LEAD EXPOSURE IN AFRICAN CHILDREN

CONTEMPORARY SOURCES AND CONCERNS

World Health Organization
REGIONAL OFFICE FOR Africa

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FOREWORD

In 2010, African Ministers of Health and Environment, in the Luanda Commitment (which followed the Libreville Declaration of 2008), highlighted their "concerns over the adverse effects on human health and the environment from the use, disposal of and exposure to hazardous chemicals and wastes which pose a major challenge for many African governments". Lead is one such hazardous substance, to which far too many Africans are exposed, from far too many sources, on a daily basis. This report shows that exposure to lead results in a range of health, social and education effects that have a direct and huge effect on African economic productivity and prospects.

A source of both concern and optimism is the knowledge that lead poisoning is preventable. With the available strategies and programmes, and with sufficient political will, we have the power and the means to eliminate lead exposure in Africa, thereby giving African children a greater chance of reaching their full potential in life, and lowering health and educational costs. Action to prevent lead poisoning will also help boost African economies by billions of dollars.

The Luanda Commitment paves the way for the development of a concerted programme of action for the Prevention of Lead Poisoning in African countries. Urgent, comprehensive and sustained action in this regard will reap huge, and much needed, health, social and economic benefits for African countries, and should therefore be implemented without delay.

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EXECUTIVE SUMMARY

Lead is a useful, but toxic substance, which has been known and used in hundreds of products and processes over millennia. Research conducted over the past century in particular, has produced unequivocal evidence of the harm caused by lead, especially in young children and at the foetal stage. For example, even at low levels in blood, lead has been associated with hearing loss, learning difficulties and poor school performance, lower levels of tertiary educational attainment and a decline in lifetime earnings. Studies have also shown that widespread lead exposure has a depressive effect on community prospects and on economies. In recent decades a growing body of evidence has associated lead exposure with elevated levels of aggression or violence. At highly elevated levels, a range of clinical effects have been demonstrated, including anaemia, damage to a range of organs, permanent muscular paralysis, coma or death. Tragically, hundreds of African children have died from lead poisoning in the past decade, including in Nigeria as a consequence of artisanal gold mining, and in Senegal from battery recycling.

The phasing out of leaded petrol in most of the continent's countries by 2006 is a laudable achievement which benefits the health and prospects of millions of African children. However, Africa lags behind other regions, in putting in place the fundamental measures needed to effectively protect people against lead from a range of other sources. Studies undertaken in a range of African countries point to ongoing lead exposure from multiple sources in African homes, schools and workplaces. These include lead paint, mines and smelters, battery manufacturing and recycling plants, automotive repair facilities, lead-related cottage industries, hobbies and recreation involving lead (such as fishing, jewellery making and the use of lead ammunition), geophagic practices under certain conditions, the use of certain traditional medicines, and the consumption of adulterated alcoholic "home brews", to mention but a few.

The detrimental health, social and educational effects of lead exposure exert an enormous economic cost on African economies. With respect to the loss of IQ points alone, health economists conservatively estimate that around US$134.7 billion are lost to the African continental economy each year because of lead exposure.

In order to protect the African populace against lead exposure and poisoning, there is an urgent need for a concerted programme of action at regional and country level that includes research and surveillance, regulation of the lead content of paint, intensive public education and awareness campaigns, implementation of worker protection programmes that also reduce para-occupational exposure, environmental assessments, the identification of high risk settings, processes and groups, screening of vulnerable or high risk groups, and rehabilitation programmes where necessary.

ACKNOWLEDEMENTS

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Angela Mathee, Nisha Naicker and June Teare of the WHO Collaborating Centre for Urban health, based in Johannesburg, South Africa, were responsible for collation of the information and drafting of the report. The report was reviewed by Dr Joanna Tempowski, Dr Magaran Bagayoko and Hawa Senkoro, and their insightful comment are gratefully acknowledged.

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1 WHAT IS LEAD?

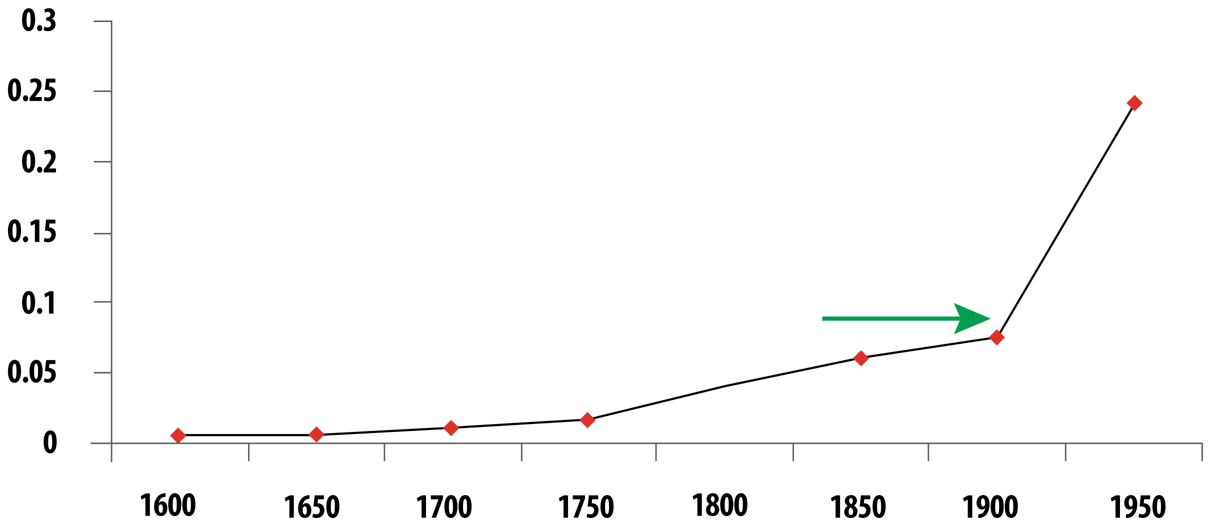
Lead (Pb) is a blue or silver grey metal which has been mined for thousands of years. It is found naturally in the environment (WHO, 2010; IARC, n.d.), usually in coal and ore with other metals such as zinc, silver and copper (WHO, 2001). It is estimated that three hundred million tonnes of lead have been released into the environment through mining and ore processing over the last five centuries (Tong et al., 2000; Hernberg, 2000).

Lead has a range of properties which have made it very useful in modern society. For example, it is soft, malleable, a relatively poor conductor of electricity, highly resistant to corrosion, and is able to absorb sounds and other vibrations, as well as radiation. Lead also has a low melting point and is resistant to fire (WHO, 2001). These characteristics have made lead a very versatile substance, and it is used in literally hundreds of products, including protective equipment (for example x-ray shields and fire protection gear), petrol (as an anti-knocking agent - though this use is close to being phased out globally), paint (to increase durability of the pigment and speed up drying), cabling, ammunition, jewellery, hair dye, computer and electrical equipment, wheel balancing weights and fishing sinkers, to mention but a few (Science Encyclopedia, n.d; WHO, 2001). Recycled lead accounted for 45 percent of global lead supply in 2003. Most of the recycled lead comes from used lead-acid batteries, with the remainder coming from other sources such as lead pipes, sheets, cable sheathing and wastes from fabricating/processing operations (UNEP, 2010).

The extensive use of lead has resulted in widespread human exposure to this toxic metal. There are no natural mechanisms for the breakdown of lead, and once released into the environment it persists for very long periods. Due to atmospheric transmission, lead can affect the most remote regions of the world (WHO, 2010).

Figure 1 (Top) Lead (Pb): atomic weight 207.2, atomic number 82, melting point 327°C, density 11.3 g/cm3. (Below) Lead in its natural form. (Source: Periodic Table, n. d.; Northern Industrial Hygiene, 2011).

Figure 2 Deposition of lead (micrograms per kilogram) in the ice in Greenland. The green arrow points to the sharp increase since 1940 attributed mainly to combustion of lead alkyl additives in petrol. (Source: WHO, 2008).



2 THE HEALTH AND SOCIAL EFFECTS OF LEAD

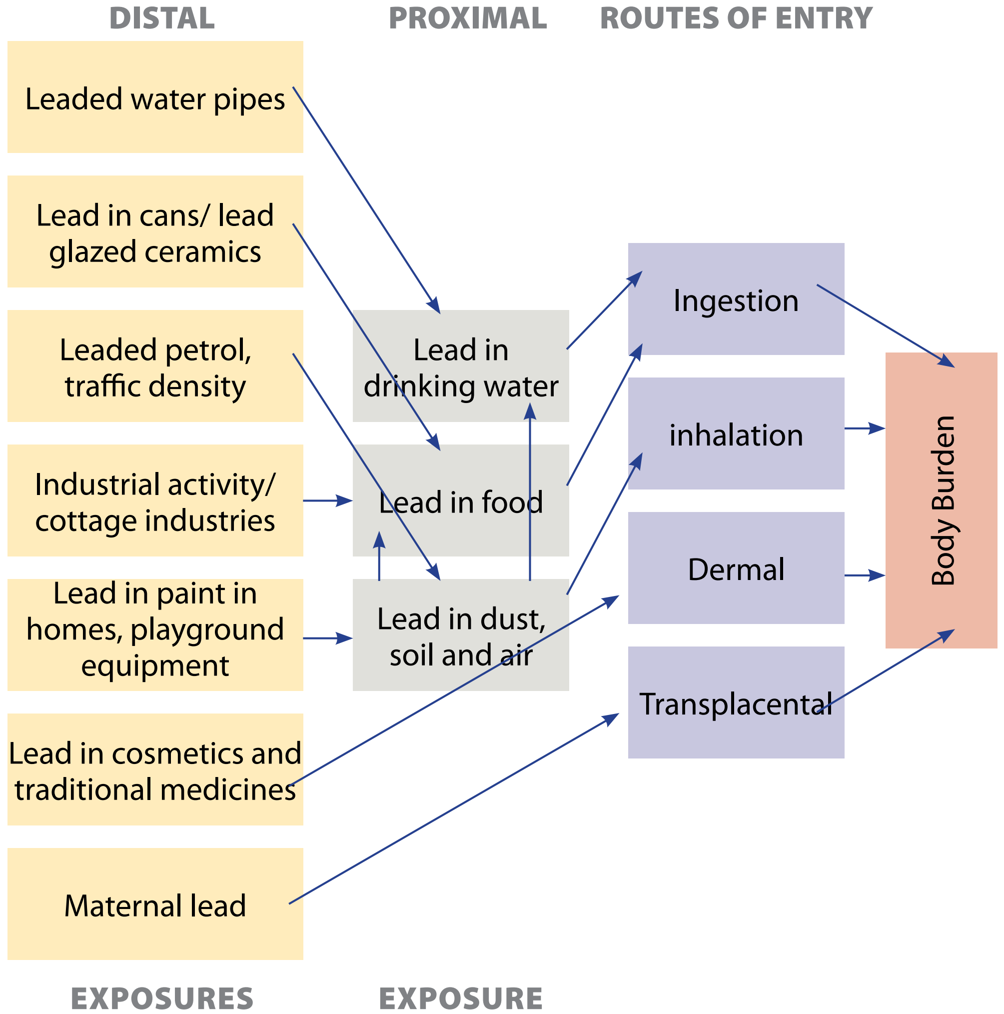
The detrimental effects of lead have been known for centuries. However, increasingly sophisticated studies undertaken in the past few decades in particular, have associated lead exposure with a wide range of abnormal laboratory findings and detrimental health effects (see Table 1). Despite growing awareness of the risks for health, the metal continues to be mined and used across the globe. Notwithstanding exposure reduction efforts at global, national and local levels in recent decades, lead remains a major public health problem throughout the world, especially in poorly resourced countries.

Unlike many other metals, such as iron and zinc, lead performs no useful function in the human body – it only causes harm. The Centers for Disease Control and Prevention (CDC) in the United States of America has set a reference level for lead in children's blood at the 97.5th percentile of the distribution in that group – currently it equals 5 µg/dl. Similarly, in France, the 98th percentile of the blood lead distribution in children under the age of 7 years equals 5 µg/dl (WHO, 2015). However there is widespread scientific consensus that there is no safe level of exposure to lead. Environmental, socio-economic and biological factors affect the degree to which individuals may be exposed to, and harmed by, lead. Children, especially those under the age of five years, are recognized to be a group that is particularly vulnerable to lead – both in terms of exposure and the health consequences.

Why Are Children Particularly Vulnerable to Lead Exposure?

Children's hand-to-mouth behaviour and highly exploratory nature, which leads them to touch and taste objects and substances with which they come into contact, are amongst the reasons for their increased vulnerability to lead. Mouthing and/or swallowing lead-containing, or lead-coated, objects or substances may result in appreciable body lead burdens in children. A habit of chewing nails or sucking fingers may also increase the ingestion of lead-contaminated soil or dust particles, for example from lead paint on the interior or exterior surfaces of dwellings, furniture and playground equipment (WHO, 2008, Mathee et al., 2009). Very high blood lead levels are often found in children with pica for soil and paint. Figure 3 summarises the key sources and routes of lead exposure.

Figure 3 Sources and routes of lead exposure (Naicker, 2012; adapted from Fewtrell et al., 2003; 2004)



Children's particular vulnerability to the health effects of lead exposure also stem from their immature organ systems and relatively ineffective mechanisms for the metabolism of lead. The rate of absorption of lead in the gastrointestinal tract in infants and children is greater than in adults (40% versus 10% respectively). Nutritional deficiencies, such as of iron and calcium (which are more common in children), increase the rate of absorption of lead (Bellinger, 2004; Wright et al., 1999; Bradman et al., 2001).

Lead is retained in the bodies of children for longer periods than adults (Bellinger, 2004; Manton et al., 2000). Children's incompletely developed organs and systems, such as the renal and hepatic systems, leads to less effective detoxification and elimination mechanisms compared to adults (WHO, 2010). Transport of lead through children's immature blood-brain barrier leads to a higher risk of adverse neurological and developmental effects (WHO, 2010).

What happens to Lead in the Body?

The amount of lead absorbed by humans depends on the particle size and its solubility. Other factors affecting lead absorption include individual characteristics such as age, sex and nutritional status (Barbosa et al., 2005). Lead entering the blood stream usually constitutes 1 to 5% of the total body lead. At low lead concentrations 95 to 99% of blood lead is bound to red blood cells (RBC) and 1% is found in the plasma. At higher lead concentrations, a larger percentage of lead is distributed in plasma. Plasma lead is relatively easily exchanged into bone and soft tissues such as the kidney and the brain. The amount of lead bound to red blood cells is reduced by half (i.e. half-life) after approximately 36 days; for lead found in plasma, the same process takes less than an hour (Sakai, 2000). Figure 4 illustrates the lead metabolism pathway from ingestion to excretion and/or storage.

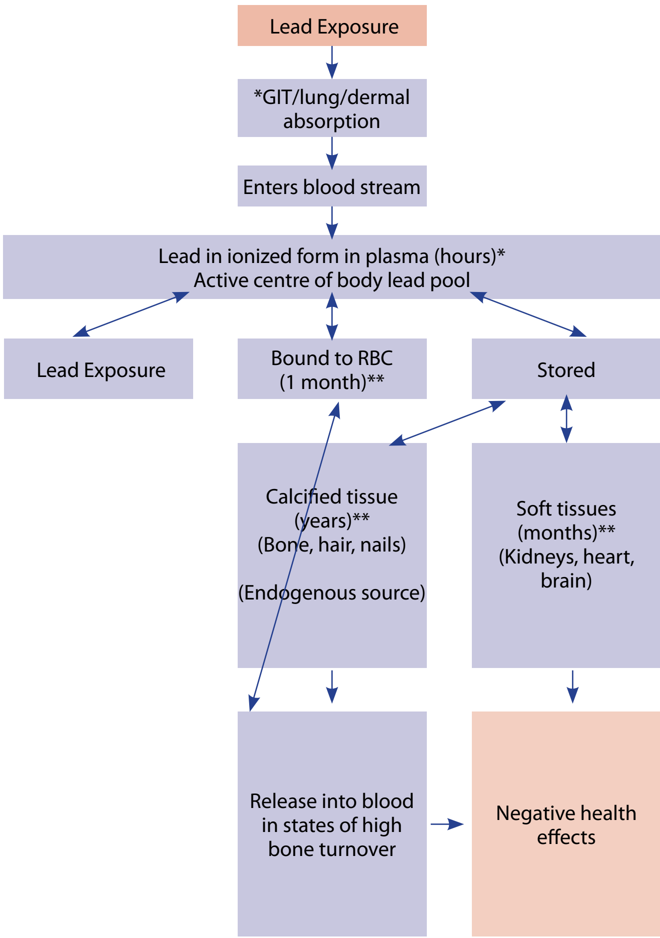
In the soft tissues lead affects various cell processes, leading to a range of toxic effects. The half-life of lead in soft tissues is approximately 40 days. In bone it replaces calcium and this is where 70 to 80% of lead is stored in children, compared to 90 to 95% in adults (Barry, 1981; Ambrose et al., 2000). Lead can be stored in bone for years, and continues to accumulate throughout an individual's lifetime. Rabinowitz (1991) estimated that the half-life of lead in bone ranged from 10 to 30 years, reflecting chronic or lifetime exposure (Rabinowitz, 1991; Hu, 1998).

Bone acts as an internal source of lead. At times, such as when bones are fractured or during menopause, lead from bone is released into the blood. This is of particular concern during pregnancy when lead may be transferred across the placenta to the foetus (Röllin et al., 2009; Ambrose et al., 2000). After birth, babies may be exposed to lead during breast feeding (Goyer, 1990; Gulson et al., 2004; Bradman et al., 2001). Studies have also shown that release of lead from bone stores is elevated during the period after childbirth, leading to increased levels of exposure in breastfed babies (Rothenberg et al., 2000; Gulson et al., 1998; Hernandez-Avila et al., 1996). Calcium supplementation has been shown to decrease the risk of lead release from bone during breastfeeding (Ettinger et al., 2006; 2007; Hernandez-Avila et al., 2003).

Bones are in a constant, dynamic process of breaking down and forming new bone. In childhood the rate of bone breakdown and formation is elevated, with lead constantly being released from bone into the blood stream (O'Flaherty, 1995). Different types of bone have different turnover times; the patella for example, has a shorter turnover time than the tibia (Barbosa et al., 2005).

Some of the lead in plasma is excreted, mainly through faeces and urine. In early post natal life and in very young children the elimination via an immature renal system is significantly decreased compared to adults. Very small amounts are excreted in saliva and sweat. The excretion process is however inefficient, and most lead remains stored in the body (Sakai, 2000; Ambrose et al., 2000).

Figure 4 Lead metabolism pathway (Naicker, 2012)
***GIT Gastrointestinal ** Indicates total time that lead is present in the various body tissues**



What are the Health Effects of Lead?

Lead exposure and poisoning are associated with a wide range of signs and symptoms; however, most are varied and non-specific, making the diagnosis of lead exposure on clinical grounds difficult.

Clinical Effects at High Levels of Exposure

Symptoms such as drowsiness, exhaustion, convulsions, permanent muscular paralysis, coma and eventually death can occur at very high blood lead concentrations of 100 µg/dl and above. Acute, high concentrations of lead in blood, for example from 70 µg/dl to 100 µg/dl, can produce severe kidney abnormalities. Initially this may be reversible but if lead exposure continues then irreversible chronic effects may result. In children, if treatment occurs within two months of exposure, there is usually good recovery (Chisolm et al., 1968). Gastro-intestinal abnormalities (anorexia, nausea, vomiting, stomach cramps) are likely to occur (WHO, 2010) at levels ≥50 µg/dl. At blood levels of ≥40 µg/dl, lead affects the activity of enzymes needed for the proper functioning of red blood cells (ATSDR, 2007), leading to anaemia. Lead also decreases the life span of red blood cells, further contributing to the development of anaemia (ADSTR, 2007). Haemolytic anaemia occurs when high levels of lead exposure occur over a short period of time. Blood lead levels under ≤30 µg/dl affect Vitamin D metabolism and calcium levels, leading in turn to abnormal growth and bone development (Table 1).

Table 1 Clinical effects associated with specific blood lead concentrations

Clinical effects in children	Blood lead in µg/dl
Death	>100
Severe brain damage (Encephalopathy)	100
Kidney damage	
Severe anaemia	
Severe stomach cramps	50
Damage to haemopoiesis (decreased haemoglobin synthesis)	40
Reduced vitamin D metabolism	30
Increased risk of hypertension in adulthood	20
Impaired nerve function-increased nerve conduction velocity	20
Increased level of erythrocyte protoporphyrin Decreased vitamin D metabolism Decreased calcium homeostasis	20-10
Developmental toxicity Hearing impairment Decreased growth (including puberty) Impaired peripheral nerve function Transplacental transfer Reduced IQ, Behaviour problems	

Effects of Low Blood Lead Levels on Intellectual Capacity and Behaviour

Usually, lead exposure results from chronic exposure to low lead levels. At levels of ≤10 µg/dl lead exposure impairs neurological (Lanphear et al., 2005; Bellinger 2004; Canfield et al., 2003; Bernard 2003) and physical (Kaji and Nishi, 2006; Vivoli et al., 1993; Frisancho and Ryan, 1991) development in children, with adverse consequences in adulthood. Hearing loss has been shown to occur at blood lead levels from <10 µg/dl (NTP Monogr, 2012; WHO, 2001; Swartz and Otto, 1987).

