Chapter 1:

GENERAL INTRODUCTION

1.1 Lead Sources, Uses and Impact in the Environment:

Lead (Pb), a naturally occurring metallic element that exists in the environment through several mechanisms such as volcanic emissions, geochemical weathering, mining and industrial activities. A significant amount of lead pollution comes from human activities to extract and to exploit the metal.[1,2] The adverse effects of lead poisoning were first acknowledged in the United States in the early 20th century as a result of the rapid industrial development. Despite this knowledge, lead was included as an ingredient of petrol in the 1920's and continued to be used in paint until the 1970s.[3,4]

Lead is used for different purposes, but most importantly it is used in the production of some types of batteries, production of ammunition, metal products such as sheet lead, solder, brass and bronze products, pipes and in ceramic glazes.[5] Other lead uses which may cause harm to humans and the environment include its use in fishing sinkers, coffee machines with brass and soldered plumbing; coffin lining and burial stone inlays; collapsible tubes (such as art paint, ointments, toothpaste); crayons; crystal glassware; curtain weight and battery repair and recycling.[6,7]

Tetraethyl lead and tetramethyl lead compounds were once used as petrol additives to increase octane rating worldwide. Their use was however, phased out in the United States in the 1980s, and lead was banned for use in gasoline for motor vehicles beginning January 1, 1996.[5] As a result of the use of these chemicals motor vehicles emissions of lead contributed to environmental contamination due to its non-biodegradable nature and long biological half-life. According to the Agency for Toxic Substances and Registry, tetraethyl lead may still be used in gasoline for off-road vehicles and airplanes.[5]

Unexpected sources of lead continue to be identified in developing countries such as an outbreak of lead poisoning in Egypt that was caused by lead solder used in flour mill grinding stones;[7] lead contaminated spices; [8] necklaces and cosmetic powders.[9] These and many other sources of lead exposure identified in developing nations,[7] call for local specific inventories of lead sources.

Such inventories would provide the necessary input for cost benefit analysis prior to the implementation of a lead reduction programs.

1.2 Lead Use in Botswana

Up until December 2005, Botswana used lead as an additive in petrol and about 95% of petrol used was leaded.[10] The use of lead in fuel was reported to be equivalent to 106 tons of lead per year.[10] It is also used as stabilizer in PVC-manufacturing.[11,12] Lead and its compounds are used in paints to enhance and to make paints more durable, corrosion resistant and to improve drying. Recent research from Nigeria has shown that latex or water-based paints contain lower levels of lead as compared to enamel (oil-based paints). According to this study, 84% of the enamel paints tested exceeded the paint regulatory level of the United States' Consumer Products Safety Commission.[13]

While the main distributors of paint in Botswana report that they do not use lead-based paint pigments currently, it is not clear when these distributors stopped using lead-based paint pigments. In South Africa, (where most of the paints used in Botswana originate from), a voluntary agreement was reached with the paint industry to limit the use of leaded pigments in the 1970's.[14] It is however not clear what the situation is in Botswana. While there is no data to ascertain whether paint used in Botswana is lead-free, surveys in the neighbouring South Africa measuring lead levels in paint from classrooms of schools in the Johannesburg city primary schools showed that half the classrooms had lead concentrations above international guidelines and standards.[15] Based on these finding, it is therefore highly likely that painted surfaces in Botswana have lead based paint.

Other practices which involve the uses of lead or lead containing products that have not been documented but observed at household level in Botswana include the backyard battery repairs, use of dry cell battery contents or used motor vehicle brake fluid to treat skin conditions such as psoriasis, ringworm or even open wounds. Used car oil is also reported to be applied on newly built homes to condition new cement floors for polishing. Other undocumented practices with a potential for lead exposure in Botswana include mending cracked/broken cooking pots with lead solder, particularly in the rural areas. Practices such as having backyard repair shops for batteries which are common in lower income families in Botswana may also expose household members

to lead and other heavy metals as well as elevated levels of these pollutants in soil and house dust.[16] Car lubricants from backyard repair shops may contain lead naphthenate ($Pb(C_7H_{12}O_2)$; an additive which is also used in wood preservative; insecticide; paint and varnish drier. Gear oil is one of the lubricants known to contain high levels of lead.[17] These may be absorbed through the skin among repair workers as well as exposing families of such workers from the oils spilled in clothing and taken home for laundry. [17-19]

Published data on lead levels in soil of certain parts of Botswana is reported to be moderately high (222mg/kg).[20] This could have adverse effects on the health of pregnant women who are known to commonly ingest non-food items such as surface soils during pregnancy. A study carried out recently by Mbongwe and colleagues (2010), revealed elevated blood-lead levels among children aged 1-6 in the City of Gaborone. In this study, 32% of children aged 1-6 old had blood lead levels above the CDC critical value of 10µg/dL of blood.[21] This finding confirms the need to study lead exposure pathways for women who could be contributing to the foetal lead load. As Fewtrell (2003) has observed, an inventory of the main sources of exposure to lead is required at country level to enable selection of the most suitable interventions for reducing the disease burden.[22]

1.3 Lead Toxicity:

Lead is a highly toxic substance and no threshold has been identified. While the Centers for Disease Control and Prevention has set a screening guideline of 10µg/dL,[23] it should be interpreted as a risk management tool and not a threshold level at which adverse effects do not occur. Epidemiological and toxicological studies continue to show that low levels of exposure to lead can over time damage several organs in the human body such as the heart, the brain, kidneys, etc. The following is a brief account of some of the detrimental health effects associated with lead exposure:

1.3.1 Central nervous system

Lead binds efficiently to sulfhydryl groups of proteins and as a result of its toxicity it distorts enzymes and structural proteins in different body organs including the central nervous system. Currently, attention has been devoted to the association between elevated blood lead levels and effects on cognitive and behavioural development of the central nervous system (CNS) of infants

and children.[24-26] In the past attention was focused mainly on encephalopathy amongst children with blood lead levels equalling or in excess of 80µg/dl. This was characterized clinically by ataxia, coma and convulsions and was often fatal. Survivors suffered a number of neurological complications such as mental retardation, deafness, blindness and convulsions.[27] Recent research has also linked lead exposure among adults with adverse health effects. For example, a significant proportion of what has been considered as "normal" age-related cognitive decline is currently being apportioned to past exposure to neurotoxicants such as lead.[28] In children neurotoxicity at very low exposure levels have shown to result in deficits in IQ, reaction time, visual motor integration, fine motor skills etc.[29-31]

1.3.2 Cardiovascular system

The relationship between elevated blood pressure and lead exposure has been raised by several researchers.[32] While not all researchers agree on this relationship,[33-35] a considerable number of studies on the other hand agree that there is a strong association between both blood-lead and bone lead levels and the prevalence of hypertension in the adult and adolescent population.[36-40]

1.3.3 Heme Synthesis

Anaemia is one of the most prominent, and most extensively studied effects of lead toxicity. Lead intoxication may produce anaemia both by inhibiting heme synthesis and by accelerating erythrocyte destruction. Lead affects the hematopoietic system at several levels. These include effects on heme and globin synthesis and on erythrocyte formation and function.[41] Due to its toxicity, lead profoundly impairs heme biosynthesis. This is characterized by elevated levels of blood δ-aminolevulinic acid (ALA) and Zinc protoporphyrin (ZPP) and urinary ALA and coproporphyrin(CUP).[41,42] On this account, lead has been also identified as a cause for secondary porphyria resulting from heme synthesis inhibition.

