179–83.
Mathee A, Naicker N, Kootbodien T, Mahuma T, Nkomo T, Naik I, et al. A cross-sectional analytical study of geophagia practices and blood metal concentrations in pregnant women in Johannesburg, South Africa. S Afr Med J [Suid-Afrik tydskr vir geneeskd] 2014;104:568–73.
Mathee A, Rollin H, Levin J, Naik I. Lead in paint: three decades later and still a hazard for African children. Environ Health Perspect 2007;115:321–2.
Mathee A, Rollin H, von Schirnding Y, Levin J, Naik I. Reductions in blood lead levels among school children following the introduction of unleaded petrol in South Africa. Environ Res 2006b;100:319–22.
Mathee A, Rollin HB, Ditlopo NN, Theodorou P. Childhood lead exposure in South Africa. S Afr Med J Suid-Afrik tydskr vir geneeskd2003;93:313.
Mathee A, Singh E, Mogotsi M, Timothy G, Maduka B, Olivier J, et al. Lead-based paint on playground equipment in public children's parks in Johannesburg, Tshwane and Ekurhuleni. S Afr Med J Suid-Afrik tydskr vir geneeskd2009;99:819–21.
Montgomery M, Mathee A. A preliminary study of residential paint lead concentrations in Johannesburg. Environ Res 2005;98:279–83.
Naicker N, Barnes B, Mathee A. Environmental lead – a public health challenge in South Africa. Epidemiology 2013;24:621–2.
Needleman HL, McFarland C, Ness RB, Fienberg SE, Tobin MJ. Bone lead levels in adjudicated delinquents. A case control study. Neurotoxicol Teratol 2002;24:711–7.
Needleman HL, Riess JA, Tobin MJ, Biesecker GE, Greenhouse JB. Bone lead levels and delinquent behavior. JAMA 1996;275:363–9.
Nevin R. Understanding international crime trends: the legacy of preschool lead exposure. Environ Res 2007;104:315–36.
Nriagu JO, Blankson ML, Ocran K. Childhood lead poisoning in Africa: a growing public health problem. Sci Total Environ 1996;181:93–100.
Reyes JW. Environmental policy as social policy? The impact of childhood lead exposure on crime BE J Econ Anal Policy 2007;7.
Thihalolipavan S, Candalla BM, Ehrlich J. Examining Pica in NYC pregnant women with elevated blood lead levels. Matern Child Health J 2012;17:49–55.
Thomas VM, Socolow RH, Fanelli JJ, Spiro TG. Effects of reducing lead i gasoline: an analysis of the international experience. Environ Sci Technol 1999;33:3942–8.
Tong S, von Schirnding YE, Prapamontol T. Environmental lead exposure: a public health problem of global dimensions. Bull World Health Organ 2000;78:1068–77.
von Schirnding Y, Bradshaw D, Fuggle R, Stokol M. Blood lead levels in South African inner-city children. Environ Health Perspect 1991a;94:125.
von Schirnding Y, Fuggle R. A study of the distribution of urban enviromental lead levels in Cape Town, South Africa. Sci Total Environ 1996;188:1–8.
von Schirnding Y, Mathee A, Kibel M, Robertson P, Strauss N, Blignaut R. A study of pediatric blood lead levels in a lead mining area in South Africa. Environ Res 2003;93:259–63.
von Schirnding Y, Mathee A, Robertson P, Strauss N, Kibel M. Distribution of blood lead levels in school children in selected Cape Peninsula suburbs subsequent to reductions in petrol lead. S Afr Med J Suid-Afrik tydskr vir geneeskd2001;91:870–2.
von Schirnding YER, Fuggle R, Bradshaw D. Factors associated with elevated blood lead levels in inner city Cape Town children. S Afr Med J 1991b;79:454–6.
Woywodt A, Kiss A. Geophagia – a forgotten diagnosis? S Afr J Surg Suid-Afrik tydskr vir chir2000;38:42.
Wright JP, Dietrich KN, Ris MD, Hornung RW, Wessel SD, Lanphear BP, et al. Association of prenatal and childhood blood lead concentrations with criminal arrests in early adulthood. PLoS Med 2008;5:e101.