Lead easily crosses the blood brain barrier. The half-life of lead in brain tissue is approximately two years. At lower blood lead concentrations studies have shown decreased IQ scores, behavioural abnormalities (including aggressive antisocial behaviour and decreased impulse control) and increased risk of developing attention deficit hyperactivity disorder (ADHD) (Lanphear et al., 2005; Canfield et al., 2003; 2004; Bellinger et al., 1994; Braun et al., 2006; Needleman et al., 2002; Nevin, 2000; Naicker et al., 2012).

Lead is associated with behavioural problems, including characteristics of Conduct Disorders and Oppositional Defiant Disorders (DSM IV, 2000). This type of behaviour includes temper tantrums, argumentativeness, active defiance and refusal to comply with adult requests and rules, deliberate attempts to annoy and upset people, frequent anger and resentment, mood instability, substance abuse, aggression towards people and animals, destruction of property, and deceitfulness, lying or stealing (AACAP n.d.; DSM IV, 2000). The longitudinal Cincinnati Lead Study showed that in children aged between 15 and 17 years there was a significant association between lead exposure and antisocial behaviour (Dietrich et al., 2001). The longitudinal Port Pirie Cohort study found similar results (Burns et al., 1999). Cross-sectional studies have also pointed to effects such as delinquency and aggressive behaviour in children exposed to low levels of environmental lead (Bellinger et al., 1994; Needleman et al., 1996). In Africa, while there are numerous studies pointing to high levels of lead exposure in children, there is a dearth of information on the health effects of chronic exposure to low level environmental lead. In 2012 Naicker et al. found that in a birth cohort, boys (13 years old) with higher blood lead levels (mean 6.3 µg/dl) were more likely to exhibit socio-behavioral problems (attacking people, arguing). Studies have shown that antisocial or aggressive behaviour in childhood can result in criminal activity as the individual gets older (Liu & Wuerker, 2005). Evidence from ecological and cross sectional studies conducted in the USA suggests that lead exposure and criminal activities are significantly associated with each other (Wright et al., 2008; Nevin, 2000; 2007; Stretesky & Lynch, 2001).

In adults associations between prenatal and early childhood exposure to lead and adult onset behavioural and mental disorders such as schizophrenia, depressive and anxiety disorders have been found (Opler et al. 2008; 2004; Guilarte, 2009; Eum et al., 2012). Over the past decade studies have highlighted the impact of chronic and cumulative lead exposure on cognitive decline in elderly men and women (Shih et al., 2007; Weuve et al., 2009). Cognitive decline has been shown to be a strong predictor for the development

Table 2 Historical evidence of health effects due to lead exposure

DATE OF DISCOVERY	PERSON RESPONSIBLE FOR THE DISCOVERY	DOCUMENTED NEGATIVE HEALTH EFFECTS	HEALTH EFFECT ATTRIBUTED TO LEAD
370 BC	Hippocrates	Colic	No
2 BC	Nicander	Lead palsy	No
1 AD	Dioscorides	Clinical manifestations of lead poisoning	Yes
1498 & 1577	Eberhard Gockel	Epidemics of lead toxicity	Yes, due to lead used in wine and ciders
16 century	Paracelsus	"Miners disease"	Yes
18 century	Ramazzini	Paralysis, lethargy, cachectic, toothless potters	Yes
1767	Sir George Baker	Devonshire colic:- palsy, encephalopathy, pallor and abdominal cramps	Yes, due to lead weights crushing apples to make cider
1831	Laennec	Anaemia	Yes
1832	Charles Thackrah	Plumbism	Yes
1839	Tanquerel des Planches	Abdominal, neurological and arthritic signs of lead poisoning.	Yes, based findings on 1200 cases
1854	Alfred Baring Garrod	Lead gout	Yes
1899	Behrend	- Basophilic stippling of erythrocytes (RBC) - Counting of these stippled cells used in health surveillance in lead workers from first half of the 20th century until 1960's.	Yes
1898	Alfred Baring Garrod	Increased excretion of porphyrins in urine	Yes
Beginning of 20th century	Jefferis Turner	Childhood lead poisoning documented	Yes
	JJ L Nye	Renal effects like Fanconi syndrome in adults who had lead poisoning in childhood.	Yes
Late 19th and early 20th century		-Abortions and stillbirths in women working in lead industry. -Higher mortality of children born to these women. -Infertility in male workers Also used to induce illegal abortions	Yes
1934	Vigliani and Angerleri	Showed that incorporation of iron into haem was disrupted, thus protophorphyrin accumulated in the RBC	Yes
1951	RF Sheets	Lead decreased lifespan of RBC which also contributes to the anaemia. Introduction of chelating agents which was sometimes used in symptomless workers as prophylaxis	Yes
1960	Haeger-Aronsen	Excretion of aminolevulinic acid (ALA) in urine of lead workers	Yes
1960's	Bonsignore and colleagues	- By late 1960's new methods for measuring lead were now developed – dithizone method and then later atomic absorption spectrophotometry which improved medical surveillance of workers	Yes
1970's	Globally	Subclinical manifestations in adults and children were noted.	Yes
1970-PRESENT	Globally	Biological disruption by low level lead exposure continues.	Yes

of dementia (Blacker et al., 2007; Elias et al., 2000; Kawas et al., 2003; Morris et al., 2001; Small et al., 2000). In addition to the neurological effects of cumulative lead exposure, lead adversely affects the cardio-vascular system and results in hypertension, ischaemic coronary heart disease, cerebrovascular accidents, and peripheral vascular disease (Vazizi and Gonick, 2008).

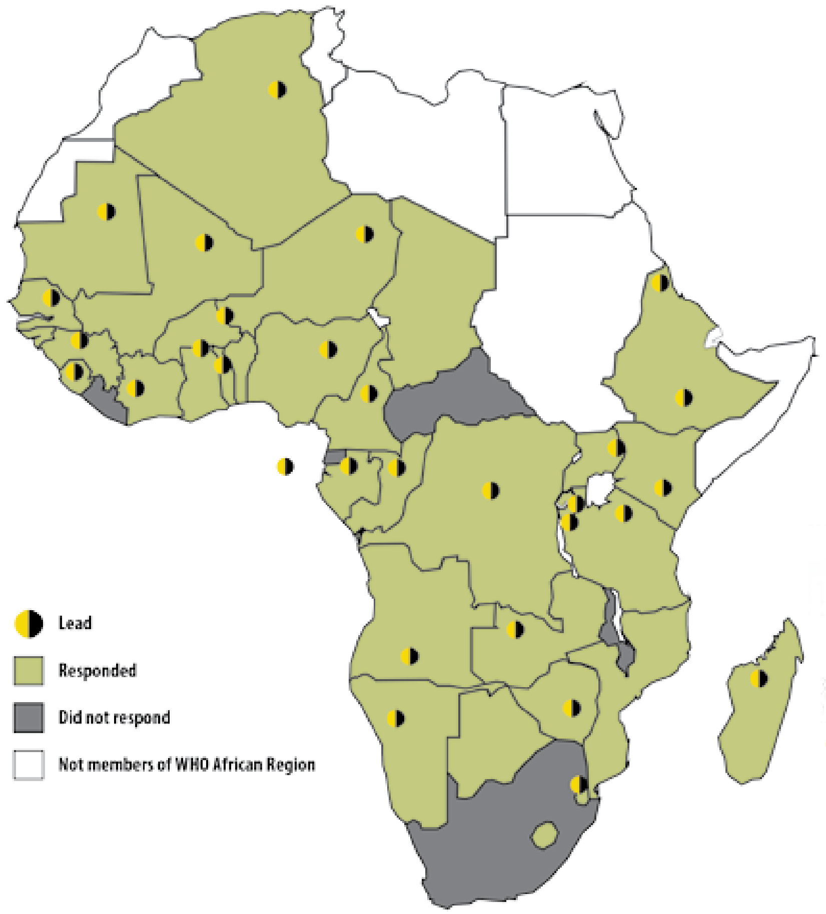
3 LEAD EXPOSURE IN A HISTORICAL CONTEXT

Evidence of toxicity due to lead exposure was documented as early as 370 BC (Tong et al., 2000). References to possible toxicity from lead exposure were found in Egyptian papyrus scrolls; however the link between lead exposure and detrimental effects on health was only made around 1AD. Dioscorides made the association between lead exposure and toxicity, and Pliny reported that toxicity from lead was common in people who built ships. In ancient Rome lead was used in pipes, glazed pottery, cooking utensils, pots used to boil and condense grape juice and to sweeten wine (Hernberg, 2000). Lead poisoning was common in the ancient Roman Empire, especially among the Roman elite (Needleman, 2004; Woolley, 1984). Higher concentrations of lead were found in bones taken from the tombs of the upper classes, relative to working class graves (Gilfillan, 1965; Hernberg, 2000). Table 2 illustrates the historical evidence of lead toxicity.

4 SOURCES OF LEAD EXPOSURE IN AFRICA

As seen in the figure below, in a recent self-assessment exercise undertaken in the African Region of WHO, the majority of countries identified a range of ongoing, lead-related public health concerns. The sources of lead reported included mining, paint, petrol, toys and occupational sources (WHO, 2014). This section of the report outlines the findings of selected studies undertaken in various African countries on sources of, and exposure to, lead in various population groups, in order to paint a picture of the range of sources of lead, to which African children may be exposed, often simultaneously. Annexure 1 to this report, tabulates African studies of lead exposure and poisoning, though the list is not exhaustive.

Figure 5 Lead exposure as a public health concern in countries of the WHO-AFRICAN REGION: SELF ASSESSMENT (Source: WHO, 2014)



Petrol

Since January 2006 the majority of African countries no longer make leaded petrol available to the general public. The cessation of the use of leaded petrol in Africa, and most of the rest of the world, constitutes a major milestone that will reap public health and social benefits for generations to come (leaded fuel may however still be available for aviation purposes). Studies in Africa have shown that past use of leaded petrol predisposed children living or attending schools in close proximity to heavily trafficked roads to elevated blood lead levels (von Schirnding et al., 1991a; von Schirnding et al., 1991b). Epidemiological studies conducted in the 1980s and early 1990s in South Africa (a period in which petrol lead concentrations in the country were amongst the highest in the world) showed that large proportions of urban children especially, were at risk of excessive exposure to environmental lead.

In 1991, when the maximum permissible petrol lead concentration in South Africa country equalled 0.4 g/L, blood lead levels among children attending inner city schools in Cape Town averaged around 16 µg/dl, and more than 90% of children had blood lead levels above 10 µg/dl (the level widely regarded as an action level at the time, but which has since been replaced with lower reference levels (Betts, 2012)). Socio economic status, housing conditions, and proximity of children's schools and homes to heavily trafficked roads were among the factors significantly associated with elevated blood lead levels. In 1996, unleaded petrol was partially introduced in South Africa. Four years later, when unleaded petrol constituted around 30% of the market share of petrol in the country, a study undertaken at the same schools as in 1991, indicated significant reductions in the mean blood lead concentration, and in the proportion of children with blood lead levels of 10 µg/dl or higher. The 2002 follow up study of 429 first grade children (mean age equalled 7 years) showed that the mean blood lead level had dropped to 6.4 µg/dl, and that 10% of children had blood lead levels equalling or exceeding 10 µg/dl. Differences in blood lead levels persisted however across suburbs with varying levels of traffic. For example, the mean blood lead level among children attending school in a busy inner city Cape Town area was 6.9 µg/dL, while that in a relatively low traffic suburb was 4.8 µg/dL (Mathee et al., 2006).

Similarly in Gaborone (Botswana), a blood lead survey conducted among children under the age of 7 years, showed that blood lead levels ranged from 1.6 to 28.6 µg/dl, and that 31% of the children had blood lead levels exceeding 10 µg/dl. Children who lived in close proximity to busy roads were at particular risk of having elevated blood lead levels (Mbongwe et al., 2010).

The phase-out of leaded petrol across large sections of the African Region has been an important step in reducing the risk of exposure to environmental lead amongst the continent's children, and thus constitutes a major public health achievement.

Lead in Paint

Awareness of the toxicity of lead, including in paint, goes back decades. Historically lead poisoning was referred to as painter's colic or painter's palsy, and there is an old saying "crazy as a painter" referring to the strange and manic behaviour of lead-poisoned painters. Famous artists such as Goya and van Gogh are thought to have suffered from lead poisoning (Montes-Santiago, 2006).

Since the phase-out of leaded petrol in 2006 in most parts of the world, lead paint has emerged to be one of the most important sources of public exposure to lead, especially among children. Lead has been added to paint for many decades, to provide colour, increase paint's durability, as well as to reduce the drying time. Since lead is not bio-degradable, leaded paint can remain a source of exposure to lead, and lead poisoning, for many decades after application to surfaces in homes, schools, playgrounds and other settings. With the passage of time, and the deterioration or weathering of lead-based residential paint, lead particles may be released, resulting in elevated lead levels in house dust and garden soil. Home dust and soil levels may become particularly elevated during and after periods of renovation or refurbishment. Young children, who spend considerable amounts of their time crawling or playing on the ground, or who display pronounced mouthing behaviour or pica, are at particular risk of lead exposure.

Given the high cost and challenges of safely removing lead paint from homes and schools in Africa, the most prudent and cost-efficient way to protect children is to prevent its use in the first place. In this light, it is of concern that African countries have lagged behind others in controlling the lead content of paint (Mathee et al., 2007). In the USA and some European countries for example, the use of lead in paint was regulated in the 1970s. By contrast, legislative controls, or the fastidious implementation thereof, appears to be absent in the majority of African countries. Recent studies indicate the availability of paint, in some instances with extremely high lead concentrations in a range of African countries, including Côte d'Ivoire, Ethiopia, Ghana, Cameroon, Nigeria and South Africa (Clark 2009; UNEP, 2013). Studies of new enamel paint in South Africa indicated lead levels up to 189 000 ppm (compared to the current recommended maxima which range from 90 to 600 ppm in several countries) in 83% of samples tested. Warnings of the high lead content of paints were seldom visible on paint cans (Mathee et al., 2007).

Paint Lead Levels in African Homes

Lead paint has been applied to a range of surfaces in settings that may put children at risk of lead exposure, including in schools, homes, playgrounds, educational equipment and toys (Mathee et al., 2007). For example, a study of levels of lead in dwellings across the city of Johannesburg, South Africa, showed that 20% of the homes sampled had lead-based paint. Lead based paint was found across the socio-economic spectrum, and in old, as well as new, homes, indicating the ongoing use of lead paint (Montgomery and Mathee, 2005).

In 2002, during a survey of blood lead levels in 383 grade 1 children attending schools in the Johannesburg suburbs of Alexandra, Soweto and Riverlea, a 7-year old girl was found to have a blood lead level of 44.4 µg/dl, which was considerably higher than the sample mean of 9.4 µg/dl. When the analysis was repeated a month later, her blood lead concentration was found to equal 52 µg/dl. During a subsequent home investigation it was revealed that the girl had a severe pica habit, and was often observed to ingest soil and paint from inside the family apartment. Analysis of water, soil and paint samples pointed to paint as being the main source of lead. Highly elevated paint lead levels were found in paint collected from her home, as well as her school, where she had also reportedly ingested paint chips. This case led to a series of further investigations being undertaken by the research team, which eventually culminated in the promulgation of regulations to control the use of lead paint in South Africa (Mathee et al., 2003).

REGULATION OF THE LEAD CONTENT OF PAINT IN SOUTH AFRICA

After investigations showed that large numbers of South African children were being exposed to lead in paint applied to homes, schools, playground equipment and toys, the South African National Department of Health introduced regulations to control the use of lead in paint in the country. The regulations, which stipulate that the maximum permissible lead level of paint intended for use by the general public should be limited to 600 ppm, came into effect in 2010.

While the promulgation of regulations to control the use of lead in paint in South Africa was a major step towards improved childhood lead poisoning prevention, few investigations have been undertaken to monitor compliance in South Africa, and to take action against paint manufacturers who flout the new laws. In this light, the new regulations may not be fully realizing their potential to prevent lead exposure and poisoning in the country, especially amongst children.

In a study of the lead levels in paint collected from residential, commercial, church and school buildings in Nigeria, residential paints were shown to have the highest lead levels. It was also noteworthy that paint lead levels decreased with the age of the building. Thus in the City of Aga, relatively new commercial buildings (aged 5 to 10 years) had the highest paint lead levels (Nduka et al, 2008). Also in Nigeria, a further study of new enamel paints showed that 96% of paint samples collected in Nigeria had levels that exceeded 600 ppm (the mean level was 15 750 ppm) (Clark et al., 2009).

Lead Paint on Toys

Paint chips or flakes may be dislodged from toys during handling or play. It is therefore a major concern that lead paint has been applied to children's toys in several parts of the world. Children with pronounced mouthing behavior, or with pica, are at particular risk. In 2008 Schmidt reported the recall of millions of toys exported from China to the USA due to the paint lead content (Schmidt, 2008). In a survey of 1200 children's products, 35% were found to contain lead. Around 17% had lead levels exceeding 600 ppm (Schmidt, 2008).

A small screening study of children's toys in South Africa showed lead levels up to 145 000 ppm in the applied paint. The toys had been purchased from major toy stores, supermarkets, stationery stores and flea markets, and were of local as well as international origin (Mathee et al., 2007). High levels of lead have also been found in children's jewelry imported in the USA (Schmidt, 2008).

Lead Paint on Playground Equipment

Lead paint has been applied to playground equipment in many parts of the world. As the lead paint decays it may result in elevated soil lead concentrations in the vicinity of play infrastructure (Takaoka et al, 2006), and pose a serious risk of lead poisoning to children with pica for paint or soil (Moore et al, 1995). A study of the lead content of paint applied to playground equipment in and around Johannesburg was undertaken in 2008. In the 49 play parks included in the study, paint lead levels (measured using a Niton X-ray fluorescence analyser) ranged up to 10.4 mg/cm2. Forty eight percent of the measurements exceeded the reference level of 1 mg/cm2 in force at the time, and lead paint was found in 96% of the parks studied (Mathee et al., 2009).

The elimination of lead paint is a high priority for children's environmental health. Since a relatively small number of companies (some of which are international companies) constitute a large market share of paint in most African countries, the regulation of the lead content of paint in Africa could be achieved with relative ease, with the guidance and support from initiatives such as the Lead Paint Alliance.

Occupational Exposure to Lead

Protective measures, such as legislation, enforcement capacity, safety gear, monitoring and surveillance initiatives and awareness programmes, which are usually strictly enforced in developed countries to prevent occupational exposure to lead, are often absent or weakly enforced in many African countries. Limited awareness of the hazards of lead may underlie risky behaviour in the workplace, such as eating, drinking and smoking in lead exposed workplace settings, and limited hand washing (Adela et al., 2012). Poor workplace practices in lead-related occupations may also pose a risk of lead exposure to the children and families of workers, since lead particles may be transferred from work to home via workers' hair, skin, clothing, footwear and vehicles (Knishkowy & Baker, 1986).

• *Automotive Garage Workers*

Working in automotive garages may involve spray painting, soldering, welding and mechanical work, all of which are associated with lead exposure. For example, spray paint and certain lubricants and grease, may contain lead (Clausen & Rastogi, 1977). A study of garage workers in the town of Jimma, Ethiopia, showed blood lead levels ranging from 11.7 to 36.5 µg/dl, which were significantly elevated compared to a control group. Blood lead levels tended to be highest in those who had worked at the garage for the longest time, and in those who chewed "khat" (a plant whose leaves are widely chewed in the region for its stimulating effect) (Adela et al., 2012). Khat chewers in service for three years had blood lead levels 61% higher than non-chewers over the same period of service.

Table 3 Blood lead levels of the garage workers and controls (adapted from Adela et al, 2012)

	Mean blood lead level (SD)	Range	% with blood lead levels > 10 µg/dl
Garage workers	19.8 (4.46)	11.7 to 36.5	100
Control group	10.7 (2.22)	5.6 to 15.6	56

A study carried out in automotive workshops in four towns in Osun State, Nigeria, found that elevated soil lead levels were widespread (Abidemi, 2011), with the highest lead levels found around an automotive welding facility.

Table 4 Concentration of Pb levels in soil of automotive workshops in four towns in Osun State, Nigeria (adapted from Abidemi, 2011)

Town	Type of facility	Mean soil lead level (mg/kg)	Standard deviation
Osogbo	Auto-mechanic	703	25
Ikirun	Auto-electrical	325	10
Iragbiji	Auto-electrical	1068	10
Iree	Auto welding	2460	16

• *Mining*

Mining is an important economic activity, but also a major source of environmental pollution in Africa, particularly in southern Africa. In their struggle to earn a living through mining, in both the formal and informal sectors, many African communities have become highly exposed to lead. Some of the worst incidents of lead poisoning in the world have occurred around African mining sites, including Zamfara (Nigeria) (CDC 2010; Dooyema et al, 2012; Greig et

International Action to Eliminate Lead in Paint | Lead Paint Alliance

In 2002, at the World Summit on Sustainable Development (WSSD) held in Johannesburg, South Africa, nations agreed to phase out lead. The United Nations Environment Programme (UNEP) and the World Health Organization (WHO) were invited to establish a global alliance to promote phasing out the use of lead in paints, to be called the Global Alliance to Eliminate Lead Paint (Lead Paint Alliance). The Lead Paint Alliance's broad objective is to promote a phase-out of the manufacture and sale of paints containing lead and to eventually eliminate the risks that such paints pose. Substitutes for lead paint are cost effective and relatively easy to obtain, and have been used in many countries for decades. They have proven to be viable, cost- effective alternatives to lead paint. Establishing legal limits on lead in new paint has been shown to be an effective tool to decrease the sale and use of lead paint, and this is currently an important focus of the Lead Paint Alliance's initiatives.

al., 2014; Plumlee et al., 2013) and Kabwe (Zambia) (CDC, 2014; Yabe et al., 2015).