1.3.4 Bone Metabolism

Bone is a major target tissue for lead storage and may affect lead metabolism. There is ample evidence that the human skeleton begins to accumulate lead during fetal development and continues to about 60 years of age.[43] Research dating as far back as 1932 has recognized that lead follows the movement of calcium in the body and as a result the physiologic regulators of

calcium metabolism affect the behaviour of lead in a qualitatively similar manner.[44,45] There is a general conclusion that lead is incorporated into the crystalline structure of bone where it replaces calcium ions at some sites. Approximately 90-95% of the total body lead burden is deposited in the adult skeleton,[46] while in children bone deposition is slightly lower (approximately 80-85%).[47] During times of physiological and pathological stress such as pregnancy, lactation, osteoporosis and renal disease, lead is mobilized into the blood stream thereby increasing not only the risks to the child but to the mother as well.[48-50]

1.4 Lead Exposure and Women's Health- A Challenge for Developing Nations

Lead exposure plays a major role in the epidemiology of spontaneous abortion[51] and hypertension.[39] Lead is vascular active and causes elevations in both systolic and diastolic blood pressure. Elevations in maternal blood pressure during pregnancy is a cause of concern for the mother and is a known risk factor for adverse pregnancy outcome, particularly in the form of retarded fetal growth that is itself a risk factor for adverse developmental effects.[52]

The general population is exposed to trace amounts of lead through air, soil, household dust, food, drinking water and various consumer products. Lead exposure pathways for pregnant women are unique and often different from children and other adults. Pregnant women have additional sources of exposure which often involve pica behaviour - an intentional ingestion of non-food items. Shannon (2003) and Klitzman et al. (2002) have observed that severe lead poisoning resulting in blood-lead levels equal to or exceeding 45µg/dL in pregnant women seem more likely to occur due to intentional pica.[53,54] Most pregnant women with elevated blood lead levels ingested soil, clay or pottery with very few cases of ingested paint chips. According to Shannon (2003) home renovation and the use of crushed bone meal were additional sources of lead exposure.[53]

Geophagia, the intentional ingestion of earths, is usually associated with cultural practices and personal habits. The ingested earth or clay is typically harvested from 2-3 feet below the surface. These clays are primarily from known and usually uncontaminated sources.[55,56] Soil pica is on the other hand recurrent ingestion of surface soil and is an important source of lead exposure. These practices have been observed among Mexicans and West Africans who have immigrated to the US.[57] Even though no studies have been carried out in Botswana, such practices have been

observed in women both in urban and rural areas. Observations of women ingesting surface soil (particularly from anthills/ant mounds) have been noted in urban areas as well. In a New York study women were likely to purchase such soils from areas where they were reared that was brought by visiting relatives.[57]

While the incidence of pica, particularly in developed countries is not known, research has shown that specific groups of women are at high risk. There is consensus.[54-56] that:

a) more information needs to be gathered in order to understand certain cultural behaviour during pregnancy;

b) there is need to understand pica as it occurs among various cultural groups especially the nature of pica use, types of materials ingested, availability of materials and cultural attitudes toward pica within particular communities.

1.5 Study Rationale

Most of the research on lead and its effects on public health have been carried out in developed countries. As a result, stringent regulatory measures are put in place to control human and environmental exposures to lead. Such measures have included the phasing out/ banning of leaded petrol; removal of leaded pipes or pH control of water; removal of leaded paints from housing and buildings; etc. Developed nations have also been able to establish the burden of illness due to lead exposure (from prevalence studies as well as studies to identify risk factors for different communities).[58-60] Another intervention which is a result of lead research in developed nations is standard screening questionnaire such as the one developed by the Centers for Disease Control and Prevention (CDC).[61,62] It is evident that Botswana, like many other developing nations, have lagged behind in terms of research that would inform policy action or priority interventions such as the ones just mentioned above to prevent or control environmental and human exposures to lead.

Ideally, one would recommend that Botswana needs not "reinvent the wheel" but use research done in developed countries to initiate policy actions and intervention programs such as blood lead screening or even adopt the CDC lead screening questionnaires for different target groups in order to minimize costs. However, such an approach is not possible due to several reasons: a)

developing nations face competing priorities for funding and other resources and as a result, universal blood screening for lead among all pregnant women would be impossible to implement. As a result, the need to come up with interventions that are affordable, efficient and appropriate for developing nations such as Botswana cannot be overemphasized; b) lead sources and exposure risks in developed nations may not be the same as those in developing nations due to social, economic, cultural and lifestyle factors.[63-66] It is therefore not practical to apply the findings of research from developed nations to developing countries situations universally. For example; exposure to leaded petrol may have been the most important sources of lead for the general public but for pregnant women the dominant exposure pathway (and a priority issue for policy action) may be soil pica, application of battery contents or brake fluid on skin to "cure ailments" or ingestion of folk remedies from polluted areas. Of greater importance is the fact that a reasonable number of studies have monitored pica behaviour during pregnancy. However, very few of such studies have explored the association of lead exposure with pica during pregnancy and yet pica is a common phenomenon in African and other developing nations. This thinking is supported by the Fewtrell (2003), who argues that potential sources of lead may be different both within and between countries.[22] c) It is common knowledge that due to poverty, developing countries have become a "dumping ground" for products that are highly regulated in developed nations. This is a result of the limited or lack of access to information on hazardous products as well as the lack of stringent regulations and protocols that control the import of consumer products that may contain lead and other hazardous substances. There is evidence that even in developed nations where there is capacity for research as well as access to information, lead containing products are still reported to be on the increase.[67-69] Globally the burden of disease from lead is more meaningfully assessed at local (i.e. regional or country) level because lead use is often localized. Fewtrell (2003) further argues that assessments of the role of lead at global level only account for "general population" exposures and have lacked the inclusion of exposures in high risk groups such as women, neonates and young children.[22]

1.6 Research Question

This research attempts to find out if lead exposure screening interventions can be used to isolate, predict and prevent potential sources of lead and risks during pregnancy and after delivery.

1.7 Aims

This thesis aims to achieve the following:

a) to develop a clinical assessment tool for lead exposure levels during pregnancy and after delivery
b) to develop a policy brief, develop guidelines for lead exposure risks among women of reproductive age for use by health care workers, and an awareness leaflet on lead for pregnant women.

Specific objectives are to:

i) To determine blood lead levels during pregnancy and after delivery in the Serowe Palapye Central Administrative District

ii) To develop a model for predicting lead exposure levels during pregnancy and after delivery

iii) To identify environmental exposure sources for lead in women of reproductive age

iv) To assess pregnancy related behaviours and practices that may have an influence on the severity of lead poisoning among women of reproductive age

v) develop a clinical assessment tool for screening possible maternal exposure to lead during pregnancy and after delivery.

1.8 Thesis structure and outline

There is ample evidence on lead exposure sources and its effects on public health, particularly among children in developed countries. As a result lead is currently subject to several risk management initiatives that are directed toward consumer products, cosmetics, drinking water, food and other products. Such initiatives have contributed to declines of lead levels in environmental media and in the general population. There is however an emergence of new sources of lead poisoning resulting from sources that were not previously thought of such as adult pica behaviour, imported condiments, recreation and domestic items, pellets and bullets, etc. Only one study has comprehensively reviewed lead poisoning as a result of atypical sources

in children in the United States of America. Interestingly, the majority of the cases in the review presented children who were asymptomatic and diagnosed only on routine screening with elevated BLLs. There is therefore a knowledge gap on atypical sources of lead poisoning in the general public, particularly in developing countries. Chapter 2 therefore systematically reviews literature on uncommon sources of lead poisoning in the public with an objective to identify population groups at the most risk, commonly reported sources of lead poisoning and the country of origin where the poisoning occurred and the proportion of lead poisoning cases from uncommon sources affecting pregnant women compared to the general population. Having reviewed common and uncommon lead exposure sources and gaps in knowledge, particularly in developing countries, the next logical step would be to assess risk behaviours and practices of pregnant women that could potentially expose them to lead (Chapter 3) and environmental sources of importance (chapter 4). This is in light of the evident limited data unique to Botswana, Understanding the behaviours and practices of pregnant women will be useful in designing interventions at individual and community levels, and will form the basis for screening lead exposure during pregnancy and after delivery. Chapter 4 is important to inform policy development for lead exposure. Chapter 5 will focus on measurement of blood lead levels from the first to the third trimesters of pregnancy. The focus will be on establishing whether there are significant changes at each trimester of pregnancy and whether geographical locations have an effect on blood lead levels. Having identified potential environmental and behaviour risks for lead exposure, assessed lead concentrations during pregnancy and in the environmental media and implication for potential adverse effects during pregnancy, Chapter 6 will focus on identifying factors that are associated with lead exposure during pregnancy and attempt to construct statistical models that can guide the development of an assessment tool that can be used for screening lead exposure levels during pregnancy and after delivery. Chapter 7 will discuss the interventions developed for lead prevention for the different target groups and the processes of validations used to develop the interventions. The final chapter (Chapter 8) will focus on the general discussion, research recommendations, conclusions and limitations of the study.

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Chapter 2

Uncommon Sources of Lead Poisoning: an Emerging Public Health Threat with Life-long Implications – A Systematic Review of Literature

2.1 ABSTRACT

This review identifies uncommon sources of lead poisoning in the general public and segments of the population most affected. Data was retrieved from CINAHL, Medline, Academic Search Premier and AltHealth websites to systematically review case studies, case reports and original journal articles on lead poisoning from uncommon sources of lead poisoning. Forty (40) publications documenting 71 incidents of lead poisoning were retrieved. The incidents were grouped into household products; bullets and pellets; folk remedies, spices and religious powders; drug addiction and related practices and ingestion of miscellaneous non-food items. About 28% and 72% of lead poisoning incidents occurred in children and adults respectively. Women were the most affected (46%) followed by men (25%) and boys (21%). While most cases were identified in developed countries where systems are in place to screen lead exposure, the country of origin of the poisoned individuals were from developing countries. This review reveals gaps in knowledge on lead exposure sources in developing countries due to limited research. It further points to a holistic approach to addressing lead poisoning exposures from all sources that may present life-long negative impacts on the health, safety and well-being of general population. It is recommend that strong public awareness interventions are implemented on uncommon sources of lead poisoning to avoid cumulative life-long lead doses that may affect unborn children. This review further reveals lead poisoning diagnosis as a challenge. Sensitization of health professionals on the symptoms of acute lead poisoning for early detection and development of awareness initiatives for the public is recommended. This is the first systematic review of lead on uncommon sources of lead poisoning addressing the general public.

Key words: Lead poisoning, adults, children, uncommon sources, folk remedies

2.2 INTRODUCTION

Lead is a toxic heavy metal that affects virtually every system in the body.[1,2] The most important of the many systems affected by lead is the central nervous system (CNS). The neurotoxic effects of lead are so far the best understood and extensively studied.[3-5] Lead disrupts the main structural components of the blood–brain barrier through primary injury of astrocytes and secondary damage to endothelial microvasculature.[5] Attention has been devoted to the association between elevated blood lead levels and effects on cognitive and behavioral development of the CNS of infants and children.[2,6-8] Exposure of children even to very low levels of lead result with deficits in IQ, reaction time, visual motor integration, fine motor skills and others.[9,10] Lead exposure equally affects the adult population. The relationship between elevated blood pressure and lead exposure has been reported by several researchers. A meta-analysis of 31 studies carried out by Nawrot and others in 2002, revealed that a two-fold increase in blood-lead level gave rise to an increase in blood pressure on an average of 1.0 mmHg (0.5-1.4 mmHg) systolic and 0.6 mm Hg (0.4-0.8 mmHg) diastolic.[11] While not all researchers agree on this relationship,[12-15] a considerable number of studies show a strong association between both blood-lead and bone lead levels and the prevalence of hypertension in the adult and adolescent population.[16-21] Lead intoxication may produce anaemia both by inhibiting heme synthesis and by accelerating erythrocyte destruction. Lead affects the hematopoietic system at several levels including effects on heme and globin synthesis and on erythrocyte formation and function.[22] Acute lead poisoning has been associated with renal failure.[23] A longitudinal study of renal function and lead levels in middle-aged and elderly people showed that a 10-fold increase in blood lead level predicted a decline in renal function equivalent to that caused by 20 years of aging. [24]