• *Aggeneys, South Africa*

The town of Aggeneys, located in the far north-western 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 young school children in Aggeneys, and in the comparison non-mining town of Pella, around 40 kilometres 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, compared to 13 µg/dl in Pella. 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).

• *Zamfara, Nigeria*

Zamfara State, in north western Nigeria, has become synonymous with rich gold deposits as well as one of the worst outbreaks of lead poisoning in world history. Zamfara is characterised by a high level of artisanal gold mining. However the gold ore in Zamfara is particularly rich in lead (Plumlee et al, 2013). In May 2010, a team of doctors from Medicines Sans Frontiers brought to light a high number of child deaths from lead poisoning in Zamfara State villages where artisanal gold mining was practiced. A subsequent study conducted by a group of international and national experts involved the administration of a cross-sectional, door-to-door questionnaire in two affected villages (CDC, 2010). Blood samples were collected from children, and soil samples taken from dwellings for lead content analysis. The results showed that 25% of children under the age of five years had died in the previous year (other investigations have revealed that well over 400 children in the area had died from lead poisoning). Most children had experienced convulsions prior to death. Among 204 children on whom blood lead tests were undertaken, all had blood lead levels exceeding 10 µg/dl, and 97% had blood lead levels ≥45 µg/dL (the level at which the initiation of chelation therapy is usually advised). Statistical analyses pointed to involvement in ore processing activities and high soil lead levels around the dwelling as being significantly associated with elevated blood lead levels (CDC, 2010; Dooyema et al., 2012; Greig et al., 2014).

• *Kabwe, Zambia*

The town of Kabwe, in Zambia, is built around a decommissioned lead-zinc mine and a smelter, which operated between 1902 and 1994, with little regard for environmental and public health. The closure of the mine was effected without any precautions being taken to protect the local population against environmental lead hazards or provisions for decontamination. In this highly impoverished area, people continue to sift through the contaminated soil searching for lead nuggets to sell, and children play in the soil and bathe in the stream running from the mine through the centre of the local town (Blacksmith Institute, 2015). Kabwe has been described as counting amongst the top ten most contaminated sites in the world (Blacksmith Institute; 2013). For example, soil lead levels ranging from 9 to 51 188 mg/kg have been measured in the surrounding areas (Nakayama et al., 2011).

In 2012, a study of 246 Kabwe children under the age of 7 years showed alarmingly high blood lead levels, ranging from 5.4 to 427.8 µg/dl. The median levels in the three study towns of Chowa, Mukulu and Kasanda respectively equalled 39.3 µg/dl, 57.1 µg/dl and 82.2 µg/dl. In Chowa, Mukulu and Kasanda respectively 18%, 25% and 57% of children had blood lead levels that exceeded 65 µg/dl. The highest blood lead levels were found in children under the age of two years (Yabe et al., 2015). Elevated lead levels have also been found in livestock in Kabwe relative to neighbouring towns. Free range chickens from Kabwe showed higher levels of lead than commercially available counterparts (Yabe et al, 2013).

Cottage Industries/Informal Sector

It is estimated that between 2005 and 2010, two thirds of employment opportunities in Africa were in the informal economy (Charmes, 2012). Cottage industries constitute a sub-group within the informal economy usually involving small enterprises in which one or more members of a family or household work from the home setting. When hazardous substances are used in cottage industries, all members of the family may be exposed. Cottage industries associated with subsistence fishing, battery recycling, electrical repairs and jewellery for example, may cause lead exposure amongst all who reside in (or close to) the home (even if they are not directly involved in the work/industry). Women, young children and those with pre-existing ill health conditions, who spend a considerable portion of their days in the home setting, may be particularly vulnerable. Lead exposure in cottage industries may be worsened by limited knowledge and awareness of the associated risks (Teare et al., 2015). A study undertaken in five settings of poverty in Johannesburg showed that in certain neighbourhoods, as many as 37% of households operated one or more cottage industries, many of which involved the use of lead (Teare et al., 2015).

• *Subsistence Fishing in South Africa*

In African subsistence fishing communities (as well as amongst recreational fisher folk) the practice of melting lead to craft fishing sinkers is widespread. A study undertaken in two remote fishing villages in South Africa in 2012 showed that 18% of households had a member who regularly melted lead. Lead collected from the shoreline (lost fishing sinkers), from wheel and tyre centres and from metal recycling depots, was usually melted in the yard of the dwelling, or inside the home. Children in 11% of households usually watched as lead was being melted, and 4% of children had themselves melted lead. In two households (n = 160) a member had accidentally swallowed a lead sinker (6% of children had been observed to place lead sinkers in their mouths), and one had been burned by molten lead. Only 20% of the study respondents were aware of the health hazards of lead (Mathee et al., 2013).

Blood lead levels in the study children, who were in grades 0, 1 and 2 (their ages ranged from 6 to 14 years, with the mean age being 7.5 years), ranged from 2.2 to 22.4 µg/dl, with the mean level being 6.9 µg/dl. Nearly three quarters of the children studied had blood lead levels of 5 µg/dl or higher (the current reference level in the USA - (Betts, 2012). Further details of the blood lead distribution is given in the table below.

Table 5

Blood lead distribution by town (µg/dl)

Town	Geometric Mean (95% CI)	Median	Range	% > 5 µg/dl	% > 10 µg/dl
Struis Bay	6.5 (5.83 ; 7.13)	6.1	2.2 to 17.8	71.6	9.9
Elands Bay	8.2 (7.29 ; 9.19)	7.2	2.4 to 22.4	76.0	21.5
Total	6.9	6.1	2.2 to 22.4	73.8	15.6

• Recycling of Batteries in the Informal Sector

The manufacture of batteries accounts for approximately 80% of lead mined in the world (van der Kuijp, 2013). Lead acid batteries are used in automobiles, electric bikes and solar panels, amongst other products (Were, 2012; van der Kuijp, 2013). Some African countries have no workplace regulations to minimize lead exposure and protect the health of workers (Adela et al 2012). Elevated air lead levels have been found in Kenyan battery manufacturing plants and concomitant, elevated blood lead levels in workers (Were et al, 2012). Were et al also showed that blood lead levels were higher among workers involved in battery recycling relative to battery manufacture. Furthermore, the study revealed elevated air lead levels in settings in which scrap metal, welding and paint industries were being undertaken. Elevated blood lead levels in battery plant workers were associated with hypertension and increased plasma cholesterol levels (Ademuyiwa, 2005).

A 1998 study of South African battery plant workers found an exposure-response relationship between blood lead levels and renal function (Ehrlich et al, 1998), evident from 40 to 50 µg/dl. New workplace lead regulations were promulgated in South Africa in 2002, addressing aspects such as exhaust ventilation systems, worker education, personal protective equipment and health surveillance (Dyosi, 2007).

Lead used in car batteries generates a huge amount of lead waste across the globe (Haefliger et al., 2009). In the neighbourhood of Thiaroye Sur Mer (population approximately 100 000), located on the outskirts of Dakar, Senegal, the main economic activity over several years, has been the informal recycling of lead-acid batteries. As is typical of many informal sector industries in Africa, the practice was unregulated, and usually undertaken in open-air settings. Over time, levels of lead in the soil escalated. Following a steep rise in the price of lead, and with growing prospects of relatively high incomes, residents started collecting bags of soil from contaminated areas, and carting them home. At home, people, mainly women, would sift through the soil to collect lead fragments, often in the presence of children.

In 2007/8 at least 18 neighbourhood children died from a disease of the central nervous system. Initially the diagnoses included cholera, meningitis and cerebral malaria. Lead poisoning was diagnosed after the realisation that the mothers of several of the children were involved in the recycling of used lead-acid batteries. A study conducted on the siblings and mothers (n = 81) of the deceased children showed that blood lead levels were highly elevated. Among 50 children studied, blood lead levels ranged from 39.8 to 613.9 µg/dl, with the mean level equalling 129.5 µg/dl (Haefliger et al., 2009)

• *E-waste*

It is estimated that around 20 to 25 million tons of electronic waste (e-waste) is produced annually in the United States, Europe and Australasia (Robinson, 2009), and transported to developing countries, mainly Africa and Asia (Nnorom and Osibanjo, 2008). E-waste consists of discarded electrical and electronic products, and includes television sets, computers microwave ovens, cameras, mobile telephones, printers and audio equipment (Frazzoli et al, 2010). In 2005 the Basel Action Plan (BAN) reported that more than 500 shipping containers of used electronic and computer waste entered Africa through Lagos, Nigeria on a monthly basis. According to the Nigeria Computer Dealers Association, around three quarters of this equipment is considered unusable (BAN, 2005). E-waste contains a range of metals such as copper and gold, which are targeted for extraction and recycling (Robinson, 2009). For example, one metric ton of computer waste may contain more gold than 17 tons of gold ore (Khaliq et al, 2014).

Lead is contained in certain types of e-waste, especially small electrical and electronic equipment – up to a weight of approximately 2.9 g/kg (Morf et al, 2007). During informal recycling activities, crude methods, such as open pit acid baths, may be used to recover lead and other metals. The process usually also incorporates open burning to reduce the volume of waste such as plastics, as well as for metal recovery. For example plastic-coated cables may be burned to extract copper (Frazzoli et al, 2010). Apart from toxic metals, those involved in e-waste recycling may thus also be exposed to particulate matter and polychlorinated biphenyls (PCBs), which may also contaminate surrounding soil, food sources and surface water (Nnorom and Osibanjo, 2008).

In 2013, Olafisoye et al. conducted a study to investigate toxic metal pollution in and around Alaba International Market, Nigeria's largest e-waste site. Samples of soil, water and plant material were collected for metal content analysis. The results showed elevated levels of lead, which declined with soil depth and distance from the e-waste site. Agbogbloshie is the largest e-waste recycling site in the world, and also counts among the ten most polluted places on earth (Blacksmith Institute, 2013). A health study undertaken amongst Agbogbloshie workers revealed highly elevated urinary lead levels (Asante et al, 2012). A further study showed very high lead levels in soil and ash sampled from open burning sites in Agbogbloshie (up to 14 000 mg/kg) (Song et al, 2009).

• *African Traditional Brews*

Traditional, home-brewed alcoholic drinks are popular in many African cultures (Mosha 1996). Home brews are usually made from fermented products, but various formulations may include additional constituents, some of which may have harmful health effects. A detailed study of the methods and ingredients used in making of Khadi, a popular traditional African beer in Botswana, has been conducted. It was found that in some instances, the contents of lead acid batteries were being added to enhance potency (Pitso, 2006). It has also been shown that high temperature processing, elevated acidity and prolonged storage in metal containers may contribute to the highly elevated levels of lead in certain African beers (Mosha et al, 1996). An analysis of a range of traditional beers in Dar es Salaam, Tanzania, revealed lead levels ranging from 0 to 0.82 ppm (Mosha et al., 1996).

• *Traditional Medicines*

In September 2012, the South African 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 (Mathee et al, 2015). The product had been imported into South Africa from India via an internet supplier, 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 and other African countries in this regard.

• *Cultural or Traditional Practices (Geophagia)*

Geophagia (the deliberate ingestion of soil) is defined as a form of pica, and has been known for centuries. The motivations for practising geophagia are poorly understood, but amongst the reasons postulated are religious beliefs, cultural, nutritional and medicinal practices, as well as famine, perceived enhancement of appearance and pregnancy-related cravings. In a study undertaken in Dar es Salaam (Tanzania) around 64% of pregnant and breastfeeding women had pica, with soil being the most common substance ingested (Nyaruhucha, 2009), while 74% in a group of pregnant women from Nairobi (Kenya), reported the habit (Ngozi, 2008). Ingestion of soil has also been shown to interfere with the bioavailability of micronutrients (leading to micronutrient deficiencies), geohelminthic infections, anaemia, hypokalaemia, peritoneal mesothelioma and intestinal obstruction or perforation (Thihalolipavan et al., 2013; Klitzman et al., 2002; Abrahams et al., 2006). Geophageous behaviour may increase exposure to metal contaminants in the soil, including arsenic and lead. In a study undertaken in the City of New York, women with pica were shown to have higher blood lead levels compared to their counterparts who did not practise pica (Thihalolipavan, 2013). In a cross-sectional study of 307 pregnant women, 23% reported practising pica, with 20% ingesting soil specifically. Geophagic women had significantly elevated blood lead levels and lower haemoglobin levels compared to non-geophagic women. At the 5% level of significance, anaemia (haemoglobin levels < 10 g/dl), craving of non-nutritive substances in a previous pregnancy and geophagia practices were associated with elevated blood lead levels.

• *The Use of Lead in Cosmetics – Port Harcourt, Nigeria*

A study of a range of cosmetic products available in the City of Port Harcourt (Nigeria) indicated a potential public health concern in some items, with lead levels exceeding international guidelines being found (Orisakwe and Otaraku, 2013). In 2011 during a routine clinic visit in Boston in the United States of America (USA), a 6-month old infant of Nigerian descent was found to have a blood lead level of 13 µg/dl. Further investigations pointed to tiro as the source of lead. Tiro, a Nigerian cosmetic and folk remedy which had been acquired from a street vendor in the City of Ilorin, Kwara State, Nigeria, had been applied to the baby's eyes since the age of two weeks. Laboratory analysis of the tiro revealed a lead content of 82.6%. Tiro is similar to "surma" in Asia and kohl in the Middle East, which have also been implicated in cases of lead exposure and poisoning (CDC 2012).

Hobbies/Recreation

• *Recreational Shooters*

Preliminary results from a study currently underway at several shooting ranges and archery centres in Johannesburg are 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). There were also concerns regarding poor hygiene and safety practices at the shooting ranges, such as eating and drinking within shooting areas, including amongst child users of the shooting ranges.

Lead in Food

Food, soil and dust account for more than 80% of lead ingested on a daily basis (WHO, 2010). The range and nature of lead sources in the surroundings determine the amount of lead in soil and plants, with some of the highest levels found around mines and smelters. Food, including staple foods such as fish and spinach, has been determined to be a pathway of exposure to lead in a range of African settings (Makokha et al., 2008; Omwenga et al., 2014; Ombaka, 2014).

A study undertaken in Cameroon showed that lead exposure could occur from the use of artisanal cookware. Amongst the materials used to produce cookware were scrap metals from engine parts, radiators, cans, and construction materials. While the lead content of the cookware was relatively low, use of the pots and pans for cooking resulted in exposures as high as 260 µg of lead per serving. Given the widespread nature, and high frequency of use of artisanal cookware in certain communities, the public health impact could be significant (Weidenhamer et al., 2014).

Lead soldered food cans may contribute significantly to food lead levels, especially in acidic food and drinks. Alcoholic drinks tend to be acidic, and contact with lead-containing packaging or products used in their manufacture may cause leaching of lead into the drinks. The smoking of tobacco is also associated with increased lead intake (WHO, 2010).

5 DISCUSSION

This report gives an outline of the broad range of sources of lead to which African communities continue to be exposed. The health risks and the vulnerability of children, in particular, to lead exposure and poisoning, have been summarized. Detrimental health effects have been shown at high, as well as very low levels of exposure to lead. There is now widespread consensus, that even at low levels of lead exposure, consequences such as reductions in intelligence scores and learning problems, socio-behavioural problems such as aggression and delinquency, and effects such as hearing loss ensue. The implications for the individual and society are enormous, and include lowered educational attainment, lowered lifetime earnings and achievement, as well as sub-optimal economic prospects at community level. A recent health economic study conservatively estimated that annually, around 98.2 million IQ points are lost in Africa due to lead exposure, translating into economic losses of US$ 134.7 billion. These losses in economic productivity did not include the economic impact associated with the role lead plays in other outcomes such as cardiac disease and violence (Attina and Trasande, 2013).

Extracting from selected publications, the report outlines the ongoing lead exposure situation from various sources in a range of African countries. It can be seen that African children continue to be exposed to lead from multiple sources, often simultaneously.

Thus recent studies document lead exposure in the African populace from, amongst other sources, mining, cottage industries, petrol, paint, battery manufacture and recycling, lead melting in subsistence fishing industries, traditional medicines, the use of lead ammunition, application of cosmetics, such as tiro, and e-waste. Since this work did not involve the conduct of an exhaustive literature review, and because there is a dearth of research on lead exposure in Africa, it is likely that further sources of lead exposure exist. Poverty is a key determinant of lead exposure and poisoning in African children, as powerfully and tragically illustrated in the artisanal mining settings of Zamfara State, Nigeria, and Kabwe, Zambia.

Despite knowledge of the ongoing exposure to, and detrimental health and socio-behavioural consequences of, lead, preventative action has been slow. Evidence of the harmful effects of lead exposure was established in the latter part of the nineteenth century, leading the United Kingdom to act to protect workers in lead industries. Childhood poisoning from lead paint was first noticed in Australia in 1892, but the Australian Lead Paint Prevention Act was only passed in 1920. In the USA legislation to control the use of lead in paint was enacted in the 1970s. Despite research evidence demonstrating extremely high levels of lead in paint, many African countries still do not have regulations in place to control this important public health hazard (Clarke et al, 2009; Mathee et al, 2007; UNEP, 2013).

In recent decades measures to control and prevent lead exposure have been a priority in well-resourced parts of the world. These include international conventions to protect the rights of children, including protections against lead exposure, and laws and regulations controlling lead use in paint and petrol (Tong et al., 2000). In the USA there are programmes specifically aimed at reducing lead exposure such as the US Department of Housing and Urban Development (HUD) Lead-Based Paint Hazard Control Grant Program. Six years after commencing this intervention an evaluation showed that dust lead levels decreased by 75% in homes (Wilson et al., 2006). Blood lead standards for children were set, and have been incrementally lowered over time. Screening, intervention and evaluation was conducted country-wide until average blood lead levels dropped, and now only high risk populations are routinely screened. National educational awareness initiatives are still in place in the USA.

Comprehensive action to protect people on the African continent against lead exposure has unfortunately been particularly patchy, and has lagged behind other regions. Most African countries discontinued the use of lead in petrol only in 2006, compared to the 1970s in the USA and several European countries). Protective measures have been put in place in some parts of Africa, but they do not always keep abreast of international trends and progress. Occupational blood lead standards for workers in developing countries for example, are often not as stringent as in developed countries.

Lead exposure reduction efforts in Africa may face complex challenges and obstacles. A strategy to address lead exposure in Africa will have to grapple with a broad array of sources of lead in African countries, in the formal as well as informal sectors. In some African settings lead exposure is life threatening, and requires urgent intervention. Artisanal mining for example has been associated with two of the worst lead poisoning episodes in history in Kabwe, Zambia and Zamfara State in Nigeria, where it resulted in the deaths of hundreds of children in recent years. Lead poisoning from the informal dismantling of batteries in a suburb of Dakar, Senegal, has also resulted in child deaths. Numerous studies have pointed to para-occupational exposure in the families of those who work in mines and other settings where lead is used, such as battery manufacturing and recycling plants. Even in such high risk settings, key programmes such as blood lead screening are often non-existent, as are lead hazard education programmes and materials. Lead-related cottage industries, which are often concealed from occupational or environmental health scrutiny, will require special attention and innovative thinking. Widespread and severe poverty is a major impediment to the prevention of lead poisoning, with the need to generate an income often overwhelming environmental health considerations.

Alongside action to address severe lead poisoning outbreaks, there is a simultaneous need for programmes in African countries to address chronic, low levels of lead exposure in children, as well as adults. The following may form the foundation for such national lead poisoning prevention programmes in African countries:

- Establishment of lead poisoning prevention offices, programmes or focal points in all African countries;
- Research and surveillance to identify high risk settings and groups (for example around mining sites, in neighbourhoods with a high prevalence of cottage industries, coastal and inland subsistence fishing communities, pregnant women who practise geophagia, users of lead ammunition (both occupational and recreational), and users of contaminated traditional medicines);
- Blood lead screening, especially in high risk settings and groups;
- Development of policies and legislation to prohibit the use of lead in paint (and other sources), and the enforcement of such legislation;
- Setting of standards and guidelines for blood lead levels in children, pregnant women and adults;
- Development of protocols to respond to cases of lead poisoning;
- High-profile and comprehensive public education programmes on the sources, pathways of exposure and health hazards of lead. Amongst the target groups for education programmes could be school children, those attending ante-natal and child health clinics, those working in lead-related industries (especially in cottage industries). There is also a need for greater awareness amongst health personnel of the sources and pathways of exposure to lead (for example some traditional medicines and cottage industries);
- Participation in national and international partnerships, and expert networks, to share experiences and best practices.

CONCLUSIONS AND RECOMMENDATIONS FOR ACTION

Lead exposure is a major public health concern in virtually all African countries. Addressing lead exposure in Africa is a complex challenge, since communities are often exposed, simultaneously (Tong et al., 2000) to multiple sources of lead, and poverty is a key factor underlying much of the lead exposure scenario in Africa. Many lead exposure reduction targets are therefore realisable only in the longer term.

Where lead-related legislative controls exist, the enforcement capacity is often limited.