Bone is a major target tissue for lead storage and may affect lead metabolism. It is believed that the human skeleton begins to accumulate lead during foetal development and continues to about 60 years of age.[25-27] Approximately 90-95% of the total body lead burden is deposited in the adult skeleton.[28] while in children bone deposition is slightly lower (approximately 80-85%).[28-30] Lead also has adverse effects on both male and female reproduction.[31,32]

Children are more vulnerable because they absorb lead 5–10 times more efficiently than adults and have greater exposure because of their exploratory behavior and frequent hand-to-mouth activity.[1, 33] Not only does the universal hand-to-mouth activity of children make children more

vulnerable to lead exposure than adults, but children's guts absorb lead more readily than an adult's; and the developing CNS is more vulnerable to toxicants than adults CNS.[33] Life-long impacts of lead exposure in children include a seven-fold increase in the rate of high school failure and six-fold increase in reading disability,[3] antisocial behavior and juvenile delinquency.[34,35] Chronic exposure of children may continue into adulthood, therefore contributing to the next generation lead exposure burden.

Pregnant women and their fetuses constitute another high risk group.[36] Lead exposure pathways for pregnant women are unique and often different from other adults. Additional sources of exposure for this group often involve intentional ingestion of non-food items. Shannon.[37] and Klitzman *et al.* [38] have observed that severe lead poisoning of blood-lead levels equal to or exceeding 45 µg/dl in pregnant women seem more likely to occur due to ingestion of soil, clay or pottery with very few cases of ingested paint chips. Women of reproductive age who have had significant lead exposures may experience decrease in fertility,[37] preterm delivery and low birth weight.[38] Pregnancy also accelerates the release of lead stored in the woman's bones to other parts of the body.[39-42]

Several studies suggest that maternal serum lead levels increase in pregnancy rising overall by 20-30%.[43] Because lead is freely transported across the placenta,[44,45] fetuses of mothers with high body lead content are potentially exposed to significant concentrations of lead during the course of the pregnancy.[43] This can result in damage to the developing fetus in any trimester, in part due to the immature fetal blood–brain barrier[46,47] and may have lifelong negative impacts on the woman and the unborn child.[28,48-50] Accumulated lead can cause problems throughout a woman's life. For example, lead may increase women's risk of heart disease, especially after menopause, when bones begin to thin and lead leaches back into the blood.[28,51] Literature suggests that women who survived lead poisoning as children are three times as likely as other mothers to have children with learning disabilities.[52]

The general population is exposed to trace amounts of lead through air, soil, household dust, food, drinking water and various consumer products.[1] Lead-based paint has been found to be the most widespread and harmful high-dose source of lead exposure for children.[53-56] Pica, the repeated ingestion of non-food substances, has been found to have a major contribution to lead

poisoning in children.[57,58] Medical literature points to children being exposed to uncommon sources of lead such as fashion accessories, folk remedies, household and recreational items, candies and pellets.[59] In adults 20%–70% of ingested lead and nearly 100% of inhaled lead enters the blood.[36] Adult lead poisoning has over the years been apportioned to occupational activities.[23] However, recent cases of acute lead poisoning from uncommon sources such as leaded dishware, bootlegged moonshine liquor, certain cosmetics, and folk remedies have been reported.[23]

This review summarizes published reports on acute lead poisoning and elevated BLLs from uncommon sources. The review excludes reports from the common lead-based paint ingestions, exposure to leaded gasoline, lead-soldered pipes, and occupational exposure. The objective is to identify knowledge gaps on uncommon sources of lead poisoning, particularly in the context of developing countries and increase awareness regarding uncommon sources of lead exposure. Reviewed data will be used to advise on policy formulation recommendations for the identification and removal of uncommon lead sources based on reported cases of lead poisoning. This review can also serve as guide for public health professionals who are confronted with the task of identifying and isolating sources of environmental lead exposures in the general public particularly for high risk groups such as women of reproductive age and children, which may not have otherwise come to light.

2.3 METHODS

Literature was retrieved from Medline, CINAHL, Academic Search Premier, and AltHealth for articles published between 2000 and 2011 inclusive. Combinations of the following terms were used: *lead poisoning, heavy metal, blood lead levels, adult, children, women, case reports, case series*. A further search for relevant published reports from the authors' files and bibliographies of retrieved papers was done (refer to figure 2). Clinical case reports, case series, original journals and other epidemiologic studies which described cases of acute lead poisoning and elevated blood lead levels ($\geq$ 10µg/dl) in the general population were included. Selected articles were only those that contained original data of the actual case, reflecting the age of the individual, measured blood lead levels (BLLs) and the source of lead exposure. The identified source of lead poisoning had to be other than the typical lead-paint chips or dust exposure and exposure from occupational or industrial settings. Reports that had unclear causes or without any

confirmed source of lead exposure were not included. For the cases meeting the selection criteria, information was extracted on the patient's age, sex, source of lead poisoning, lead-source concentration, highest reported BLL, presenting symptoms, intervention, and case outcome.

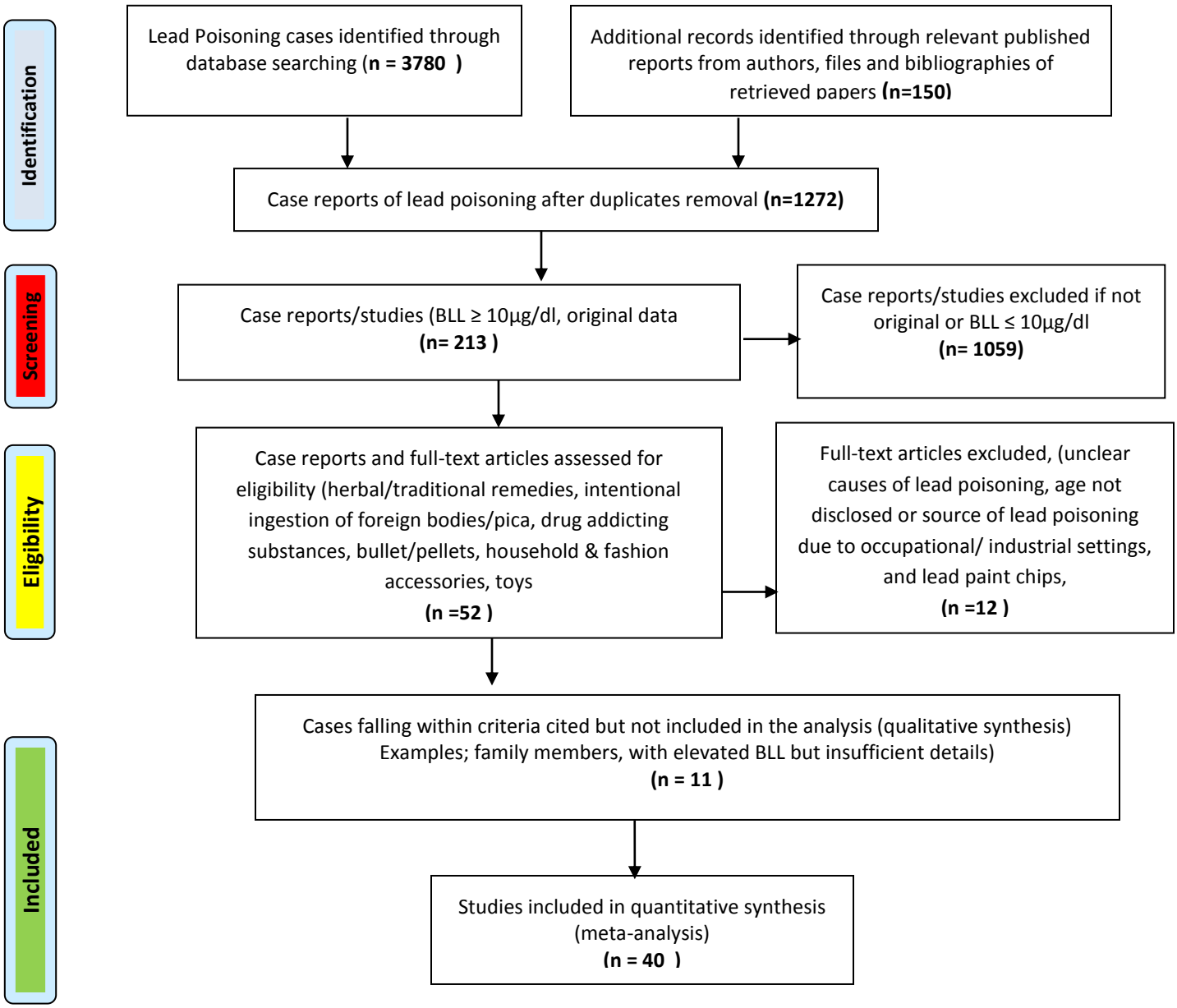

Figure 2.1: Schematic diagram of the systematic selection of lead poisoning incidents

Family members such as siblings, diagnosed to have elevated BLLs falling within the selection criteria discovered during the investigation of the original case and lacking sufficient details were cited but not counted as part of the review. All pregnant women were included in the analysis even if their age records were missing.

For the purposes of this review the following definitions were used; a child refers to any individual who is ≤ 14 years of age, while an adult would be anyone 15 years of age and above. A woman of child-bearing age is any female >14 and ≤ 49 years of age. These definitions are for purposes of this work, based on the WHO common definition of women of childbearing age which as categorized as 15- 49 years. However, this review focuses on the general public.

2.4 RESULTS

This review retrieved 40 published articles matching the set inclusion criteria out of which 71 lead poisoning incidents were identified. Of the 71 cases reported to have occurred between the years 2000 and 2011, 28% occurred in children and 72% in adults. The highest number of lead poisoning incidents (46%) occurred in women, followed by men (25%) then boys (21%). Of the cases that occurred in women, 87% were in their reproductive age. Infants and girls below the age of 15 were the least affected (7%). The average age of children and adults was 3 years and 37 years respectively. The youngest case was a 2 months whilst the oldest was 62 years of age. Men were on average 6 years older than women and had higher BLLs (average 123µg/dL) than women (average 90µg/dL). Boys on the other hand, had higher BLLs (average 57µg/dL) than girls (36 µg/dL). Lead poisoned women of reproductive age had negative outcomes such as elevated cord BLLs, delayed infant milestones and preterm delivery.[60-67] Twelve cases of lead poisoned pregnant women were encountered out of which 9 gave birth to newborns with elevated blood lead levels ranging from 20-113 µg/dl.[60-67]

Lead poisoning sources were grouped into 5 categories based on the use of the items leading to the poisoning incident. The categories were: household products (Table 1); Bullets and pellets;[76-81] folk remedies, spices and religious powders (Table 2); drug addiction and related practices (Table 3) and ingestion of miscellaneous non-food items (Table 4). Two lead poisoning cases occurred from ingestion of Mexican candies.[68] One case of lead poisoning was due to multiple sources involving a pregnant woman.[61] The multiple sources included cooking utensils, a kettle, a herbal remedy, and a Mexican candy.

Folk remedies, spices and religious powders (FRSRP) accounted for the highest proportion (44%) of the reported lead poisoning incidents. Moreover, BLL concentrations from FRSRP tended to be high ranging from 18-161 µg/dl with an average of 75µg/dl. The highest reported BLL from FRSRP resulted from ingestion of Ayurvedic herbal medication in India by a 41 year old man.[69] Ingestion of miscellaneous non-food items category had the second highest incidents of lead poisoning (23%). BLL concentrations in this category ranged from 26-180µg/dl with the highest concentration observed in a 4-year old boy who ingested a metallic charm which resulted in a fatality.[70] There were more pregnant women affected by intentional ingestion of miscellaneous non-food objects resulting with negative outcomes for both the mother and the newborns (Table4). Ingested substances included roofing plates, candle wax, fishing sinkers, clay pottery, soil, etc.