The phase-out of leaded petrol in most African countries in 2006 constituted a major public health milestone, with studies indicating concomitant reductions in child blood lead levels. Growing momentum to curb the use of lead in paint, in which the WHO/UNEP-led Lead Paint Alliance is playing a key role, is also very encouraging. African Ministers of Health and Environment, in the Luanda Commitment of November, 2010, have already highlighted their "concerns over the adverse effects on human health and the environment from the use, disposal of and exposure to hazardous chemicals and wastes which pose a major challenge for many African governments". The Luanda Commitment paves the way for the development of a concerted programme of action for the Prevention of Lead Poisoning in African countries. Urgent, comprehensive and sustained action to prevent lead exposure and poisoning will reap huge, and much needed, health, social and economic benefits for African countries, and should therefore be implemented without delay.

Conflict of Interest Statement

The authors declare no conflicts of interest.

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APPENDIX 1 A COMPILATION OF SELECTED STUDIES OF LEAD EXPOSURE IN AFRICAN COUNTRIES

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Algeria	Environment -air pollution	2011	Inhalation	Analysis of tree pine needles	NA	NA	Aissa & Kéloufi. Determining the heavy metal pollution in Mascara (Algeria) by using Casuarina equisetifolia. Ecologia Balkanica 2012;4:1-7.
Algeria	Food -fruit -vegetables	2012	Ingestion	Consumers	843	0	Cherfi et al. Food survey: Levels and potential health risks of chromium, lead, zinc and copper content in fruits and vegetables consumed in Algeria. Food and Chemical Toxicology 2014;70:48-53.
Algeria	Soil -industrial	NS	Inhalation	Soil and vegetation analysis	NA	NA	Benselhoub et al. Bioecological assessment of soil pollution with heavy metals in Annaba (Algeria). Vasile Goldis University Press 2015;25:17-22.
Angola	Environment -Street dust	2002	Inhalation	Street dust analysis	NA	NA	Ferriera-Baptista & Miguel. Geochemistry and risk assessment of street dust in Luanda, Angola: A tropical urban environment. Atmospheric Environvironment 2005;39:4501-4512.
Benin	Traditional medicine	2012-2013	Ingestion	Analysis of Moringa oleifera (also known as the drumstick tree) leaf powders	NA	NA	Aissi et al. Evaluation of toxicological risk related to presence of lead and cadmium in Moringa oleifera Lam. leaves powders marketed in Cotonou (Benin). Food and Nutrition Sciences 2014;5:770-778.
Benin		2006	Ingestion	Analysis of giant snail tissue	NA	NA	Edorh et al. An assessment of the contamination of Achatina achatina by toxic metals in Okpara village (Benin). International Journal of Biological and Chemical Sciences 2009;3:1428-1436.
Benin	Food -fish	2010	Ingestion	Analysis of fish from Lake Nokoué	NA	NA	Hounkpatin et al. Assessment of exposure risk of lead and cadmium via fish consumption in the lacustrine village of Ganvié in Benin republic. Journal of Environmental Chemistry and Ecotoxicology 2012;4:1-10.
Benin	Food -fish -water -sediment	2010-2012	Ingestion	Analysis of fish, water and sediment from Lake Nokoué and Porto Novo lagoon.	NA	NA	Yehouenou et al. Monitoring of heavy metals in the complex "Nokoué lake-Cotonou and Porto-Novo lagoon" ecosystem during three years in the Republic of Benin. Research Journal of Chemical Sciences 2013;3:12-18.
Benin	Food -vegetables	NS	Ingestion	Irrigation water, soil and vegetable analysis.	NA	NA	Koumolou et al. Health-risk market garden production linked to heavy metals in irrigation water in Benin. Comptes Rendus Biologies 2013;336:278-283.
Benin	Water -borehole	NS	Ingestion	Blood lead analysis and water analysis	25	0	Elegbede et al. Blood lead levels and bio-markers of lead toxicity via the consumption of drinking water in Kerou (Benin) in watershed of the Niger. International Journal of Environmental Protection 2012;2:10-15.
Botswana	Environment -Soil -Paint	NS	Inhalation/ ingestion	Children 1-6 years of age – blood lead analysis and soil-lead analysis	213	0	Mbongwe et al. Exposure to lead among children aged 1-6 years in the city of Gaborone, Botswana. Journal of Environmental Health Research 2010;10:17-26.
Botswana	E-waste	2005	Inhalation	Consumer survey	NA	NA	Mburu & Tuduetso. Investigation of consumer behaviour on discarding of their electrical/ electronic waste: A case of Gaborone city. E3 Journal of Business Management and Economics 2013;4:200-205.
Botswana	Traditional home brews	NS	Ingestion	Ingredients in home brews	NA	NA	Pitso. Field tales of hazardous home brewed alcoholic beverages: the case of Selebi Phikwe, Botswana. African Journal of Drug Alcohol Studies 2006;6:89-103.
Botswana	Traditional medicine	NS	Ingestion	Herbal plant analysis	NA	NA	Okatch et al. Determination of potentially toxic heavy metals in traditionally used medicinal plants for HIV/AIDS opportunistic infections in Ngamiland District in Northern Botswana. Analytica Chimica Acta 2012;730:42-48.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Cameroon	Paint	2012	Ingestion	News report	NA	NA	Pittsburgh Post-Gazette. PPG refuses to recall leaded paint in Cameroon. Available from: http://www.post-gazette.com/news/world/2012/02/06/PPG-refuses-to-recall-leaded-paint-in-Cameroon/stories/201202060268 (accessed 19 August 2015)
Cameroon	Paint	2011	Inhalation/ ingestion	Paint analysis	NA	NA	Gottesfeld et al. Lead concentrations and labelling of new paint in Cameroon. Journal of Occupational and Environmental Hygiene 2013;10:243-249.
Cameroon	Food -cookware	NS	Ingestion	Analysis of cookware and utensils	NA	NA	Weidenhamer et al. Lead exposure from aluminium cookware in Cameroon. Science of the Total Environment 2014;496:339-347.
Chad	Food -edible algae	2006-2009	Ingestion.	Algae analysis	NA	NA	Carcea et al. Nutritional characterization of traditional and improved dihé alimentary blue-green algae from the Lake Chad region in Africa. LWT – Food Science and Technology 2015;62:753-763.
Cote d'Ivoire	Food -Vegetables	2009	Ingestion	Vegetable analysis	NA	NA	Koffi et al. Cadmium and lead levels in some vegetables sold in Abidjan and estimated dietary intakes in the Ivorian adult. Journal of Nutrition and Food Sciences 2013;4:251.
Cote d'Ivoire	Food -Vegetables	2006-2007	Ingestion	Vegetable analysis	NA	NA	Kouakou et al. Level of exposure to trace metals (cadmium, copper, zinc, lead, nickel) of amaranth (Amaranthus paniculatus L.) and lettuce (Lactuva sativa L.) cultivated on market gardens in the city of Abidjan (Abidjan/Ivory Coast. International Journal of Innovation and Applied Studies 2015;10:21-29.
Democratic Republic of Congo	Petrol	NS	Inhalation	Sample population of Kinshasa, 0-70 years of age	485	0	Tuakuila et al. Blood lead levels in the Kinshasa population: a pilot study. Archives of Public Health 2010;68:30-41.
Democratic Republic of Congo	Petrol	2011	Inhalation	Children	100	0	Tuakuila et al. Blood lead levels in children after phase-out of leaded gasoline in Kinshasa, the capital of Democratic Republic of Congo (DRC). Archives of Public Health 2013;71:5.
Democratic Republic of Congo	-Petrol -Battery recycling -Geophagia	ABSTRACT	Inhalation	Urban and rural population	335	0	Tuakuila et al. Elevated blood lead levels and sources of exposure in the population of Kinshasa, the capital of the Democratic Republic of Congo. Journal of Exposure Science and Environmental Epidemiology 2013;23:81-87.
Democratic Republic of Congo	Mining -Copperbelt	NS	Inhalation	Medical students	109	0	Molayi et al. Heavy metal in hair samples of 109 non-industrial (miners) population in Katanga. Sante 2011;21:41-46.
Democratic Republic of Congo	Oil industry	NS	Inhalation/ ingestion	Workers	24	0	Mputu et al. Evaluation of lead occupational exposure in an oil company in Kinshasa. Presented at the 7th International Symposium on Recent Advances in Environmental Health Research. September 12–15, 2010, Jackson, Mississippi.
Ethiopia	Petrol	2004	Inhalation	Analysis of particulate matter	NA	NA	Etyemezian et al. Results from a pilot-scale air quality study in Addis Ababa, Ethiopia. Atmospheric Environment 2005;39:7849-7860.
Ethiopia	Petrol	2008	Inhalation	Analysis of roadside soils	NA	NA	Teju et al. Determination of the levels of lead in the roadside soils of Addis Ababa, Ethiopia. Ethiopian Journal of Science 2012;35:81-94.
Ethiopia	Battery repairs	NS	Inhalation	Adults, 23-57 years	51 (45 male, 6 female)	0	Ahmed et al. Lead exposure study among workers in lead acid battery repair units of transport service enterprises, Addis Ababa, Ethiopia: a cross-sectional study. Journal of Occupational Medicine and Toxicology 2008;3:30.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Ethiopia	Battery charging/ repairs	NS	Inhalation	Male and female adults, 18 to > 46 years of age	15	0	Geleta & Alemu. Assessments of lead toxicity awareness among battery charging garage workers of Jimma Town, southwest, Ethiopia. Journal of Biological and Chemical Research 2014;31:1063-1071.
Ethiopia	Automotive garage	NS	Inhalation/ ingestion	Adult males and one adult female	45	0	Adela et al. Occupational lead exposure among automotive garage workers – a case study for Jimma town, Ethiopia. Journal of Occupational Medicine and Toxicology 2012;7:15.
Ethiopia	Construction	NS	Inhalation	Adult male and female construction workers	45	0	Gebrie et al. Elevated blood lead levels among unskilled contruction workers in Jimma, Ethiopia. Journal of Occupational Medicine and Toxicology 2014;9:12.
Ethiopia	Traditional medicine	NS	Ingestion	Medicinal plant analysis	NA	NA	Baye & Hymete. Lead and cadmium accumulation in Medicinal plants collected from environmentally different sites. Bulletin of Environmental Contamination and Toxicology 2010;84:197-201
Ethiopia	Environment -urban vs. rural	ABSTRACT	Inhalation/ ingestion	Children -Analysis of primary incisor teeth	NS	NS	Tvinnereim et al. Lead levels in primary teeth in children from urban and rural areas in Ethiopia. Ethiopian Medical Journal 2011;49:61-66.
Ethiopia	Food -vegetables	1994	Ingestion	Vegetable analysis	NA	NA	Rahlenbeck et al. Lead and cadmium in Ethiopian vegetables. Bulletin of Environmental Contamination and Toxicology 1999;62:30-33.
Ethiopia	Food -vegetables	1998	Ingestion	Vegetable analysis	NA	NA	Itanna F. Metals in leafy vegetables grown in Addis Ababa and toxicological implications. Ethiopian Journal of Health and Development 2002:16:295-302.
Ethiopia	Food -fruit -vegetables	NS	Ingestion	Fruit and vegetable analysis	NA	NA	Gebrekidan et al. Toxicological assessment of heavy metals accumulated in vegetables and fruits grown in Ginfel River near Sheba Tannery, Tigray, Northern Ethiopia. Ecotoxicology and Environmental Safety 2013;95:171-178.
Ethiopia	Food -fish	2008	Ingestion	Analysis of fish tissues	NA	NA	Dsikowitzky et al. Assessment of heavy metals in water samples and tissues of edible fish species from Awassa and Koka Rift Valley Lakes, Ethiopia. Environmental Monitoring and Assessment 2013;185:3117-3131.
Ghana	Toys	NS	Ingestion	Analysis of new soft plastic toys	NA	NA	Gati et al. Assessment of level of lead and cadmium in selected plastic toys imported from China on the Ghanaian market. Chemistry and Materials Research 2014;6:62-68.
Ghana	Petrol	NS	Inhalation/ ingestion	School age children	100 (50 boys, 50 girls)	0	Golow & Kwaansa-Ansah. Comparison of lead and zinc levels in the hair of pupils from four towns in the Kumasi municipal area of Ghana. Bulletin of Environmental Contamination and Toxicology 1994;53:325-331.
Ghana	Petrol	ABSTRACT	Inhalation	Children 11-15 years	NS	NS	Ankrah et al. Lead exposure in urban and rural school children in Ghana. African Journal of Health Sciences 1998;5:85-88.
Ghana	Petrol	2001	Inhalation	Road dust and roadside soil analysis	NA	NA	Kylander et al. Impact of automobile emissions on the levels of platinum and lead in Accra, Ghana. Journal of Environmental Monitoring 2003;5:91-95.
Ghana	Mining	2009	Inhalation	Males	57	0	Basu et al. Multiple metals exposure in a small-scale artisanal gold mining community. Environmental Research 2011;111:463-467.

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Ghana	Battery recycling, Automobile radiator repair, Construction, Glassworks, Stained glass production, Ceramic pottery.	NS	Inhalation	Child labour	NS	NS	Ide & Parker. Hazardous child labor: Lead and neurocognitive development. Public Health Reports 2005;120:607-613.
Ghana	Lead smelters Auto-mechanics Gasoline retailers	ABSTRACT	Inhalation	Workers	NS	NS	Ankrah et al. Lead levels and related biochemical findings occurring in Ghanaian subjects occupationally exposed to lead. East African Medical Journal 1996;73:375-379.
Ghana	Steel processing plant, Lead battery recycling plant, Mechanic workshop, Waste oil recycling plant, Municipal waste disposal site, Municipal playground, School parks, Schools, Residential facilities, Auto workshops, Scrap yards	NS	Inhalation	Soil analysis	NA	NA	Aboh et al. Assessing levels of lead contamination in soil and predicting pediatric blood lead levels in Tema, Ghana. Journal of Health and Pollution 2013;5:7-12.
Ghana		2008	Inhalation	E-waste workers	NS	NS	Greenpeace International. Report: August 2008. Poisoning the poor: Electronic waste in Ghana. Available from: http://www.greenpeace.org/denmark/Global/denmark/p2/other/report/2008/poisoning-the-poor-electroni.pdf (accessed 02 September, 2015).
Ghana	E-waste -Agbogbloshie	2008	Inhalation	Male e-waste workers	20	0	Asante et al. Multi-trace element levels and arsenic speciation in urine of e-waste recycling workers from Agbogbloshie, Accra in Ghana. Science of the Total Environment 2012;424:63-73.
Ghana	E-waste -Agbogbloshie	2013	Inhalation	General information	NA	NA	Blacksmith Institute. Top Ten Toxic Threats in 2013: Cleanup, progress, and ongoing challenges. Available from: http://www.blacksmithinstitute.org/new-report-cites-the-world-s-worst-polluted-places.html (accessed 30 July 2015).
Ghana	E-waste -Agbogbloshie	2010	Inhalation	Soil/ash analysis	NA		Itai et al. Variation and distribution of metals and metalloids in soil/ash mixtures from Agbogbloshie e-waste recycling site in Accra, Ghana. Science of the Total Environment 2014;470-471:707-716.
Ghana	E-waste -Agbogbloshie	NS	Inhalation	General information	NA		Amankwaa et al. Recyclers at risk? Analysis of E-waste and blood lead levels at Ghana's recycling hub, Agbogbloshie. International Growth Centre (IGC). Available from: http://www.theigc.org/project/recyclers-at-risk-analysis-of-e-waste-and-blood-lead-levels-at-ghanas-recycling-hub-agbogbloshie/

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Ghana	Geophagia	NS	Ingestion	Analysis of clay soil samples	NA		Tayie et al. Geophagia clay soil as a source of mineral nutrients and toxicants. African Journal of Food, Agriculture, Nutrition and Development 2013;13:1-14.
Ghana	Food -domestic and venison liver	NS	Ingestion	Liver tissue analysis	NA		Adei & Forson-Adaboh. Toxic (Pb, Cd, Hg) and essential (Fe, Cu, Zn, Mn) metal content of liver tissue of some domestic and bush animals in Ghana. Food Additives and Contamination: Part B 2008;1:100-105.
Ghana	Food -spices	NS	Ingestion	Analysis of spices	NA		Nkansah & Amoako. Heavy metal content of some common spices available in markets in the Kumasi metropolis of Ghana. American Journal of Scientific and Industrial Research 2010;1:158-163.
Ghana	Food -vegetables	NS	Ingestion	Vegetable analysis	NA		Ackah et al. Uptake of heavy metals by some edible vegetables irrigated using wastewater: a preliminary study in Accra, Ghana. Environmental Monitoring and Assessment 2014;186:621-634.
Ghana	Water -borehole	2004-2005	Ingestion	Water analysis	NA	NA	Obiri. Determination of heavy metals in water from boreholes in Dumasi in the Wassa West District of Western Region of Republic of Ghana. Environmental Monitoring and Assessment 2007;130:455-463.
Ghana	Water -drinking water	2004	Ingestion	Water analysis	NA	NA	Asante et al. Contamination status of arsenic and other trace elements in drinking water and residents from Tarkwa, a historic mining township in Ghana. Chemosphere 2007;66:1513-1522.
Ghana	Water -borehole -tap water -surface water	2008	Ingestion	Water analysis	NA	NA	Obiri et al. Evaluation of lead and mercury neurotoxic health risk by resident children in the Obuasi municipality, Ghana. Environmental Toxicology and Pharmacology 2010;29:209-212.
Ghana	Water -drinking water	NS	Ingestion	Water analysis	NA	NA	Obiri-Danso et al. Effect of agrochemical use on drinking water quality of Agogo, a tomato growing community in Ashanti Akim, Ghana. Bulletin of Environmental Contamination and Toxicology 2011;86:71-77
Ghana	Experimental -rats	NS	Ingestion	Palm oil administered to lead-poisoned rats	NA	NA	Twumasi et al. Treatment of lead-poisoned rats through oral administration of palm oil extracts. African Journal of Biochemistry Research 2014;8:43-51.
Guinea	Geophagia	1993	Ingestion	Children 1-18 years	286	0	Glickman LT, Camara AO, Glickman NW, McCabe GP. Nematode intestinal parasites of children in rural Guinea, Africa: prevalence and relationship to geophagia. International Journal of Epidemiology 1999;28:169-174.
Kenya	Paint	NS	Inhalation/ ingestion	Paint analysis	NA	NA	Nganga C. Lead in Kenyan household paint. IPEN 2012. Available from: http://ipen.org/sites/default/files/documents/Lead%20in%20Kenyan%20Household%20Paint%20Sept.%202012.pdf (accessed 20 August 2015).
Kenya	Paint	NS	Inhalation/ ingestion	Children and pregnant mothers	NA	NA	United Nations Environment Programme (UNEP). Children and pregnant mothers in developing world face widespread exposure to toxic lead in paint. Press release, Nairobi, 22 October 2013. Available from: http://www.unep.org/Documents.Multilingual/Default.asp?DocumentID=2752&ArticleID=9657&l=en (accessed 21 August 2015).

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Kenya	Petrol	2006-2007	Inhalation	Children <6 years	200	0	Were et al. Use of human nails as bio-indicators of heavy metals environmental exposure among school age children in Kenya. Science of the Total Environment 2008;393:376-384.
Kenya	Mining -Migori gold mining belt	NS	Inhalation/ ingestion	Soil and water analysis	NA	NA	Ogola et al. Impact of gold mining on the environment and human health: A case study in the Migori gold belt, Kenya. Environmental Geochemistry and Health 2002;24:141-158.
Kenya	Mining -Migori gold mining belt	NS	Ingestion (via hand washing)	Water analysis	NA	NA	Odumo et al. Energy Dispersive X-ray Fluorescence analysis of mine waters from the Migori gold mining belt in Southern Nyanza, Kenya. Bulletin of Environmental Contaminationand Toxicology 2011;87:260-263.
Kenya	Battery manufacture & recycling	2009-2010	Inhalation	Male workers 21-50 years	NS	NS	Were et al. Air and blood lead levels in lead acid battery recycling and manufacturing plants in Kenya. Journal of Occupational and Environmental Hygiene 2012;9:340-344.
Kenya	Battery recycling	NS	Inhalation	Dust wipe samples taken at Owino-Uhuru informal settlement (houses, a nursery school, a playground, and vegetable garden) for analysis	3 children diagnosed with lead poisoning prior to study	NA	Kamonji F. Lead poisoning from used lead acid battery recycling: A case study of Owino-Uhuru, Mombasa, Kenya. Presented at The Geological Society of America Northeastern Section – 47th Annual Meeting, 18-20 March 2012, Hartford, Connecticut.
Kenya	Battery recycling	2014	Inhalation	Workers and local community in the Owino Uhuru district	3 000	3	The Borgen Project. Lead poisoning in Kenya. Available from: http://borgenproject.org/lead-poisoning-kenya/ (accessed 20 August 2015)
Kenya	Battery recycling	2014	Inhalation	Children of the Owino Uhuru district, 9-12 months of age	200	NS	Standard Digital News. Slum residents tested for lead poisoning. Available from: http://www.standardmedia.co.ke/article/2000148046/slum-residents-tested-for-lead-poisoning (accessed 20 August 2015)
Kenya	Battery recycling	2015	Inhalation/ ingestion	Owino Uhuru community	NA	NA	The Guardian. 'East African Erin Brockovich' wins prize for closing polluting lead smelter. Available from http://www.theguardian.com/environment/2015/apr/20/east-african-erin-brockovich-wins-prize-for-closing-polluting-lead-smelter (accessed 20 August).
Kenya	Battery recycling, Auto mechanic, Radiator repairs,	NA	Inhalation	Workers	141	0	
Kenya	Battery manufacture, Battery recycling, Paint production,-Welding.	2011-2012	Inhalation	Adults	233	0	Were et al. Lead exposure and blood pressure among workers in diverse industrial plants in Kenya. Journal of Occupational and Environmental Hygiene 2014;11:706-715.
Kenya	Sugar industry	2014	Inhalation/ ingestion	Use of lead sub-acetate in Kenya's sugar factories – Occupational Health and Safety document	NA	NA	IUF Global Sugar Program & KUSPAW: Research on Occupational Safety and Health Issues. Available from: http://www.iuf.org/sugarworkers/wp-content/uploads/2014/09/PUB-KUSPAW-Research-documents-July-2014.pdf (accessed 02 September 2015).
Kenya	Occupational and environmental	NS	Inhalation	Children and adults	308	0	Njoroge et al. Environmental and Occupational exposure to lead. East African Medical Journal 2008;85:284-291.