Lead poisoning due to drug addiction practices affected males only and accounted for 11% of all lead poisoning incidents. The most common practice was opium ingestion (Table 3). The highest BLLs (350 µg/dl) in this category was detected in a 25 year old Iranian man who inhaled and ingested opium.[71] Bullets and pellets, though accounting for only six lead poisoning incidents (9%), had the highest average (151 µg/dl) with a range of 48-391 µg/dl.[76-81]

Table 2.1: Lead poisoning cases-household products

Reference	Country	Age/ Sex	Lead source	Lead Content	BLL (µg/dl)	Presenting symptoms	Intervention	Outcome
Hellstrom-Lindberg *et al*[60]	Sweden	42/F	Blue glazed Greek jug storing juice	520 mgPb/l	330	Fatigue , restless legs, sleep disturbance, abdominal pain, nausea	Chelation therapy	BLL dropped to 27µg/dl after 32 days, recovery from symptoms observed after a week of treatment
		30/F	Blue glazed Greek jug storing juice	300 mgPb/l	72	Asymptomatic	Stopped using jug	BLL dropped to 35 µg/dl after a month 6months baby BLL 16 µg/dl suggesting in *utero* exposure
CDC[72]	USA	12mo/M	Ceramic dinnerware	29.6 µgPb/ml	23	Diagnosed on routine screening,	Discontinued use of dinnerware	BLL dropped to 8 µg/dl after 8 months
Ziegler *et al*[73]	Austria	16F	Mug with ceramic inner surface serving lemon tea	1.27 gPb/l	91.9	Colic-like abdominal pain, hypertonus, and anemia; weight loss	Chelation therapy	BLL dropped to 62.7 µg/dl over 3 days
Amundson *et al*[74]	Norway	54/F	Glazed ceramic wine jug from Greece	Not reported	76	Anaemia and unspecific gastrointestinal symptoms	Chelation therapy	Haemoglobin was normalised
CDC[68]	USA	48mo/M[s1]	Imported Mexican candies	Non reported	26	Diagnosed on routine screening	Discontinued candy consumption	BLL dropped to 13.2 µg/dl after two years
		48mo/M[s1]			22			BLL dropped to 11 µ/dl after One year

Table 2.2: Lead poisoning cases -Folk remedies, spices and religious powders

Reference	Country	Age/ Sex	Lead source	Lead Content	BLL (µg/dl)	Presenting symptoms	Intervention	Outcome
Gupta *et al* [75]	India	28/M	Ayurvedic medication	300,000 ppm	145	Abdominal pain, constipation	Chelation therapy	Symptoms relieved after a week
Lin *et al* [76]	India	10mo/M	Rubbing religious powder on child's forehead	89 000 µg/g	43	Referred for elevated BLL	Discontinuation of powder use, Chelation therapy	BLL dropped to 15 µg/dl by 21st month of age
	India	9mo/M	Application of powder (Orange shringar) to child's forehead(religious practice)	220 000 µg/g	21	Referred for elevated BLL	Discontinuation of powder	BLL dropped to 13 µg/dl in two months
	India	45mo/F	Regular ingestion of religious powder	4800 µg/g	18	Referred for elevated BLL	Discontinuation of powder	BLL dropped to 8 µg/dl in eight months
	India	12mo/M	Use of spices, herbal remedies and religious powders	Spices11, brown mustard seed (0.6 µg/g), Osafoetida (0.8 µg/g), Tumeric (1.4)	28	Referred for elevated BLL	Discontinuation of spices and religious powders	BLL dropped to 14 µg/dl in six months
Woolf *et al* [77]	USA	12mo/M	Asian tongue powder(*Ya Kward Pak*)	109,000 ppm (>10% of product weight)	61	Diagnosed on routine screening	Chelation removal of source	BLL dropped to 23 µg/dl
Madhusudhanan and Lall [78]	Oman	2mo/M	Omani traditional medicine for constipation	20% of medicine	83.3	Constipation	Glycerine suppository, Chelation therapy, discontinue use of medication	BLL dropped to 49µg/dl after one month
Geraldine *et al* [79]	India	27/F	3 Herbal medications	160, 2300,35 (range in ppm)	79	Abdominal pain	Chelation therapy	BLL drop reported (not quantified)
Atre *et al* [69]	India	41/M	Consumption of ayurvedic medication(mahayo garaj-gugul)	Not reported	161	Memory loss, anorexia, anhedonia	Chlation therapy, Discontinuation of ayurvedic medication	Recovered
Table 2 Continued								
Roche *et al* [80]	New Zealand	51/F	Consumption of ayurvedic medication	Not reported	69.3	Nausea, vomiting, abdominal pain myalgia	Discontinuation of ayurvedic medication	BLL dropped to 20 µg/dl after 5 months

CDC[81]	USA	60mo/F	Litargirio	790,000 ppm	28	Diagnosed on routine screening	Litargirio application discontinued and removed from house	BLL dropped to 7 µg/dl after nine months
Vassilev *et al*[82]	USA	13mo/M[5]	Sindoor	580,000 ppm	57	Diagnosed on routine screening	Sindoor used discontinued	Not reported
		23/F	Sindoor*	580,000 ppm	85	Diagnosed after discovery of a lead poisoned infant	Sindoor used discontinued	Not reported
Woolf and Woolf [83]	USA	24moM	Spices (*Kozhambu*- combination of turmeric, coriander seeds, chilis and lentils)	310 ppm	31	Diagnosed on routine screening	Chelation therapy Discontinue use	BLL dropped to 15 µg/dl after 4 weeks
	USA	29mo/M	Spices (*Swanuri marili* and *Kharchos suneli*)	23, 100 ppm	37	Diagnosed on routine screening	Chelation therapy	BLL dropped to 15 µ/dl after 4 weeks
CDC[84]	USA	40/F	Ayurvedic medication (Jambrulin)	44000 ppm	92	Not reported	Chelation therapy Patient advised to stop the medication	Not reported
	USA	25/F	Ingesting ayurvedic medications (a pill)	79000 ppm	91	Not reported	Chelation therapy Patient advised to stop the medication	Not reported
	USA	31/F	Ingesting ayurvedic medications (9 different types)	73 000 ppm	112	Hospitalized for severe, persistent microcytic anemia with prominent basophilic stippling	Iron supplementation, Chelating therapy	BLL dropped to 71 µg/dl in a week BLL 22 µg/dl 9.5 months after initial BLL testing
	Table 2 Continued							
	USA	19/F	Ayurvedic medication (Sundari Kalp -pill and liquid)	96 000 ppm	46	Not reported	Not reported	Not reported