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Kenya	Geophagia	1997	Ingestion	Pregnant women	52	0	Geissler et al. Perceptions of soil-eating and anaemia among pregnant women on the Kenyan coast. Social Science and Medicine 1999;48:1069-1079.
Kenya	Geophagia	NS	Ingestion	Postpartum female, 37 years	1	0	Kim & Nelson. Are you what you eat? Pica in pregnancy. Emergency Medicine July 2012. Available from http://www.emed-journal.com/fileadmin/qhi_archive/ArticlePDF/EM/044070004.pdf (accessed 17 August 2015)
Kenya	Geophagia and environmental exposure	1998	Inhalation/ ingestion	Pregnant women, 15-40	223	0	Odhiambo et al. A survey of blood lead levels in pregnant women attending two public prenatal clinics in Nairobi City, Kenya. Journal of American Science 2009;5:41-51.
Kenya	Environment -street dust	1989	Inhalation	Soil analysis	NA	NA	Onyari et al. Lead contamination in street soils of Nairobi City and Mombasa Island, Kenya. Bulletin of Environmental Contamination and Toxicology 1991;46:782-789.
Kenya	Environment -game reserve	NS	Ingestion	Waterbuck study	NA	NA	Jumba et al. Animal Health Problems Attributed to Environmental Contamination in Lake Nakuru National Park, Kenya: A Case Study on Heavy Metal Poisoning in the Waterbuck Kobus ellipsiprymnus defassa (Ruppel 1835). Archives of Environmental Contamination and Toxicology 2007;52:270–281.
Kenya	Environment -Soil	2007	Inhalation/ Ingestion	Children 6-59 months – blood lead analysis and soil analysis	387	NS	Olewe et al. Blood lead levels and potential environmental exposures among children under five years in Kibera slums, Nairobi. East African Journal of Public Health 2009;6:6-10.
Kenya	Environment -urban vs. rural	NS	Inhalation/ ingestion	Males and females, 18-71 years	NS	NS	Mogwasi et al. Effect of environmental exposure on the lead levels in human blood in Kenya. Journal of Environment and Earth Sciences 2012;53-63.
Kenya	Environment-urban vs. rural	NS	Inhalation/ ingestion	Children and adolescents,3-20 years of age	308	0	Kimani NG. Blood lead levels in Kenya: A case study for children and adolescents in selected areas of Nairobi and Olkalou, Nyandurua District. Available from: http://www.unep.org/urban_environment/pdfs/bloodleadlevels-kenya.pdf (accessed 31 August 2015).
Kenya	Environment -dump site	NS	Inhalation	Children and adults, 0-70 years of age	120	0	Owino et al. Lead metal exposure to residents in informal settlement: A case study of residents in Nakuru Municipality, Kenya. Kabarak Journal of Research and Innovation 2015;3:41-47. Available from: http://www.academia.edu/11706968/Lead_Metal_Exposure_to_Residents_Residing_in_Informal_Settlement_A_Case_Study_of_Residents_in_Nakuru_Municipality_Kenya (accessed 20 August 2015).
Kenya	Food -subsistence crops	NS	Ingestion	Food and soil analysis	NA	NA	Dickinson et al. Lead and potential health risks from subsistence food crops in urban Kenya. Environmental Geochemistry and Health 1987;9:37-42.
Kenya	Food -maize -wheat -milk -soil	ABSTRACT	Ingestion	Food and soil analysis	NA	NA	Kunguru & Tole. Contamination of soils, maize, wheat and milk with lead from motor vehicle emissions in Uasin Gishu district, Kenya. Discovery and Innovation 1994;6:261-264.
Kenya	Food -kale	NS	Ingestion	Nairobi sukumawiki (kale) contains lead	NA	NA	City Farmer. Urban Agriculture Notes. Lead poison: How safe is sukumawiki (kale)? Available from: http://www.cityfarmer.org/lead.html (accessed 02 September, 2015).

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Kenya	Food -vegetables -cereals -legumes	NS	Ingestion	Food, soil and water analysis	NA	NA	Makokha et al. Environmental lead pollution and contamination in food around Lake Victoria, Kisumu, Kenya. African Journal of Environmental Science and Technology 2008;2:349-353.
Kenya	Food -fish	2006	Ingestion	-Hair and nails from children < 5 years -Fish analysis	49	NS	Oyoo-Okoth et al. Monitoring exposure to heavy metals among children in Lake Victoria, Kenya: Environmental and fish matrix. Ecotoxicology and Environmental Safety 2010;73:1797-1803.
Kenya Tanzania Uganda	Food -maize -beans -fish	2007-2009	Ingestion	Food, soil and water analysis	NA	NA	Makokha et al. The effects of environmental lead pollution in Kisumu, Mwanza and Kampala. The Open Environmental Engineering Journal 2011;4:133-140.
Kenya	Food -fish	ABSTRACT	Ingestion	Analysis of organs and tissues of farmed tilapia fish	NA	NA	Omwenga et al. Assessment of lead and cadmium residues in farmed fish n Machakos and Kiambu counties, Kenya. Toxicology and Environmental Chemistry 2014;96:58-67.
Kenya	Food -dairy cows	ABSTRACT	Ingestion	Acute lead poisoning of dairy cattle	NA	NA	Mbaria et al. Forensic case of lead poisoning from a battery manufacturing company in Nakuru, Kenya. Japanese Journal Veterinary Research 2014;61.
Kenya	Food -spinach	NS	Ingestion	Vegetable analysis	NA	NA	Ombaka O et al. Spectrophotometric determination of traces of lead (II) in spinach samples marketed in Chuka, Kenya. International Journal of Modern Chemistry 2014;6:1-17.
Kenya	Water -groundwater	NS	Ingestion	Water analysis	NA	NA	Chege et al. Physico-chemical analysis of groundwater in the Gazi-Mrima Hill region of Kwale County, Kenya. Asian Journal of Science and Technology 2013;4:55-58.
Kenya	Water -wells	NS	Ingestion	Well water analysis	NA	NA	Chege et al. Lead contamination of traditional hand-dug wells in parts of Kwale County, Kenya. International Journal of Physical Science 2013;8:835-839.
Madagascar	Water -groundwater	2012-3013	Ingestion	Water analysis	NA	NA	Akers et al. Lead (Pb) contamination of self-supply groundwater systems in coastal Madagascar and predictions of blood lead levels in exposed children. Environmental Science and Technology 2015;49:2685-2693.
Malawi	Geophagia	NS	Ingestion	Soil analysis	NA	NA	Lakudzala & Khonje. Nutritive potential of some 'edible' soils in Blantyre city, Malawi. Malawi Medical Journal 2011;23:38-42.
Malawi	Food -fish	2003	Ingestion	Analysis of farm-raised fish	NA	NA	Purchase & Juma. Determination of lead levels in farm-raised fish (Oreochromis shiranus) in Zomba district, Malawi. Malawi Journal of Aquaculture and Fisheries 2009;1:2-5.
Malawi	Water	2004-2005	Ingestion	Lead remediation with seed powder	NA	NA	Mataka et al. Lead remediation of contaminated water using Moringa Stenopetala and Moringa oleifera seed powder. International Journal of Environmental Science and Tech 2006;3:131-139.
Mali	Traditional medicine, Food -vegetables	2002	Ingestion	Plant analysis	NA	NA	Maiga et al. Determination of some toxic and essential metal ions in medicinal and edible plants from Mali. Journal of Agriculture and Food Chemistry 2005;53:2316-2321.
Mozambique	Food -fish	NS	Ingestion	Fish analysis	NA	NA	Kaya & Akbulut. Effects of waterborne lead exposure in Mozambique Tilapia: Oxidative stress, osmoregulatory responses, and tissue accumulation. Journal of Aquatic Animal Health 2015;27:77-87.
Namibia	Mining -Berg Aukas (Pb, Zn and vanadium mine)	NA	Inhalation	General information	NA	NA	Mapani et al. Human health risks associated with historic ore processing at Berg Aukas Grootfontein area, Namibia. Communications of the Geological Survey of Namibia 2009;14:25-40.
Namibia	Mining -Rosh Pinah mine	NS	Inhalation	Tailings dam soil and grass analysis	NA	NA	Křibek et al. Contamination of soils with dust fallout from the tailings dam at the Rosh Pinah area, Namibia: Regional assessment, dust dispersion modelling and environmental consequences. Journal of Geochemical Exploration 2014;144:391-408.
Namibia	Environment -Wild springbok	ABSTRACT	Inhalation/ ingestion	Analysis of organs and tissues of wild springbok	NA	NA	Magwedere et al. Lead and cadmium levels in liver, kidney and muscle of harvested wild springbok (Antidorcus marsupialis) under extensive management in southern and southeastern Namibia. South African Journal of Wildlife Research 2013;43:52-60.
Namibia	Environment -Road construction	2013	Inhalation	Roadside dust analysis	NA	NA	Abah et al. Survey of the levels of some heavy metals in roadside dusts along Katma Mulilo Urban road construction, Namibia. American Journal of Environmental Protection 2014;3:19-27.
Namibia	Food -black mussel -sediments	2012	Ingestion	Analysis of the black mussel and sediments from Walvis Bay harbour	NA	NA	Vellemu & Omoregie. Lead pollution: A growing concern along the Namibian coastal waters. International Science and Technology Journal of Namibia 2014;3:21-34.
Nigeria	Paint	NS	Inhalation	Paint factory workers	50	0	Orisakwe et al. Liver and kidney function tests amongst paint factory workers in Nkpor, Nigeria. Toxicology and Industrial Health 2007;23:161-165.
Nigeria	Paint	2006	Inhalation/ ingestion	Paint analysis	NA	NA	Adebamowo et al. Lead content of dried films of domestic paints currently sold in Nigeria. Science of the Total Environment 2007;388:116-120.
Nigeria	Paint.	NS	Ingestion	Paint flakes analysis	NA	NA	Nduka et al. Lead levels in paint flakes from buildings in Nigeria: a preliminary study. Toxicology and Industrial Health 2008;24:539-542.
Nigeria	Paint	2006	Ingestion	Paint analysis	NA	NA	Clark et al. Lead levels in new enamel household paints from Asia, Africa and South America. Environmental Research 2009;109:930-936.
Nigeria	Petrol	ABSTRACT	Inhalation	Traffic pollution estimation by analysis of roadside dust	NA	NA	Ogunsola et al. Traffic pollution: preliminary elemental characterisation of roadside dust in Lagos, Nigeria. Science of the Total Environment 1994;146-147:175-184.
Nigeria	Petrol	NS	Inhalation	Analysis of vehicular emissions	NA	NA	Agbo S. Effects of lead poisoning in children, in Proceedings at a Workshop on Vehicular Emission and Lead Poisoning in Nigeria, 1997. Eds. Falomo AA and Chikwendu CC. Organised by Friends of the Environment (FOTE) Lagos, 20-28.
Nigeria	Petrol	1998	Inhalation	Roadside soil analysis and traffic density	NA	NA	Onianwa PC. Roadside topsoil concentrations of lead and other heavy metals in Ibadan, Nigeria. Soil and Sediment Contamination 2001;10:577-591.
Nigeria	Petrol	NS	Inhalation	Roadside soil analysed	NA	NA	Fakayode & Olu-Owolabi. Heavy metal contamination of roadside topsoil in Osogbo, Nigeria: its relationship to traffic density and proximity to highways. Environmental Geology 2003;44:150-157.

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Nigeria	Petrol	NS	Inhalation	Roadside soil and vegetation analysed	NA	NA	Amusan et al. Effect of traffic density on heavy metal content of soil and vegetation along roadsides in Osun State, Nigeria. West African Journal of Applied Ecology 2003;4:107-114.
Nigeria	Petrol	NS	Inhalation	Analysis of lead in samples of moss taken from major and minor roads	NA	NA	Ogunfowokan et al. Trace lead, zinc, and copper levels in Barbula lambarenensis as a monitor of local atmospheric pollution in Ile-Ife, Nigeria. Journal of Applied Sciences 2004;4:380-383.
Nigeria	Petrol	2002	Inhalation	Analysis of suspended particulate along motorways	NA	NA	Obioh et al. Chemical characterization of suspended particulate along air corridors of motorways in two Nigerian cities. Journal of Applied Sciences 2005;5:347-350.
Nigeria	Petrol	NS	Inhalation	Adults and children	275	0	Wright et al. Causes of lead toxicity in a Nigerian city. Archives of Disease in Childhood 2005;90:262-266.
Nigeria	Petrol	2006	Inhalation	Soil and vegetation analysis	NA	NA	Okunola et al. Levels of trace metals in soil and vegetation along major and minor roads in metropolitan city of Kaduna, Nigeria. African Journal of Biotechnology 2007;6:1703-1709.
Nigeria	Petrol	ABSTRACT	Inhalation	Air and noise pollution analysis	NA	NA	Osuntogun & Koku. Environmental-impacts of urban road transportation in south-western states of Nigeria. Journal of Applied Sciences 2007;7:2356-2360.
Nigeria	Petrol	NS	Inhalation	Tree bark analysis	NA	NA	Majolagbe et al. Concentration of heavy metals in tree barks as indicator of atmospheric pollution in Oyo Town, Southwest Nigeria. Archives of Applied Science Research 2010;2:170-178.
Nigeria	Petrol	NS	Inhalation	Roadside dust analysis	NA	NA	Bada & Oyegbami. Heavy metals concentrations in roadside dust of different traffic density. Journal of Environment and Earth Science 2012;2:54-59.
Nigeria	Petrol	NS	Inhalation	Review article	NA	NA	Orisakwe et al. Metal pollution in Nigeria: A biomonitoring update. Journal of Health and Pollution 2014;4:40-52.
Nigeria	Mining -Zamfara	2010	Inhalation/ ingestion	Children < 5 years	205	118 children < 5 yrs had died during previous year	Centers for Disease Control and Prevention (CDC). Notes from the field: Outbreak of acute lead poisoning among children aged <5 years – Zamfara, Nigeria, 2010. Available from Available from: http://www.cdc.gov/mmwr/preview/mmwrhtml/mm5927a3.htm accessed 21 July 2015.
Nigeria	Mining -Zamfara	2010	Inhalation/ ingestion	Children < 5 years	204	118 children < 5yrs had died during previous year	Dooyema et al. Outbreak of fatal childhood lead poisoning related to artisanal gold mining in Northwestern Nigeria, 2010. Environmental Health Perspectives 2012;120:601-607.
Nigeria	-Mining -Zamfara	2010	Inhalation/ ingestion	Children 2 months – 5 years	70	NS	Lo et al. Childhood lead poisoning associated with gold ore processing: a village-level investigation – Zamfara State, Nigeria, October – November 2010. Environmental Health Perspectives 2012;120:14501455.
Nigeria	Mining -Zamfara	NS	Inhalation/ ingestion	Ore and soil analysis	NA	NA.	Plumlee et al. Linking geological and health sciences to assess childhood lead poisoning from artisanal gold mining in Nigeria. Environmental Health Perspectives 2013;121:744-750.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Nigeria	Mining -Zamfara	2010-2011	Inhalation/ ingestion	Children aged ≤5 years with VBLL ≥45 µg/dL	972	14	Greig et al. Association of blood lead level with neurological features in 972 children affected by an acute severe lead poisoning outbreak in Zamfara State, Northern Nigeria. PloS ONE 2014;9:e93716.
Nigeria	Mining -Zamfara	2010-2011	Inhalation/ ingestion	Soil analysis	NA	NA	Bartrem et al. Unknown risk: co-exposure to lead and other heavy metals among children living in small-scale mining communities in Zamfara State, Nigeria. International Journal of Environmental Health Research 2014;24:304-319.
Nigeria	Mining -Zamfara	NS	Ingestion	Soil analysis	NA	NA	Mohammed & Abdu. Horizontal and vertical distribution of lead, cadmium, and Zinc in farmlands around a lead-contaminated gold-mine in Zamfara, Northern Nigeria. Archives of Environmental Contamination and Toxicology 2014;66:295-302.
Nigeria	Mining -Zamfara	May, 2015	Inhalation/ ingestion	Children 5 years	65	28 (since 2011 reports)	World Bulletin report. Available from: http://www.worldbulletin.net/todays-news/159161/28-nigeria-children-killed-by-lead-poisoning (accessed 21 August 2015)
Nigeria	Mining -Ishiagu	NS	Inhalation	Soil analysis	NA	NA	Ezeh & Chukwe. Small scale mining and heavy metals pollution of agricultural soils: The case of Ishiagu Mining District, South Eastern Nigeria. Journal of Geology and Mining Research 2011;3:87-104.
Nigeria	Mining -soil and dust	NS	Inhalation/ ingestion	Soil analysis	NA	NA	Environmental Health News. Available from: http://www.environmentalhealthnews.org/ehs/newscience/2013/04/lead-poisoning-in-nigeria-came-from-contact-with-dust-soil (accessed 25 August 2015).
Nigeria	Oil industry	NS	Ingestion	Analysis of seafood, water and sediment	NA	NA	Ololade et al. Influence of diffuse and chronic metal pollution in water and sediments on edible seafoods within Ondo oil-polluted coastal region, Nigeria. Journal of Environmental Science and Health, Part A 2011;46:898-908.
Nigeria	Oil industry	2010 & 2011	Ingestion	Water and sediment analysis	NA	NA	Uzoekwe & Oghosanine. The effect of refinery and petrochemical effluent on water quality of Ubeji Creek Warri, southern Nigeria. Ethiopian Journal of Environmental Studies and Management 2011;4:107-116.
Nigeria	Cement manufacturing industry	NS	Inhalation	Analysis of cement dust in the vicinity of cement manufacturer	NA	NA	Gbadebo & Bankole. Analysis of potentially toxic metals in airborne cement dust around Sagamu, Southwestern Nigeria. Journal of Applied Sciences 2007;7:35-40.
Nigeria	Battery chargers	ABSTRACT	Inhalation	Workers	71	0	Sofoluwe et al. Urinary delta-aminolevulinic acid determinations among workers charging lead accumulator batteries in Lagos, Nigeria. Archives of Environmental Health 1971;23:18-22.
Nigeria	Battery recycling	NS	Inhalation Ingestion Dermal absorption	Workers	20 workers	0	Abiola O. Total blood and urinary lead levels in battery charging artisans in two metropolitan cities of South West Nigeria. Journal of Applied Biosciences 2009;14:796-799.
Nigeria	Lead smelter	ABSTRACT	Inhalation	Soil analysis	NA	NA	Fatoki & Lansberger. Simultaneous analysis of lead and tine in soil samples from a lead smelter in Jos, Nigeria by X-ray fluorescence spectrometry. International Journal of Environmental Studies 1996;50:139-144.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Nigeria	Lead workers	ABSTRACT	Inhalation	Workers, 22-58 years	130	0	Anetor & Adeniyi. Decreased immune status in Nigerian workers occupationally exposed to lead. African Journal of Medicine and Medical Science 1998;27:169-172.
Nigeria	Lead workers	NS	Inhalation	Workers, 16-65 years	81	0	Ukaejiofo et al. Haematological assessment of occupational exposure to lead handlers in Enugu urban, Enugu State, Nigeria. Nigerian Journal of Clinical Practice 2009;12:58-64.
Nigeria	Lead workers	NS	Inhalation	Workers	270 adults	0	Alasia et al. Association of lead exposure, serum uric acid and parameters of renal function in Nigerian lead-exposed workers. International Journal of Occupational and Environmental Medicine 2010;1
Nigeria	Auto-mechanics, Petrol station attendants	NS	Inhalation/ ingestion (petrol siphoned by mouth)	Petrol station attendants and auto mechanics	21 auto mechanics; 27 petrol station attendants	0	Onunkwor et al. Biomarkers of lead exposure in petrol station attendants and auto-mechanics in Abeokuta, Nigeria: effect of 2-week ascorbic acid supplementation. Environmental Toxicology and Pharmacology 2004;17:169-176.
Nigeria	Auto-mechanics, Battery chargers, Welders.	NS	Inhalation	Workers, 25-50 years. Liver and renal function analysis	25	0	Dioka et al. Liver and renal function tests in artisans occupationally exposed to lead in Mechanic Village in Nnewi, Nigeria. International Journal of Environmental Research and Public Health 2004;1:21-25.
Nigeria	Auto-mechanics, Battery chargers, Petrol station attendants, Welders, Auto-electricians, Drivers, Auto-painters, Panel beaters, Spares and oil sellers, Car upholsterers.	NS	Inhalation	Workers	110	0	Ademuyiwa et al. Reversal of aminolevulinic acid dehydratase (ALAD) inhibition and reduction of erythrocyte protoporphyrin levels by vitamin C in occupational lead exposure in Abeokuta, Nigeria. Environmental Toxicology and Pharmacology 2005;20:404-411.
Nigeria	Auto-mechanics, Auto-painters, Panel beaters, Petrol station attendants, Welders, Vulcanizers.	NS	Inhalation	Workers, men and women	148	0	Ademuyiwa et al. Erythrocyte acetylcholinesterase activity as a surrogate indicator of lead-induced neurotoxicity in occupational lead exposure in Abeokuta, Nigeria. Environmental Toxicology and Pharmacology 2007;24:183-188.
Nigeria	Occupational -Automobile garage	NS	Inhalation	Workers – blood, hair and finger nail analysis	38	0	Babalola et al. Lead levels in some biological samples of auto-mechanics in Abeokuta, Nigeria. Indian Journal of Biochemistry and Biophysics 2005;42:401-403.
Nigeria	Automobile garage	2002	Inhalation	Workers, 19-54 years	52	0	Dosumu et al. Biomarkers of lead exposure in auto-mechanics in Abeokuta, Nigeria. Trace Elements and Electrolytes 2005;22:185-191.
Nigeria	Automobile garage	NS	Inhalation	Soil analysis	NA	NA	Abidemi. Levels of Pb, Fe, Cd and Co in soils of automobile workshop in Osun State, Nigeria. Journal of Applied Science and Environmental Management 2011;15:279-282.