	USA	37/F	Ingesting five ayurvedic medications	17,000 ppm	81	Rheumatoid arthritis, diffuse abdominal pain, nausea, and vomiting of 6 days' duration.	Stopped medication Chelation therapy	BLL dropped to 35 µg/dl Two years later BLL rose to 64 µg/dl (re-used medications)
	USA	34/M	Ayurvedic medication (pill)	78 000 ppm	80	Back pain, abdominal pain	Chelation therapy	BLL dropped to 17µg/dl 7.5 months after initial BLL
	USA	62/M	Ayurvedic medication (Mahayogaraj-gugul tablets)	14 000 ppm	89	Back pain, abdominal pain	Multiple Chelation therapy Chronic anti-convulsant therapy	Recovered, but had residual anoxic brain damage
	USA	56/F	Ayurvedic medication (guglu tablets)	14 000 ppm	89	Not reported	Chelation therapy	Not reported
	USA	52/M	Ayurvedic medication	Not Reported	49	Not reported	Not reported	Not reported
	USA	57/F	Ayurvedic medication	Not Reported	27	Not reported	Not reported	Not reported
	USA	56/M	Ayurvedic medication (Powder)	Not Reported	100	Not reported	Chelation therapy	Not reported
	USA	50/M	Ayurvedic medication (Jambrulin)	26,700 ppm	49	Not reported	Chelation therapy	Not reported
Weide *et al*[85]	Germany	39/F	Ayurvedic Indian plant (4 natural plant pills)	50.4 mg/g/pill	88	hypochromic, microcytic anaemia with a haemoglobin of 7.9 g/dl	Chelation therapy	Patient neurological condition improved and radial paresis resolved gradually. Patient hematological parameters normalized

Fung *et al*[86]	Hongkong	23/F	Consumption of home-made medication for acne (Bao Ning Dan)	7.1mg/pill	66.6	Musculoskeletal pain	Advised to discontinue medication	Musculoskeletal pains gradually disappeared in two weeks after stoppage of medication. Other laboratory tests resolved in four months
Tait *e tal*[62]	Australia	24/F	Consumption of ayurvedic medicines for nine years	Not reported	107	Abdominal pain, disorientation and progressive confusional state culminating in seizures	Advised to discontinue medication, Chelation therapy	Chronic Lead encephalopathy, Ante-partum haemorrhage, induced delivery Cord blood lead level 140 µg/dl. Baby had delayed milestones with peripheral weakness
Ibrahim and Latif[87]	Qatar	56/F	Use of a herbal medicine (powder) from India	Not reported	152.9	Generalised weakness, headaches, recurrent dark urine	Chelation therapy Advised to discontinue the medication	Abdominal pain improved and laboratory tests returned to normal
Van Vonderen *et al*[88]	Netherlands	35/F	Ayurvedic preparations	31 ppm	140	Severe colicky abdominal pain, vomiting, obstipation & weight loss, severe pain in the extremities & loss of concentration and short-term memory	Chelation therapy	Symptoms disappeared Rapidly, blood lead level decreased to 20 µg/dl after 6 months.

Table 2.3: Lead poisoning cases - Drug addiction and related practices

Reference	**Country**	**Age/ Sex**	**Lead source**	**Lead Content**	**BLL (µg/dl)**	**Presenting symptoms**	**Intervention**	**Outcome**
Jalil and Azizkhani[89]	Iran	32/M	Opium ingestion	35.2 mgPb/100g opium	50	lower abdominal pain and constipation	Chelation therapy, discontinuation of opium ingestion	Symptoms subsided after one week of chelation
Verheij *et al*[90]	Netherlands	40/M	Opium ingestion	Not reported	86	Severe, constant, upper abdominal pain	Chelation therapy, discontinuation of opium ingestion	Serum lead levels dropped to 2 µg/dl after 14 days
Begovic *et al*[91]	Serbia	16/M	Ingestion of Petrol through siphoning	Not reported	30	Exhaustion, dizziness, abdominal cramps and constipation	Petrol siphoning stoppage	Spontaneous recovery and stomach returned to normal position
Fatemi *et al*[71]	Iran	25/M	Inhalation and ingestion of opium	indicated as very high	350	Severe vomiting, nausea and abdominal pain	Chelation therapy, discontinuation of opium ingestion	Symptoms subsided after initiation of treatment over two weeks. Laboratory abnormalities returned to normal after 45 days

Beigmohammadi *et al*[92]	Iran	40/M	Opium ingestion	Not reported	200	headache, nausea, abdominal pain, weakness in lower and upper extremities	Chelation therapy, discontinuation of opium ingestion	BLL dropped to 20 µg/dl, patient referred for rehabilitation
Masoodi *et al*[93]	Iran	34/M	Opium ingestion	not reported	95	Abdominal pain nausea and vomiting	Chelation therapy, discontinuation of opium ingestion	Symptoms improved after 4 days of chelation. asymptomatic after 3 weeks
		45/M	Opium ingestion	not reported	37.5	Severe epigastric and periumbilical pain	Discontinuation of opium ingestion	Symptoms stopped after 4 days of opium discontinuation
		57/M	Opium ingestion	Not reported	81	Abdominal pain, nausea, severe constipation	Chelation therapy, discontinuation of Opium ingestion	Laboratory tests normal after three weeks, patient asymptomatic

Table 2.4: Lead poisoning cases-ingestion of miscellaneous non-food items

Reference	**Country**	**Age/ Sex**	**Lead source**	**Lead Content**	**BLL (µg/dl)**	**Presenting symptoms**	**Intervention**	**Outcome**
Sabouraud *et al*[94]	France	37/M	Ingestion of lead roofing plates Ate candle wax and plastics since childhood	Not reported	112.4	Abdominal pain, constipation	GI decontamination, administration of laxative, chelation therapy Psychiatric follow up. Advised not to eat lead	BLL dropped to 14.5 µg/dl four months later Acute leukemia identified
St Clair and Benjamin[95]	USA	96mo/M	Ingestion of fishing sinkers	Not reported	55	Abdominal pain, nausea, headache	Chelation therapy, bowel cleanout	Serum Lead level dropped to 12 µg/dl after day 462
Cleveland *et al*[63]	USA	28/F (Pregnant)	Pica behavior – ingestion of pieces of Mexican clay pottery(pregnant)		60	Enrolled in a lead study	Advised to stop eating pieces of clay pot, Chelation therapy	BLL dropped at the time of delivery to 45 µg/dl . Neonate BLL elevated (70µg/dl 2 days after delivery)
Guillard *et al*[103)]	France	24mo/M	Ingestion of money made from pure metallic lead	Not reported	61	Asymptomatic	Chelation therapy	BLL dropped to 10 µg/dl after a series of chelation treatments over several months
Berkowitz and Tarrago[70]	USA	48mo/M	Ingested metallic charm	99% lead	180	Vomiting, decreased energy	Lead toxicity diagnosed postmortem	Lead encephalopathy resulting with death