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Nigeria	Automobile garage	2011	Inhalation	Auto repair workers	353 workers (2 female, 31 male)	0	Saliu et al. Comparative assessment of blood lead levels of automobile technicians in organised and roadside garages in Lagos, Nigeria. Journal of Environmental and Public Health 2015. Available from: http://dx.doi.org/10.1155/2015/976563 (accessed 18 August 2015).
Nigeria	Automobile garage, Petrol station attendants.	NS	Inhalation	Adult male workers	110	0	Ademuyiwa et al. Plasma lipid profiles and risk of cardiovascular disease in occupational lead exposure in Abeokuta, Nigeria. Lipids in Health and Disease 2005;4:19.
Nigeria	Tricycle repair	2013	Inhalation/ ingestion (petrol siphoned by mouth)	Workers	20	0	Nwachukwu et al. Nature and extent of lead poisoning in tricycle repairers in Nigeria. Sci-Afric Journal of Scientific Issues, Research and Essays 2014;2: 83-84.
Nigeria	E-waste	NS	Inhalation	General information	NA	NA	The Basel Action Network (BAN). The digital dump: Exporting re-use and abuse to Africa, 2005, available from http://ban.org/library/TheDigitalDump.pdf accessed 20 July 2015.
Nigeria	E-waste	NS	Inhalation	General information	NA	NA	Schmidt CW. Spheres of influence. Unfair trade: E-waste in Africa. Environmental Health Perspectives 2006;114:A232-235.
Nigeria	E-waste	NS	Inhalation	General information	NA	NA	Osibanjo & Nnorom. The challenge of electronic waste (e-waste) management in developing countries. Waste Management and Research 2007;25:489-501.
Nigeria	E-waste	NS	Inhalation	General information	NA	NA	Nnorom & Osibanjo. Electronic waste (e-waste): Material flows and management practices in Nigeria. Waste Management 2008;28:1472–1479.
Nigeria	E-waste -vegetables	2011-2012	Ingestion	Water, soil and plant analysis	NA	NA	Olafisoye et al. Heavy metals contamination of water, soil and plants around an electronic waste dumpsite. Polish Journal of Environmental Studies 2013;22:1431-1439.
Nigeria	Printing presses	NS	Inhalation/ dermal absorption	Analytical estimation	NA	NA	Oke et al. Occupational lead exposure in printing presses: An analytical approach. The Pacific Journal of Science and Technology 2008;9:263-271.
Nigeria	Occupational and Environmental	ABSTRACT	Inhalation/ ingestion	Occupationally exposed and occupationally unexposed people	Exposed n=137; Unexposed n=880	0	Adeniyi & Anetor. Lead poisoning in two distant states of Nigeria: an indication of the real size of the problem. African Journal of Medicine and Medical Science 1999;28:107-112.
Nigeria	Occupational and Environmental	ABSTRACT	Inhalation/ ingestion	Adults	270 (190 test subject, 80 controls)	0	Alasia et al. Occupational and environmental lead exposure in Port Harcourt, Nigeria: analysis of its association with renal function indices. Nigerian Journal of Medicine 2010;19:407-414.
Nigeria	Geophagia	NS	Ingestion	Pregnant and lactating women	240	0	Izugbara CO. The cultural context of geophagy among pregnant and lactating Ngwa women of southeastern Nigeria. The African Anthropologist 2003;10:180-199.
Nigeria Kenya	Geophagia	NS	Ingestion	Pregnant women -Chalk and soil analysis	NA	NA	Abrahams et al. Human geophagia, Calabash chalk and Undongo: mineral element nutritional implications. PloS ONE 2013;8:e53304. Available from doi:10.1371/journal.pone.0053304 (accessed 14 August 2015)
Nigeria	Geophagia	NS	Ingestion	Pregnant women -Clay analysis	NA	NA	Agene et al. The effects of geophagy on pregnant women in Nigeria. American Journal of Human Ecology 2014;3:1-9.
Nigeria	Geophagia	2013	Ingestion	Pregnant women -Clay analysis	NA	NA	Ijeoma et al., Assessment of heavy metals in edible clays sold in Onitsha metropolis of Anambra State, Nigeria. British Journal of Applied Science and Technology 2014;2114-2124.

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Nigeria	Traditional medicine	ABSTRACT	Ingestion	Medication analysis	NA	NA	Healy et al. Traditional medicine and lead-containing preparations in Nigeria. Public Health 1984;98:26-32.
Nigeria	Traditional medicine	2005	Ingestion	Female child, 2 years	1	0	Otaigbe & Adesina. Crude oil poisoning in a 2 year old Nigerian – A case report. Anil Aggrawal's Internet Journal of Forensic Medicine and Toxicology 2005;6: Available from: http://www.anilaggrawal.com/ij/vol_006_no_002/papers/paper004.html accessed 21 July 2015
Nigeria	Traditional medicine	NS	Ingestion	Analysis of medicinal plants	NA	NA	Obi et al. Heavy metal hazards of Nigerian herbal remedies. Science of the Total Environment 2006;369:35-41.
Nigeria	Traditional medicine	2009	Ingestion.	Children (particularly those with febrile convulsions)	420	NS	Dienye et al. Uses of crude oil as traditional medicine: a survey of mothers in a rural clinic in South-south Nigeria. Rural and Remote Health 2012;12:1858.
Nigeria	Medication -Paediatric syrup	NS	Ingestion	Analysis of paediatric syrup	NA	NA	Oriskwe & Nduka. Lead and cadmium levels of commonly administered pediatric syrups in Nigeria: A public health concern? Science of the Total Environment 2009;407:5993-5996.
Nigeria	Environment and household	1996	Inhalation/ ingestion	Children 1-6 years	87	0	Nriagu et al. Lead poisoning of children in Africa, III. Kaduna, Nigeria. Science of the Total Environment 1997;197:13-19.
Nigeria	Environment -atmospheric	NS	Inhalation	Tree bark analysis	NA	NA	Odukoya et al. Pb, Zn, and Cu levels in tree barks as indicator of atmospheric pollution. Environment International 2000;26:11-16.
Nigeria	Environment	ABSTRACT	Inhalation/ ingestion	Children	218	NS	Pfitzner et al. Prevalence of elevated blood lead levels in Nigerian children. Ambulatory Child Health 2000;6:115-123.
Nigeria	Environment	ABSTRACT	Inhalation/ ingestion	Blood and urine analysis of university students, petrol station attendants and pregnant women	NS	NS	Ademuyiwa et al. Lead levels in blood and urine of some residents of Abeokuta, Nigeria. Trace Elements and Electrolytes 2002;19:63-69.
Nigeria	Environment -Industrialised areas	NS	Inhalation/ ingestion	Males and females, 1-30 years – hair analysis	NA	NA	Nnorom et al. Multielement analysis of human scalp hair samples from three distant towns in southeastern Nigeria. African Journal of Biotechnology 2005;4:1124-1127.
Nigeria	Environment -domestic	2004	Inhalation/ ingestion	Focus group discussions	NA	NA	Adebamowo et al. An examination of knowledge, attitudes and practices related to lead exposure in South Western Nigeria. BMC Public Health 2006;6:82.
Nigeria	Environment	NS	Inhalation	Children, 1-6 years	306	0	Ogunseitan & Smith. The cost of environmental lead (Pb) poisoning in Nigeria. African Journal of Environmental Science and Technology 2007;1:27-36.
Nigeria	Environment -lead and malaria	NS	Inhalation/ ingestion	Children 2-9 years Pb/Malaria association	653	0	Nriagu et al. Lead poisoning associated with malaria in children of urban areas of Nigeria. International Journal of Hygiene and Environmental Health 2008;211:591–605.
Nigeria	Environment -"unexposed" control subjects	ABSTRACT	Inhalation/ ingestion	High BLLs in Nigeria cast doubt on the researchers' ability to find real 'unexposed' subjects	NA	NA	Orisakwe OE. Environmental pollution and blood lead levels in Nigeria: Who is unexposed? International Journal of Occupational and Environmental Health 2009;15:315-317.
Nigeria	Environment	NS	Inhalation	School children	197	0	Esimai & Awotoye. Estimation of lead in urine of school children in south western Nigeria and effect of ascorbic intervention. African Journal of Environmental Science and Technology 2009;3:370-375.

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Nigeria	Environment	2006-2008	Inhalation	Pregnant women,17-49 years	214	0	Adekunle et al. Assessment of blood and urine lead levels in pregnant women residing in Lagos, Nigeria. Environmental Monitoring and Assessment 2010;170:467-474.
Nigeria	Environment -roadside soil -dust -rain water	2007 & 2008	Inhalation	Soil, dust and rain water analysis	NA	NA	Nduka & Orisakwe. Assessment of environmental distribution of lead in some municipalities of south-eastern Nigeria. International Journal of Environment Research and Public Health 2010;7:2501-2513.
Nigeria	Environment -Pb and breast cancer	NS	Inhalation/ ingestion	Blood, hair and tumour analysis	12	NS	Alatise & Schrauzer. Lead exposure: A contributing cause of the current breast cancer epidemic in Nigerian women. Biological Trace Element Research 2010;136:127-139.
Nigeria	Environment	ABSTRACT	Inhalation	Analysis of amniotic fluid of pregnant women, 15-45 years	50	0	Yahaya & Ogunfowokan. Elemental profile in amniotic fluid of some Nigerian pregnant women. East African Journal of Public Health. 2011;8:92-97.
Nigeria	Environment	NS	Inhalation	Analysis of classroom dust	NA	NA	Popoola et al. Heavy metals content in classroom dust of some public schools in Metropolitan Lagos, Nigeria. Research Journal of Environmental and Earth Sciences 2012;4:460-465.
Nigeria	Environment	NS	Inhalation	Pregnant women	349	0	Ugwuja et al. Blood Pb Levels in pregnant Nigerian women in Abakaliki, South-Eastern Nigeria. Environmental Monitoring and Assessment 2013;185:3795-3801.
Nigeria	Environment	NS	Inhalation	General information	NA	NA	Orisakwe OE. Lead and cadmium in public health in Nigeria: Physicians neglect and pitfall in patient managements. North American Journal of Medical Sciences 2014;6:61-70.
Nigeria	Environment	NS	Inhalation	Pregnant women, 15-45 years	50	0	Yahaya et al. Essential and Non-Essential Metals Profile in Blood of some Nigerian Pregnant Women. Journal of Applied Science and Environmental Management 2014;18:653-659.
Nigeria	Environment, Mining, Paint.	Review article	Inhalation/ ingestion	Children	NA	NA	Ajayi et al. A review paper on lead exposure and poisoning in Nigerian children: The way forward. Elixir Pollution 2014;70:23808-23811.
Nigeria	Food -African catfish -Nile tilapia Non biting midge Water bug	NS	Ingestion	Analysis of fish and insects	NA	NA	Oladimeji & Offem. Toxicity of lead to Clarias lazera, Oreochromis niloticus, Chironomus tentans and Benacus sp. Water, Air, and Soil Pollution 1989;44:191-201.
Nigeria	Food -breast milk	1998	Ingestion	Analysis of breast milk	NA	NA	VanderJagt et al. Lead levels in the milk of Fulani women in Nigeria. Journal of the National Medical Association 2001;93:104-108.
Nigeria	Food -infant formula	2000	Ingestion	Analysis of infant formula	NA	NA	Ikem et al. Levels of 26 elements in infant formula from USA, UK, and Nigeria by microwave digestion and ICP-OES. Food Chemisty 2002;77:439-447.
Nigeria	Food -chicken eggs	NS	Ingestion	Chicken egg analysis	NA	NA	Fakayode & Olu-Owolabi. Trace metal content and estimated daily human intake from chicken eggs in Ibadan, Nigeria. Archives of Environmental Health 2003;58:245-251.
Nigeria	Food -bread	NS	Ingestion	Lead levels (due to exhaust fumes) in bread sold at bus terminals	NA	NA	Awofolu OR. Impact of automobile exhaust on levels of lead in a commercial food from bus terminals. Journal of Applied Science and Environmental Management 2004;8:23-27.
Nigeria	Food -vegetables	NS	Ingestion	Vegetable analysis	NA	NA	Bakare et al. Cadmium, lead and mercury in fresh and boiled leafy vegetables grown in Lagos, Nigeria. Environmental Technology 2004;25;1367-1370.

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Nigeria	Food -smoked fish	NS	Ingestion	Analysis of fish before and after exposure to atmosphere. Traffic density analysis	NA	NA	Adekunle & Akinyemi. Lead levels of certain consumer products in Nigeria: a case study of smoked fish foods from Abeokuta. Food and Chemical Toxicology 2004;42:1463-1468.
Nigeria	Food -cassava -fruit	ABSTRACT	Ingestion	Vegetable, fruit, soil and water analysis – lead battery contaminated area	NA	NA	Orisakwe et al. Impact of effluents from a car battery manufacturing plant in Nigeria on water, soil, and food qualities. Archives of Environmental Health 2004;59:31-36.
Nigeria	Food -cocoa beans -cocoa products	2002	Ingestion	Cocoa bean, shell and chocolate analysis	NA	NA	Rankin et al. Lead contamination in cocoa and cocoa products: Isotopic evidence of global contamination. Environmental Health Perspectives 2005;113:1344-1348.
Nigeria	Food -vegetables	NS	Ingestion	Soil, crop and irrigation water analysis	NA	NA	Pasquini. The use of town refuse ash in urban agriculture around Jos, Nigeria: Health and environmental risks. Science of the Total Environment 2006;354:43-59.
Nigeria	Beverages	2005	Ingestion	Soft drink analysis	NA	NA	Maduabuchi et al. Lead and cadmium exposures from canned and non-canned beverages in Nigeria: A public health concern. Science of the Total Environment 2006;366:621-626.
Nigeria	Beverages -canned fruit drinks	NS	Ingestion	Canned fruit drink analysis	NA	NA	Iwegbue et al. Heavy metal composition of some imported canned fruit drinks in Nigeria. American Journal of Food and Technology 2008;3:220-223.
Nigeria	Food -periwinkles	NS	Ingestion	Periwinkle shell and tissue analysis	NA	NA	Ideriah et al. Distribution of lead and total hydrocarbon in tissues of periwinkles (Tympanotonus fuscatus and Pachymelania aurita) in the upper Bonny River, Nigeria. Journal of Applied Science and Environmental Management 2006;10:145-150.
Nigeria	Food -farmland	NS	Ingestion	Soil analysis	NA	NA	Achudume AC. Assessment of farmland sediments after flooding in Ubeji Land in Niger Delta of Nigeria. Environmental Monitoring and Assessment 2007;135:335-338.
Nigeria	Food -farmland near landfill	2005-2006	Ingestion	Crop and soil analysis	NA	NA	Oluyemi et al. Seasonal variations in heavy metal concentrations in soil and some selected crops at a landfill in Nigeria. African Journal of Environmental Science and Technology 2008;2:89-96.
Nigeria	Food -African sharptooth catfish	NS	Ingestion	Fish analysis	NA	NA	Adeyemo OK. Haematological profile of Clarias gariepnus (Burchell, 1822) exposed to lead. Turkish Journal of Fisheries and Aquatic Sciences 2007;7:163-169.
Nigeria	Food -fish	ABSTRACT	Ingestion	Fish analysis	NA	NA	Etesin & Benson. Cadmium, copper lead and zinc tissue levels in bonga shad (Ethmalos fimbriata) and Tilapia (Tilapia guineensis) caught from Imo River, Nigeria. American Journal of Food and Technology 2007;2:48-54.
Nigeria	Food -vegetables -legumes -cereals -water -soil	2003-2004	Ingestion	Analysis of vegetables, cereals, water and soil	NA	NA	Edeogu et al. Public health significance of metals' concentration in soils, water and staple foods in Abakaliki south eastern Nigeria. Trends in Applied Science Research 2007;2:439-444.
Nigeria	Food -fish	2005	Ingestion	Fish analysis	NA	NA	Adeniyi et al. Assessments of the exposure of two fish species to metals pollution in the Ogun river catchments, Ketu, Lagos, Nigeria. Environmental Monitoring and Assessment 2008;137:451-458.

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Nigeria	Food -fish	2006	Ingestion	Fish analysis	NA	NA	Ekpo et al. Determination of lead, cadmium and mercury in surrounding water and organs of some species of fish from Ikpoba River in Benin city, Nigeria. International Journal of Physical Sciences 2008;3:289-292.
Nigeria	Food -vegetables	NS	Ingestion	Analysis of leafy vegetables	NA	NA	Adekunle et al. Assessments of lead levels and daily intakes from green leafy vegetables of southwest Nigeria. Nutrition and Food Science 2009;39:413-422.
Nigeria	Food -goat meat	2007	Ingestion	Analysis of goat meat	NA	NA	Okoye & Ugwu. Impact of environmental cadmium, lead, copper and zinc on quality of goat meat in Nigeria. Bulletin of the Chemical Society of Ethiopia 2010;24:133-138.
Nigeria	Food -bread	NS	Ingestion	Analysis of 23 brands of bread	NA	NA	Emeje et al. Assessment of bread safety in Nigeria: Quantitative determination of potassium bromate and lead. African Journal of Food Science 2010;4:394-397.
Nigeria	Food -chicken feed	NS	Ingestion	Analysis of chicken feed	NA	NA	Okoye et al. Assessment of metals in chicken feeds sold in south eastern Nigeria. Advances in Applied Science Research 2011:2:63-68.
Nigeria	Food -okra	2011	Ingestion	Plant analysis	NA	NA	Akpofure R-R. Uptake of heavy metals by okro (Hibiscus Esculentus) grown on abandoned dump sites in Effurum, Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences 2012;3:640-644.
Nigeria	Food -chicken	ABSTRACT	Ingestion	Chicken muscle analysis	NA	NA	Olusola et al. Assessment of tetracycline, lead and cadmium residues in frozen chicken vended in Lagos and Ibadan, Nigeria. Pakistan Journal of Biological Science 2012;15:839-44.
Nigeria	Food -edible beef offal	ABSTRACT	ingestion	Analysis of cow liver, kidney, intestine and tripe.	NA	NA	Ihedioha & Okoye. Cadmium and lead levels in muscle and edible offal of cow reared in Nigeria. Bulletin of Environmental Contamination and Toxicology 2012;88:422-427.
Nigeria	Food -food crops -fruit	NS	Ingestion	Analysis of cereals, vegetables and fruit.	NA	NA	Orisakwe et al. Heavy metals health risk assessment for population via consumption of food crops and fruits in Owerri, South Eastern, Nigeria. Chemistry Central Journal 2012;6:77.
Nigeria	Food -lactating cows -forage grasses -leachate	2010	Ingestion	Analysis of blood, milk and faeces from cows, and pasture grasses and leachate	NA	NA	Ogundiran et al. Heavy metals levels in forage grasses, leachate and lactating cows reared around lead slag dumpsites in Nigeria. International Journal of Environmental Research 2012;6:695-702.
Nigeria	Food and drink	2013	Ingestion	Food and drink analysis	NA	NA	Iweala et al. Metal contamination of foods and drinks consumed in Ota, Nigeria. Research Journal of Environmental Toxicology 2014;8:92-97.
Nigeria	Food -cereals -vegetables -seafood	2012	Ingestion	Analysis of seafood and farm produce	NA	NA	Orisakwe et al. Heavy metals in seafood and farm produce from Uyo, Nigeria. Sultan Qaboos University Medical Journal 2015;15:e275-282.
Nigeria	Soil -near battery factory	2000	Inhalation	Soil and vegetation analysis	NA	NA	Onianwa & Fakayode. Lead contamination of topsoil and vegetation in the vicinity of a battery factory in Nigeria. Environmental Geochemistry and Health 2000;22:211-218.
Nigeria	Soil -urban	2008	Inhalation/ ingestion	Urban soil analysis	NA	NA	Odewande & Abimbola. Contamination indices and heavy metal concentrations in urban soil of Ibadan metropolis, southwestern Nigeria. Environmental Geochemistry and Health 2008;30:243-254.

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Nigeria	Soil -animal waste site (farmland)	2007	Inhalation	Soil analysis	NA	NA	Azeez et al. Effect of nine years of animal waste deposition on profile distribution of heavy metals in Abeokuta, south western Nigeria and its implication for environmental quality. Waste Management 2009;29:2582-2586.
Nigeria	Municipal dump sites -soil -cocoyam	2005	Inhalation/ ingestion	Soil and root vegetable analysis	NA	NA	Oyedele et al. Changes in soil properties and plant uptake of heavy metals on selected municipal solid waste dump sites in Ile-Ife, Nigeria. African Journal of Environmental Science and Technology 2008;3:107-115.
Nigeria	Municipal refuse dump -soil	2010	Inhalation	Soil analysis	NA	NA	Adelekan & Alawode. Contributions of municipal refuse dumps to heavy metals concentrations in soil profile and groundwater in Ibadan Nigeria. Journal of Applied Biosciences 2011;40:2727-2737.
Nigeria	Dump sites -soil	NS	Inhalation/ ingestion	Soil analysis and heavy metal bioavailability assessment	NA	NA	Obasi NA. Assessment of physico-chemical properties and heavy metals bioavailability in dumpsites along Enugu-Port Harcourt expressways, south-east Nigeria. Asian Journal of Applied Sciences 2012;5:342-356.
Nigeria	Water -river	NS	Ingestion	River sediment analysis	NA	NA	Ntekim et al. Heavy metal distribution in sediments from Calabar River, southeastern Nigeria. Environmental Geology 1993;21:237-241.
Nigeria	Water -tap water	ABSTRACT	Ingestion	Tap water analysis Blood lead analysis of	NS	NS	Omokhodion FO. Blood lead and tap water lead levels in Ibadan, Nigeria. Science of the Total Environment 1994;151:187-190.
Nigeria	Water -drinking -groundwater	1991 & 1992	Ingestion	Water analysis	NA	NA	Asubiojo et al. Trace elements in drinking and groundwater samples in Southern Nigeria. Science of the Total Environment 1997;208:1-8.
Nigeria	Water -sachet water	NS	Ingestion	Water analysis	NA	NA	Orisakwe et al. Heavy metal hazards of sachet water in Nigeria. Archives of Environmental and Occupational Health 2006;61:209-213.
Nigeria	Water -river	2005	Ingestion	Water and soil analysis	NA	NA	Igwilo et al. Toxicological study of the Anam River in Otuocha, Anambra State, Nigeria. Archives of Environmental and Occupational Health 2006;61:205-208.
Nigeria	Water -Wells	NS	Ingestion	Water analysis	NA	NA	Adekunle et al. Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. International Journal of Environmental Research and Public Health 2007;4:307-318.
Nigeria	Water -groundwater near battery factory	NS	Ingestion	Water analysis	NA	NA	Dawodu & Ipeaiyeda. Evaluation of groundwater and stream quality characteristics in the vicinity of a battery factory in Ibadan, Nigeria. African Journal of Biotechnology 2008;7:1933-1938.
Nigeria	Water -groundwater sources	NS	Ingestion	Water analysis	NA	NA	Abiola OP. Lead and coliform contaminants in potable ground water sources in Ibadan, South-West Nigeria. Journal of Environmental Chemistry and Ecotoxicology 2010;2:79-83.
Nigeria	Water -groundwater near dumpsite	NS	Ingestion	Water analysis	NA	NA	Nubi & Ajuonu. Impacts of industrial effluent and dumpsite leachate discharges on the quality of groundwater in Oyo state, Nigeria. Journal of Biodiversity and Environmental Sciences 2011;1:13-18.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Nigeria	Water -well water -borehole water -tap water -river/stream water	NS	Ingestion	Water analysis	NA	NA	Ignatius et al. Lead in potable water sources in Abakaliki metropolis, South-East Nigeria. Bulletin of Environmental Contamination and Toxicology 2012;88:793-796.
Nigeria	Water -groundwater	NS	Ingestion	Water analysis	NA	NA	Shabanda & Shabanda. Heavy metal concentrations in ground water from Northern Nigeria. Journal of Water Resource and Hydraulic Engineering 2015. Available from: http://www.academicpub.org/jwrhe/paperInfo.aspx?PaperID=16790 (accessed 18 August 2015).
Nigeria	Cosmetics	NS	Dermal absorption	Product analysis	NA	NA	Nnorom et al. Trace metal contents of facial (make-up) cosmetics commonly used in Nigeria. African Journal of Biotechnology 2005;4:1133-1138.
Nigeria	Cosmetics	2007	Dermal absorption	Product analysis	NA	NA	Ayenimo et al. Iron, lead, and nickel in selected consumer products in Nigeria: A potential public health concern. Toxicological and Environmental Chemistry 2010;92:51-59.
Nigeria	Cosmetics -eyeliner	2011	Dermal absorption	Male infant, 6 months of age	1	0	Centers for Disease Control and Prevention (CDC). Infant lead poisoning associated with use of Tiro, and eye cosmetic from Nigeria – Boston, Massachusetts. Morbidity and Mortality Weekly Report 2012;61:574-576.
Nigeria	Cosmetics	NS	Dermal absorption	Product analysis	NA	NA	Adepoju-Bello et al. Evaluation of the concentration of toxic metals in cosmetic products in Nigeria. African Journal of Biotechnology 2012;11:16360-16364.
Nigeria	Cosmetics	2011	Dermal absorption	Product analysis	NA	NA	Orisakwe & Otaraku. Metal concentrations in cosmetics commonly used in Nigeria. The Scientific World Journal 2013. Available from http://dx.doi.org/10.1155/2013/959637 (accessed 11 August 2015).
Nigeria	Tobacco -smoking	ABSTRACT	Inhalation	Male smokers 19-56 years.	47	0	Babalola et al. Selected heavy metals in blood of male Nigerian smokers. Pakistan Journal of Biological Science 2007;10:3730-3733.
Nigeria	Experimental -rat study	NS	Ingestion	Lead-induced gastric ulcers in rats	NA	NA	Olaleye et al. Lead exposure increases oxidative stress in the gastric mucosa of HCl/ethanol-exposed rats. World Journal of Gastroenterology 2007;13:5121-5126.
Nigeria	Experimental -rat study	NS	Ingestion	Analysis of lead-exposed rat tissues	NA	NA	Ademuyiwa et al. Lead-induced phospholipidosis and cholesterogenesis in rat tissues. Chemico-Biological Interactions 2009;179:314-320.
Nigeria	Experimental -rat study	NS	Ingestion	Rats exposed to Nigerian Bonny light crude oil	NA	NA	Adedara et al. Tissues distribution of heavy metals and erythrocytes antioxidant status in rats exposed to Nigerian bonny light crude oil. Toxicology and Industrial Health 2011;29:162–168.
Nigeria	Experimental	NS	Inhalation/ ingestion	Review article on toxic effects of lead on organs and tissues	NA	NA	Adikwu et al. Lead organ and tissue toxicity: Roles of mitigating agents. British Journal of Pharmacology and Toxicology 2013;4:232-240.
Senegal	Petrol	1999	Inhalation	Children 8-12 years	330	0	Diouf et al. Environmental lead exposure and its relationship to traffic density among Senegalese children: a cross-sectional study. Human and Experimental Toxicology 2006;25:637-644.

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Senegal	Battery recycling	2008	Inhalation/ ingestion	Siblings and mothers of deceased children	81 (50 children, 31 adults)	18 children died prior to study	Haefliger et al. Mass lead intoxication from informal used lead-acid battery recycling in Dakar, Senegal. Environmental Health Perspectives 2009;117:1535-1540.
Senegal	Environment -Landfill	NS	Inhalation/ ingestion:	Children 1-16 years	26 (from exposed site) 32 (from control site)	0	Cabral et al. Low-level environmental exposure to lead and renal adverse effects: A cross-sectional study in the population of children bordering the Mbeubeuss landfill near Dakar, Senegal. Human and Experimental Toxicology 2012;31:1280–1291.
South Africa	Paint -home		Ingestion	Paint analysis and survey of residential homes	NA	NA	Montgomery & Mathee. A preliminary study of residential paint lead concentrations in Johannesburg. Environmental Research 2005;98:279-283.
South Africa	Paint -pica	2002	Ingestion	7 year old girl	1	0	Mathee & Röllin. Childhood lead exposure in South Africa. South African Medical Journal 2003;93:313.
South Africa	Paint -playground equipment	2008	Ingestion	Lead levels in paint on playground equipment measured	NA	NA	Mathee et al. Lead-based paint on playground equipment in public children's parks in Johannesburg, Tshwane and Ekurhuleni. South African Medical Journal 2009;99:819-821.
South Africa	Paint -toys	NS	Ingestion	Analysis of paint on toys	NA	NA	Mathee et al. Lead in paint: Three decades later and still a hazard for African children? Environmental Health Perspectives 2007;115:321-322.
South Africa	Petrol	NS	Inhalation	Children 6-8 years	200	0	von Schirnding et al. Blood lead levels in South African inner-city children. Environmental Health Perspectives 1991;94:125-130.
South Africa	Petrol	1995	Inhalation	Analysis of particulate matter	NA	NA	Nriagu et al. Atmospheric lead pollution in KwaZulu/Natal, South Africa. Science of the Total Environment 1996;191:69-76.
South Africa	Petrol	NS	Inhalation/ ingestion	General information	NA	NA	Diab RD. A note on changes in atmospheric lead content in seven cities in South Africa. South African Journal of Science 1999;95:117-120.
South Africa	Petrol	NS	Inhalation	Grade 1 school children	510	0	von Schirnding et al. Distribution of blood lead levels in school children in selected Cape Peninsula suburbs subsequent to reductions in petrol lead. South African Medical Journal 2001;91:870-872.
South Africa	Petrol	NS	Inhalation	Children 6-9 years	433	0	Mathee et al. A survey of blood lead levels among young Johannesburg school children. Environmental Research 2002;90:181-184.
South Africa	Petrol	NS	Inhalation	Policy forming document	NA	NA	Mathee et al. A study of childhood blood levels in selected Johannesburg suburbs following the introduction of unleaded petrol in South Africa (Urban Phase), 2003. Policy forming towards removal of lead from petrol.
South Africa	Petrol	2002	Inhalation	Children 5-11 years	429	0	Mathee et al. Reductions in blood lead levels among school children following the introduction of unleaded petrol in South Africa. Environmental Research 2006;100:319-322.
South Africa	Petrol	2001 & 2003	Inhalation	Coal, mine-dump sand, gasoline and lichen analysis	NA	NA	Monna et al. Origin of atmospheric lead in Johannesburg, South Africa. Atmospheric Environment 2006;40:6554-6566.
South Africa	Petrol	NS	Inhalation	Children	1282	0	Röllin et al. Examining the association between manganese and blood lead levels in schoolchildren in four selected regions of South Africa. Environmental Research 2007;103:160-167.
South Africa	Petrol	2006-2007	Inhalation	Soil and leaf analysis	NA	NA	Olowoyo et al. Trace metals in soil and leaves of Jacaranda mimosifolia in Tshwane area, South Africa. Atmospheric Environment 2010;44:1826-1830.
South Africa	Petrol	2007	Inhalation	Tree bark analysis	NA	NA	Olowoyo et al. Investigating Jacaranda mimosifolia tree as biomonitor of atmospheric trace metals. Environmental Monitoring and Assessment 2010;164:435-443.
South Africa	Petrol	NS	Inhalation	Lichen analysis	NA	NA	Olowoyo et al. Trace element concentrations from lichen transplants in Pretoria, South Africa. Environmental Science and Pollution Research 2011;18: 663-668.
South Africa	Mining -Aggeneys	NS	Inhalation	General information	NA	NA	Snodgrass RA. Lead in South Africa. Journal of the South African Institute of Mining and Metallurgy 1986;86:97-111.
South Africa	Mining -Aggeneys	NS	Inhalation	Children 6-10 years	154	0	von Schirnding et al. A study of paediatric blood lead levels in a lead mining area in South Africa. Environmental Research 2003;93:259-263.
South Africa	Mining -Aggeneys	1991-2008	Inhalation	Grade 1 school children, 6-8 years	244	0	Naicker & Mathee. Trends in lead exposure in a rural mining town in South Africa, 1991-2008. South African Medical Journal 2015;105:515.
South Africa	Mining, Industrial, Urban.	2005-2008	Inhalation	Soil analysis	NA	NA	de Villiers et al. Identification of sources of environmental lead in South Africa from surface soil geochemical maps. Environmental Geochemistry and Health 2010;32:451-459.
South Africa	Mining, Industrial.	2007-2012	Inhalation	Analysis of particulate matter	NA	NA	Oosthuizen et al. Human health risk assessment of airborne metals to a potentially exposed community: a screening exercise. The Clean Air Journal 2015;25:1-7.
South Africa	Battery factory	NS	Inhalation	Workers	381	0	Ehrlich et al. Lead absorption and renal dysfunction in a South African battery factory. Occupational and Environmental Medicine 1998;55:453-460.
South Africa	Battery factory	1996	Inhalation	Workers	381	0	Todd et al. Repeatability of tibia lead measurement by X-ray fluorescence in a battery-making workforce. Environ Res Sect A 2000;84:282-289.
South Africa	E-waste	NS	Inhalation	General information	NA	NA	Finlay A. E-waste challenges in developing countries: South Africa case study. Association for Progressive Communications (APC) issue paper. Available from: https://www.apc.org/en/system/files/e-waste_EN.pdf (accessed 09 September 2015).
South Africa	Battery recycling	2002	Inhalation	Workers: 21 adult males 1 adult female	22	0	Dyosi S. Evaluation of preventative and control measures for lead exposure in a South African lead-acid battery recycling smelter. Journal of Occupational and Environmental Hygiene 2007;4:762-769.
South Africa	Lead recycling	2001	Inhalation	Overview of lead recycling	NA	NA	Joseph & Verwey. An overview of lead recycling in South Africa. Presented at UNCTAD workshop. Building national capacity in rapidly industrializing countries on sustainable management of recoverable material/resources, 20-22 Sept, Bangkok, Thailand.
South Africa	Cottage industry -subsistence fishing	NS	Inhalation	School children	160	0	Mathee et al. Lead exposure in young school children in South African subsistence fishing communities. Environmental Research 2013;126:184-191.

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South Africa	Cottage industry	2012	Inhalation	Workers, families and neighbours	NA	NA	Teare et al. The extent, nature and environmental health implication of cottage industries in Johannesburg, South Africa. International Journal of Environmental Research and Public Health 2015;12:1894-1901.
South Africa	Geophagia	NS	Ingestion	1 Female patient, 45 years	1	1	Woywodt & Kiss. Perforation of the sigmoid colon due to geophagia. Archives of Surgery 1999;134:88-89.
South Africa	Geophagia	NS	Ingestion	General information	NA	NA	Woywodt A. Geophagia: the history of earth eating. Journal of the Royal Society of Medicine 2002;95:143-146.
South Africa	Geophagia	NS	Ingestion	1 female patient, 29 years	1	0	McKenna D. Myopathy, hypokalaemia and pica (geophagia) in pregnancy. Ulster Medical Journal 2006;75:159-160.
South Africa	Geophagia	NS	Ingestion	Pregnant women	2	0	Meel BL. Geophagia in Transkei region of South Africa: case reports. African Health Sciences 2012;12:566-568.
South Africa	Geophagia	2010	Ingestion	Pregnant women 18 to 30 years	307	0	Mathee et al. A cross-sectional analytical study of geophagia practices and blood metal concentrations in pregnant women in Johannesburg, South Africa. South African Medical Journal 2014;104(8):568-573.
South Africa	Traditional medicine	NS	Ingestion	Plant and soil analysis	NA	NA	Olowoyo et al. Uptake and translocation of heavy metals by medicinal plants growing around a waste dump site in Pretoria, South Africa. South African Journal of Botany 2012;78:116-121.
South Africa	Traditional medicine	ABSTRACT	Ingestion	Review article	NA	NA	Street R. Heavy metals in medicinal plant products – An African perspective. South African Journal of Botany 2012;82;67–74.
South Africa	Traditional medicine	NS	Ingestion	Consumers	65	0	Steenkamp et al. Metal concentrations in plants and urine from patients treated with traditional remedies. Forensic Sci Int 2000;114:89-95. Forensic Science International 2000;114:89-95.
South Africa	Traditional medicine	2012	Ingestion	5 females, 3 males, 14-25 years of age	8	0	Mathee et al. Retrospective investigation of a lead poisoning outbreak from the consumption of an Ayurvedic medicine: Durban, South Africa. International Journal of Environmental Research and Public Health 2015;12:7804-7813.
South Africa	Environment	NS	Inhalation/ ingestion	Blood lead levels in children Analysis of shed teeth	226 children	0	White et al. Lead absorption in Cape children. South African Medical Journal 1982;62:799-802.
South Africa	Environment	NS	Inhalation/ ingestion	Pre-school children 4-6 years	323	0	Deveaux et al. Blood lead levels in preschool children in Cape Town. South African Medical Journal 1986;69:421-424.
South Africa	Environment	NS	Inhalation/ ingestion	General information	NA	NA	von Schirnding YE. Reducing environmental lead exposure – time to act. South African Medical Journal 1989;76(7):293-294.
South Africa	Environment	NA	Inhalation/ ingestion	General information	NA	NA	von Schirnding & Aucamp. Urbanisation and environmental health. South African Medical Journal 1991;79(8):414-415.
South Africa	Environment	NS	Inhalation/ ingestion	Grade 1 school children	104	0	von Schirnding et al. Factors associated with elevated blood lead levels in inner-city Cape Town children. South African Medical Journal 1991;79:454-456.
South Africa	Environmental and occupational	NA	Inhalation/ ingestion	General information	NA	NA	Myers & von Schirnding. Occupational and environmental epidemiology – similarities and contrasts. South African Medical Journal 1992;81(11):557-560.

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South Africa	Environment	NS	Inhalation/ ingestion	Maternal and cord blood analysis.	21	0	Chetty et al. Lead levels in maternal and umbilical cord blood at Kind Edward VIII Hospital, Durban. South African Medical Journal 1993;83:227.
South Africa	Environment -air -dust -traffic	NS	Inhalation	Air and dust analysis. Traffic density analysis	NA	NA	von Schirnding & Fuggle. A study of the distribution of urban environmental lead levels in Cape Town, South Africa. Science of the Total Environment 1996;187(1):1-8.
South Africa	Environment -lead plumbing and solder	NS	Ingestion	Tooth analysis of people buried between 1902 and 1922	28	NA	Grobler et al. Evidence of undue lead exposure in Cape Town before the advent of leaded petrol. South African Medical Journal 1996;86:169-171.
South Africa	Environment	1995	Inhalation/ ingestion	Children 8-10 years	>880	0	Nriagu et al. Lead poisoning of children in Africa, II. Kwazulu/Natal, South Africa. Science of the Total Environment 1997;197:1-11.
South Africa	Environment -street dust	NS	Inhalation	Dust lead analysis	NA	NA	Liggans & Nriagu. Lead poisoning of children in Africa, IV: Exposure to dust lead in primary schools in south-central Durban, South Africa. Science of the Total Environment 1998;221:117-126.
South Africa	Environment	NA	Inhalation/ ingestion	Policy brief	NA	NA	Mathee & von Schirnding. Environmental lead exposure and child health in South Africa. MRC Policy Brief 1999;3(Oct):1-2.
South Africa	Environment	NA	Inhalation/ ingestion	Review article	NA	NA	Tong et al. Environmental lead exposure: a public health problem of global dimensions. Bulletin of the World Health Organization 2000;78(9):1068-1077.
South Africa	Environment	NS	Inhalation/ ingestion	General information	NA	NA	Harper et al. The health impact of environmental pollutants: a special focus on lead exposure in South Africa. International Journal of Hygiene and Environmental Health 2003;206:315-322.
South Africa	Environment	NA	Inhalation/ ingestion	Air pollution analysis	NA	NA	Mathee & von Schirnding. Air quality and health in Greater Johannesburg. In: McGranahan G, Murray F. eds. Air Pollution & Health in Rapidly Developing Countries. Earthscan Publications Ltd, London UK, 2003.
South Africa	Environment	NS	Inhalation/ ingestion	Children	NA	NA	Mathee et al. Lead poisoning in South African children: the hazard is at home. Reviews on Environmental Health 2004;19:347-361.
South Africa	Environment -soil -water -stationery -ceramics -cosmetics	2000	Inhalation/ ingestion	Various items analysed	NA	NA	Okonkwo. Assessment of lead exposure in Thohoyandou, South Africa. The Environmentalist 2004;24:171-178.
South Africa	Environment -day care centres	NS	Inhalation/ ingestion	Time activity analysis Air, surface soil and indoor dust analysis Traffic density analysis	216 children	NA	John et al. Our children in day care: reducing exposure to environmental lead at day care centres. South African Journal of Science 2004;100:135-138.
South Africa	Environment	NA	Inhalation/ ingestion	Overview	NA	NA	Mathee et al. An overview of lead poisoning in South African children: The hazard is at home. Epidemiology 2005;16(5):S136. Presented at the 17th Annual ISEE Conference, 13-16 Sept, Johannesburg, South Africa.
South Africa	Environment	NS	Inhalation/ ingestion	Pregnant women, 17-43 years	120	0	Mathee et al. Limited awareness of lead hazards among pregnant women in South Africa. Epidemiology 2006;17:S196. Presented at the 18th Annual ISEE Conference, Paris, France.
South Africa	Environmental and occupational	2000	Inhalation/ ingestion	Children < 5years Adults > 30 years (Burden of disease investigation)	NA	NA	Norman et al. Estimating the burden of disease attributable to lead exposure in South Africa in 2000. South African Medical Journal 2007;97:773-780.

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South Africa	Environment	NS	Inhalation/ ingestion	Pregnant women	119	0	Haman et al. Low levels of awareness of lead hazards among pregnant women in Johannesburg. Medical Research Council Research Brief 2008.
South Africa	Environment	2005-2006	Inhalation/ ingestion	Maternal mothers	96	0	Röllin et al. Levels of toxic and essential metals in maternal and umbilical cord blood from selected areas of South Africa – results of a pilot study. Journal of Environmental Monitoring 2009;11:618-627.
South Africa	Environment	NS	Inhalation/ ingestion	Mother-newborn pairs – cord blood analysis and placenta permeability assessment	62	0	Rudge et al. The placenta as a barrier for toxic and essential elements in paired maternal and cord blood samples of South African delivering women. Journal of Environmental Monitoring 2009;11(7):1322-1330.
South Africa	Environment	2003	Inhalation	Girls, 13 years	682	0	Naicker et al. Lead exposure is associated with a delay in the onset of puberty in South African adolescent females: Findings from the Birth to Twenty cohort. Science of the Total Environment 2010;408:4949-4954.
South Africa	Environment	2003	Inhalation	13-year old children and their mothers	3 273	0	Naicker et al. Prenatal and adolescence blood lead levels in South Africa: Child, maternal and household risk factors in the Birth to Twenty cohort. Environmental Research 2010;110:355-362.
South Africa	Environment	NS	Inhalation/ ingestion	Maternal mothers	NS	NS	Röllin et al. Concentrations of toxic metals in blood and cord blood of delivering women from three Indian ocean coastal communities, South Africa. North-South research collaboration. Epidemiology 2011;20(6):S254-S255. Presented at the 23rd Annual ISEE Conference, 13-16 Sept, 2011, Barcelona, Spain.
South Africa	Environment	2003	Inhalation	Adolescents 13 years 487 boys and 554 girls	1 041	0	Naicker et al. Environmental lead exposure and socio-behavioural adjustment in the early teens: The birth to twenty cohort. Science of the Total Environment 2012;414:120-125.
South Africa	Environmental and occupational	NA	Ingestion/ inhalation	General information	NA	NA	Mathee A. Lead Poisoning. In: van Niekerk A, Suffla S, Seedat M (Eds.) Crime, violence and injury in South Africa: 21st century solutions for child safety. Psychological Society of South Africa (PsySSA), Houghton, South Africa 2012; Chapter 4:44-55.
South Africa	Environment	2007	Inhalation	Children 5 to 12 years (51% boys and 49% girls).	1 349	0	Naicker et al. Environmental lead – A public health challenge in South Africa. Epidemiology 2013;24(4):621-622.
South Africa	Environment -atmospheric (power plants, metal smelters and traffic)	NS	Inhalation	Analysis of street dust	NA	NA	Žibret et al. Metal content in street dust as a reflection of atmospheric dust emissions from coal power plants, metal smelters, and traffic. Environmental Science and Pollution Research 2013;20:4455-4468.
South Africa	Environment	2007-2008	Inhalation/ ingestion	Grade 1 children	1349	0	Naicker et al. A follow-up cross-sectional study of environmental lead exposure in early childhood in urban South Africa. South African Medical Journal 2013;103(12):935-938.
South Africa	Environment	1960-1998	Inhalation/ ingestion	Bone lead analysis	Skeletal remains of 101 adult males (72 black and 29 white individuals)	NA	Hess et al. Lead exposure in adult males in urban Transvaal Province, South Africa during the apartheid era. Plos ONE 2013;8:e58146.

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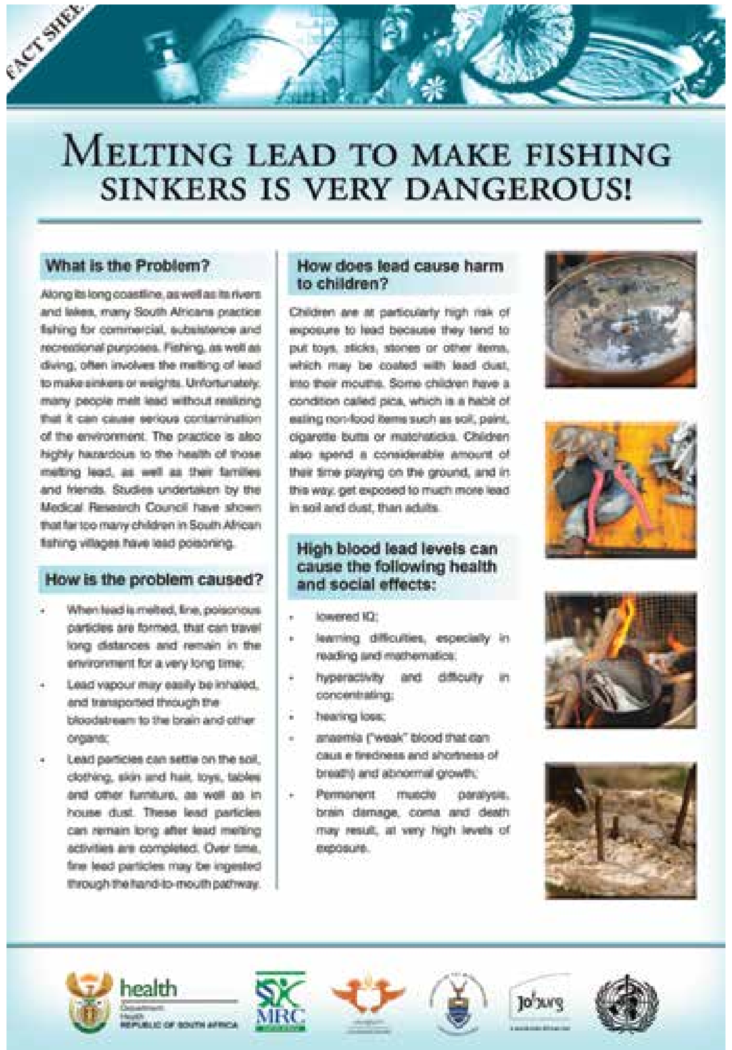
South Africa	Environment	NS	Inhalation/ ingestion	General information	NA	NA	Mathee A. Towards the prevention of lead exposure in South Africa: Contemporary and emerging challenges. NeuroToxicology 2014;45:220-223. Available from http://dx.doi.org/10.1016/j.neuro.2014.07.007 (accessed 24 August 2015)
South Africa	Environment -dust	NS	Inhalation	Study on behaviour change in order to reduce household dust – Women 16-50 years of age	27	0	Feit M et al. Using behaviour change to reduce child lead exposure in resource poor settings: A formative study. Health Education Research 2014;29:933-940. Available from: http://dx.doi.org/10.1093/her/cyu054 (accessed 24 August 2015.
South Africa	Food -fish (Moggel)	1994-1995	Ingestion	Fish analysis	NA	NA	Nussey et al. Bioaccumulation of chromium, manganese, nickel and lead in the tissues of the moggel, Labeo umbratus (Cyprinidae), from Witbank Dam, Mpumalanga. Water SA 2000;26:269-284.
South Africa	Food -African sharp-tooth catfish -Moggel	1994-1994	Ingestion	Fish analysis	NA	NA	Coetzee et al. Metal concentrations in Clarias gariepinus and Labeo umbratus from the Olifants and Klein Olifants River, Mpumalanga, South Africa: Zinc, copper, manganese, lead, chromium, nickel, aluminium and iron. Water SA 2002;28:433-448.
South Africa	Food -soil -vegetables	NS	Ingestion	Soil and vegetable analysis	NA	NA	Kootbodien et al. Heavy metal contamination in a school vegetable garden in Johannesburg. South African Medical Journal 2012;102:226-227.
South Africa	Food -bovine meat	NS	Ingestion	Organ, tissue and bone analysis of bovine meat	NA	NA	Ambushe et al. Assessment of levels of V, Cr, Mn, Sr, Cd, Pb, and U in bovine meat. South African Journal of Chemistry 2012;65:159-164.
South Africa	Food -water -soil -vegetables	NS	Ingestion	Irrigation water, soil and vegetable analysis	NA	NA	Malan et al. Heavy metals in the irrigation water, soils and vegetables in the Phillppi Horticultural area in the Western Cape Province of South Africa. Environmenta; Monitoring and Assessment 2015;187:4085.
South Africa	Food -fish	2010	Ingestion	Fish analysis	NA	NA	Jooste et al. Sharptooth catfish shows its metal: A case study of metal contamination at two impoundments in the Olifants River, Limpopo river system, South Africa. Ecotoxicology and Environmental Safety 2015;112:96-104.
Swaziland	Petrol	NS	Inhalation	School children 6-12 years	257	0	Okonkwo et al. Measurement of lead concentration in the hair of school children in the Manzini region, Swaziland. International Journal of Environmental Studies 1999;56:419-428.
Swaziland	Petrol	NS	Inhalation	School children 6-12 years	257	0	Okonkwo et al. Determination of urinary lead in school children in Manzini, Swaziland, Southern Africa. The Environmentalist 2001;21:205-209.
Togo	Mining -soil	1996	Inhalation	Analysis of soil from abandoned mine pits	NA	NA	Gnandi & Tobschall. Heavy metals distribution of soils around mining sites of cadmium-rich marine sedimentary phosphorites of Kpogamé and Hahotoé (southern Togo). Environmental Geology 2002;41:593-600.
Togo	Food -fish -crab -shrimp -seawater	NS	Ingestion	Analysis of marine fish, crustaceans, and seawater from mine-tailings marine outfall area	NA	NA	Gnandi et al. The impact of phosphate mine tailings on the bioaccumulation of heavy metals in marine fish and crustaceans from the coastal zone of Togo. Mine Water and the Environment 2006;25:56-62.
Togo	Food -cassava -Nile tilapia fish	2011-2012	Ingestion	Analysis of soil, water, cassava and fish	NA	NA	Bouka et al. Heavy metals concentration in soil, water, Manihot esculenta tuber and Oreochromis niloticus around phosphates exploitation area in Togo. Research Journal of Environmental Toxcology 2013;7:18-28.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Togo	Food -marine con-tamination	NS	Ingestion	Men and women who eat mainly seafood	440	0	Mamatchi et al. Oxidative stress in human due to metallic traces elements bioconcentration in three coastal villages near phosphate treat-ment factory in Togo. African Journal of Food Science and Technology 2013;4:141-147.
Uganda	Petrol	2009	Inhalation	Children 4-8 years	164	0	Graber et al. Childhood lead exposure after the phaseout of leaded gasoline: An ecolog-ical study of school-age children in Kampala, Uganda. Environmental Health Perspectives 2010;118:884-889.
Uganda	Environment	NS	Inhalation/ ingestion	Food analysis Stool analysis of 4 children, 3-4 years. Bone analysis from 21 child necropsies.	NA	NA	Barltrop et al. Exposure of children to lead in Uganda. Archives of Disease in Childhood 1973;48:642-644.
Uganda	Environment -Landfill	2010	Inhalation/ ingestion	School-aged children	163	NS	Mount Sinai Hospital. Mount Sinai researchers find lead poisoning highly prevalent among school-aged children in Uganda. Available from: http://www.mountsinai.org/about-us/newsroom/press-releases/lead-poison-ing-uganda (accessed 21 August 2015).
Uganda	Food -vegetables	2003	Ingestion	Water, soil and plant analysis	NA	NA	Nabulo et al. Assessment of lead cadmium, and zinc contamination of roadside soils, surface films, and vegetables in Kampala City, Uganda. Environmental Research 2006;101:42-52.
Uganda	Food -vegetables	NS	Ingestion	Plant analysis	NA	NA	Nabulo et al. Assessing risk to human health from tropical leafy vegetables grown on contaminated urban soils. Science of the Total Environment 2010;408:5338-5351.
Uganda	Food -vegetables		Ingestion	Plant analysis	NA	NA	Nabulo et al. Does consumption of leafy vegetable grown in peri-urban pose a risk to human health? Environmental Pollution 2012;162:389-398.
United Re-public of Tanzania	Petrol	2002	Inhalation	Analysis of sulphur dioxide, particulate matter, and particulate lead.	NA	NA	Jackson MM. Roadside concentration of gaseous and particulate matter pollutants and risk assessment in Dar-es-Salaam, Tanzania. Environmental Monitoring and Assessment 2005;104:385-407.
United Re-public of Tanzania	Cottage industry -welding -spray painting -woodwork -metalwork	1994-1996	Inhalation	Focus group discus-sions with workers	310	NA	Rongo et al. Occupational exposure and health problems in small-scale industry workers in Dar-es-Salaam, Tanzania: a situation analysis. Occupational Medicine 2004;54:42-46.
United Re-public of Tanzania	Geophagia	1995-1997	Ingestion	HIV-infected pregnant women	971	0	Kawai et al. Geophagy (soil-eating) in relation to anemia and helminth infection among HIV-infected pregnant women in Tanzania. American Journal of Tropical Medicine and Hygiene 2009;80:36-43.
United Re-public of Tanzania	Geophagia	2012	Ingestion	Pregnant women, 15-49 years	340	0	Nyanza et al. Geophagy practices and the content of chemical elements in the soil eaten by pregnant women in artisanal and small scale gold mining communities in Tanzania. BMC Pregnancy and Childbirth 2014;14:144.
Republic of Tanzania	Environment	NS	Inhalation/ ingestion	Cord blood of newborn babies	150	0	Azayo et al. Lead levels in women at delivery at the Muhimbili National Hospital: A public health problem. Journal of Tropical Pediatrics 2009;55:138-139.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Republic of Tanzania	Environment	2012	Inhalation/ ingestion	School-age children Pregnant women	44 60	0	Bisanz et al. Randomized open-label pilot study of the influence of probiotics and the gut microbiome on toxic metal levels in Tanzanian pregnant women and school children. mBio 2014;5:e01580-14. Doi:10.1128/mBio.01580-14.
Republic of Tanzania	Food -vegetables -cereal -legume grains	NS	Ingestion	Analysis of water, soil, vegetables dry cereal and legume grains	NA	NA	Magoha et al. Lead pollution in the envi-ronment and contamination in food around Mwanza, Tanzania. Journal of Applied Biosci-ences 2008;9:396-402.
Zambia	Petrol	NS	Inhalation	Analysis of roadside soil	NA	NA	Makondo et al. Lead deposition from mobile sources: a case study of Ndola-Kitwe dual carriage highway. American Journal of Envi-ronmental Protection 2013;2:128-133.
Zambia	Mining -Kabwe	1991-1992	Inhalation	Soil analysis	NA	NA	Tembo et al. Distribution of copper, lead, cadmium and zinc concentrations in soils around Kabwe town in Zambia. Chemosphere 2006;63:497–501
Zambia	Mining -Kabwe	2008	Inhalation	General information	NA	NA	Geotimes. Mining leaves nasty legacy in Zambia. Available from: http://www.geotimes.org/jan08/article.html?id=nn_zambia.html (accessed 21 August 2015).
Zambia	Mining -Kabwe	2009	Inhalation/ ingestion	Soil and animal study	NA	NA	Nakayama et al. Metal and metalloid contam-ination in roadside soil and wild rats around a Pb-Zn mine in Kabwe, Zambia. Environmental Pollution 2011;159:175-181.
Zambia	-Mining -Kabwe	NS	Ingestion	Animal study	NA	NA	Yabe et al. Uptake of lead, cadmium and other metals in the liver and kidneys of cattle near a lead-zinc mine in Kabwe, Zambia. Environmental Toxicology and Chemistry 2011;30:1892-1897.
Zambia	Mining -Kabwe	NS	Ingestion	Animal study	NA	NA	Yabe et al. Metal distribution in tissues of free-range chickens near a lead-zinc mine in Kabwe. Environmental Toxicology and Chem-istry 2013;32:189-192.
Zambia	Mining -Kabwe	2014	Inhalation	Children 2-8 years	196	NS	Centers for Disease Control and Preven-tion (CDC). Notes from the field: Severe environmental contamination and elevated blood lead levels among children – Zambia, 2014. Available from http://www.cdc.gov/mmwr/preview/mmwrhtml/mm6344a7.htm (accessed 29 July 2015).
Zambia	Mining -Kabwe	2012	Inhalation/ ingestion	Children <7 years	246	NS	Yabe et al. Lead poisoning in children from townships in the vicinity of a lead-zinc mine in Kabwe, Zambia. Chemosphere 2015;119:941-947.
Zambia	Mining -Kabwe	ABSTRACT	Inhalation/ ingestion	Animal study	NA	NA	Ikenaka et al. Effects of environmental lead contamination on cattle in a lead/zinc mining area: Changes in cattle immune systems on exposure to lead in vivo and in vitro. Environmental Toxicology and Chemistry 2012;31:2300-2305.
Zambia	Mining -Kabwe -Chingola	2008-2009	Inhalation/ ingestion	Rat study	NA	NA	Nakayama et al. Accumulation and biological effects of metals in wild rats in mining areas of Zambia. Environmental Monitoring and Assessment 2013;185:4907-4918.
Zambia	Mining -Kabwe -Copperbelt -Lusaka	2008	Inhalation/ ingestion	River and lake sedi-ments and soil analysis	NA	NA	Ikenaka et al. Heavy metal contamination of soil and sediment in Zambia. African Journal of Environmental Science and Technology 2010;4:729-739.

Country	Setting	Year of Occurrence	Pathway of exposure	Population affected/ Investigation	Number of individuals involved	Number of deaths	Reference
Zambia	Mining -Copperbelt	NS	Ingestion	Kafue River sediment and fish analysis	NA	NA	Mwase et al. Effects on tropical fish of soil sediments from Kafue River, Zambia. Bulletin of Environmental Contamination and Toxicology 1998;61:96-101.
Zambia	Mining -Copperbelt	NS	Ingestion	Kafue River water and fish analysis	NA	NA	Norrgren et al. Environmental monitoring of the Kafue River, located in the Copperbelt, Zambia. Archives of Environmental Contamination and Toxicology 2000;38:334-341.
Zambia	Mining -Copperbelt	NS	Ingestion	Kafue River water and fish analysis, and Lechwe liver analysis.	NA	NA	Syakalima et al. Bioaccumulation of lead in wildlife dependent on the contaminated environment of the Kafue Flats. Bulletin of Environmental Contamination and Toxicology 2001;67:438-445.
Zambia	Mining -Copperbelt	2008	Inhalation	Tree core and soil analysis	NA	NA	Mihaljevič et al. Lead isotopic and metallic pollution record in tree rings from the Copperbelt mining-smelting area, Zambia. Water, Air and Soil Pollution 2011;216:657-668.
Zambia	Mining -Copperbelt	NS	Inhalation	Soil analysis	NA	NA	Ettler et al. Differences in the bioaccessibility of metals/metalloids in soils from mining and smelting areas (Copperbelt, Zambia). Journal of Geochemical Exploration 2012;113:68-75.
Zimbabwe	Environment -air quality	NS	Inhalation	Lichen analysis	NA	NA	Mupa et al. Lead content of lichens in metropolitan Harare, Zimbabwe. Air quality and health risk implications. Greener Journal of Environmental Management and Public Safety. 2013;2:75-82.


FACT SHEET

Melting lead to make fishing sinkers is very dangerous!

What is the Problem?

Along its long coastline, as well as its rivers and lakes, many South Africans practice fishing for commercial, subsistence and recreational purposes. Fishing, as well as diving, often involves the melting of lead to make sinkers or weights. Unfortunately, many people melt lead without realizing that it can cause serious contamination of the environment. The practice is also highly hazardous to the health of those melting lead, as well as their families and friends. Studies undertaken by the Medical Research Council have shown that far too many children in South African fishing villages have lead poisoning.

How is the problem caused?

- When lead is melted, fine, poisonous particles are formed, that can travel long distances and remain in the environment for a very long time;
- Lead vapour may easily be inhaled, and transported through the bloodstream to the brain and other organs;
- Lead particles can settle on the soil, clothing, skin and hair, toys, tables and other furniture, as well as in house dust. These lead particles can remain long after lead melting activities are completed. Over time, fine lead particles may be ingested through the hand-to-mouth pathway.

How does lead cause harm to children?

Children are at particularly high risk of exposure to lead because they tend to put toys, sticks, stones or other items, which may be coated with lead dust, into their mouths. Some children have a condition called pica, which is a habit of eating non-food items such as soil, paint, cigarette butts or matchsticks. Children also spend a considerable amount of their time playing on the ground, and in this way, get exposed to much more lead in soil and dust, than adults.

High blood lead levels can cause the following health and social effects:

- lowered IQ;
- learning difficulties, especially in reading and mathematics;
- hyperactivity and difficulty in concentrating;
- hearing loss;
- anaemia ("weak" blood that can caus e tiredness and shortness of breath) and abnormal growth;
- Permanent muscle paralysis, brain damage, coma and death may result, at very high levels of exposure.

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