Hackley and Katz-Jacobson[64]	USA	33/F (Pregnant)	Soil pica during pregnancy	Not Reported	26	Identified through routine prenatal screening	Advised to stop pica. Referred for genetic and nutritional counseling Referred to special lead clinic	BLL dropped to 13 µg/dl at 23 weeks At 6 weeks baby's BLL elevated to 20 µg/dl
Shannon [65]	USA	F (Pregnant)	Tierra (ingestion of soil/clay-based substance)	Not reported	61	Malaise, fatigue, anaemia	Chelation therapy	Neonate BLL 55 µg/dl
	USA	F (Pregnant)	Tierra (ingestion of soil/clay-based substance)	Not Reported	117	Malaise, fatigue, anaemia	Chelation therapy	Neonatal BLL 67 µg/dl
	USA	F (Pregnant)	Tierra (ingestion of soil/clay-based substance)	Not Reported	49	Malaise, fatigue, anaemia	Chelation therapy	Neonate BLL 51µg/dl
	USA	F (Pregnant)	Tierra cotta(ingestion of soil/clay-based substance)	Not Reported	55	Malaise, fatigue, anaemia	Chelation therapy	Neonate BLL 87µg/dl
	USA	F (Pregnant)	Tierra (ingestion of soil/clay-based substance)	Not Reported	40	Malaise, fatigue, anaemia	Chelation therapy	Neonate BLL 26 µg/dl
	USA	F (Pregnant)	Bone meal ingestion	Not Reported	66	Malaise, fatigue, anaemia	Chelation therapy	Neonate BLL 62 µg/dl
VanArsdale *et al*[96]	USA	48mo/M	Ingested toy medallion	38.8% lead	123	abdominal cramping, vomiting, and diarrhea without fever	Chelation therapy	BLL levels dropped to 40 µg/dl after treatment
Klitzman *et al*[67]	USA	24/F (Pregnant)	Ingestion of dirt from her backyard	Not Reported	53	Identified on routine prenatal screening	Not reported	Not reported
Hamilton *et al*[66]	USA	25/F (Pregnant)	Ingestion of clay pottery during pregnancy	Not Reported	119.4	Diagnosed on routine prenatal screening	Not reported	Child BLL 113.6 µg/dl two days after delivery
Dargan *et al*[97]	United Kingdom	48mo/F	Ingested snooker chalk	7200 ppm	36	Suspected viral upper respiratory infection	Chelation therapy, removal of source	BLL levels dropped to 8 µg/dl after 30 months of treatment

2.5 DISCUSSIONS

Lead poisoning is an important environmental disease resulting in detrimental life-long health effects in people globally. The Centers for Disease Control and Prevention (CDC) has established ≥10 µg/dl Blood Lead Level (BLL) as the cut-off value for intervention.[1] The findings in this review suggest that children, women and the general public may be at higher risk than conservatively estimated and highlight the need for more studies on lead containing products. Exposure sources can also vary among and within countries depending on past and current uses.[98] Such sources may range from historic contamination,[99] recycling old lead products or from manufacturing new products.[98] The use of lead has been controlled by many developed countries to reduce public exposure. Such measures included lead removal from paint, petrol and other environmental products.[100] These interventions have gone a long way to address lead exposure from those sources commonly known to have the potential for lead exposure. The findings of this review however, point to a trend of increasing reports of lead poisoning from unexpected or uncommon sources of lead exposure.

The objectives of this paper were to identify uncommon sources of lead poisoning in the general population. Several lead poisoning sources have been identified and these include glazed items used for household purposes,[60,68,72-74] bullets and pellets,[101-105] folk remedies including spices and religious powders,[62,75,76,84-88] drug addicting substances,[71,89-93] and ingestion of miscellaneous non-food items.[63-65,70,94,95,106] These findings are consistent with recent medical literature on uncommon sources of lead poisoning and suggest that if unattended, these sources may become silent killers particularly in less developed countries where environmental lead exposure sources are less regulated.[107] A study looking at immigration status and lead poisoning revealed that immigrant families to the United States of America use lead contaminated products from their home countries while living in the United States.[107] This paper has identified these similarities for example in the case of the use of folk remedies, spices and glazed household utensils. The lead content in herbal medicines from countries such as India may vary from 12% to 72%.[88] Lead has also been reported to be an ingredient of choice for different folk remedied such as *Hai Ge Fen* (clamshell powder) and *Zhen qi jianf tnag* in Chinese herbal medicines,[108] Indian herbal medicines,[109,110] folk remedies used in Oman,[111] Mexico, and countries of the

Caribbean and South Asia.[107] While Ibrahim and others argue that folk remedies and traditional cosmetics such as Kohl used in Asia, Africa and Middle East may be an important source of lead poisoning in those areas and amongst individuals from those areas who have immigrated to developed countries,[87,112] severe cases of lead poisoning from similar sources, including encephalopathy and death have been reported in the developed world.[111]

Lead is hazardous to children particularly due to its toxic effects on the developing nervous system. Certain characteristics of children such as hand to mouth behavior expose children to sources that were initially not thought of as a concern for lead poisoning. This is evidenced by cases involving the ingestion of fish sinkers,[95] lead BB pellets,[113] pellets from ankle weights,[105] snooker chalks,[97] and ingestion of money made of pure metallic lead.[106] Findings of this review are consistent with those of studies involving ingestion of foreign objects.[59,114,115] These cases were identified in developed countries such as the United States of America, Canada and the United Kingdom. While the ingestion of foreign objects is often associated with children and infants, occasional instances of similar behavior has been observed in adults. This is evident from the cases of a 45 year old male who ingested lead tainted bullets,[104] and that of a 45 year female who ingested lead shot pellets.[101] Moreover, cases of ingestion of non-food items, commonly soil,[64,65] and clay/pottery,[63,66] by pregnant women were common. It is worth noting that lead sources for pregnant women were often similar to those of children.

The findings of this review showed that 46% of women are lead poisoned compared to 25% of men. Additionally, 87% of the women were in their reproductive age with 36% pregnant. Elevations in maternal blood pressure during pregnancy are not only a cause of concern for the mother but also a known risk factor for adverse pregnancy outcomes, particularly in the form of retarded foetal growth that is itself a risk factor for adverse developmental effects.[116,117] Out of the twelve pregnant women 9 gave birth to newborns with elevated blood lead levels ranging from 20-113 µg/dl. This is a cause for concern for an ever-increasing risk for exposed children who may grow into adulthood with elevated blood lead levels, which they may in turn, transfer to the next generation. Exposure to environmental lead during infancy, adolescence and through adulthood may result in lead accumulation which means the burden of stored lead will

increase throughout life. Bone lead stores may be mobilized during pregnancy and lactation. Gulson has demonstrated that the skeletal contribution to blood lead level increases from 9% to 65 % during pregnancy.[118 125] Thus, potentially included among lead sources of importance is *in utero* lead transmission and according to recent estimates 0.5% of women of childbearing age may have blood lead levels greater than 10µg/dl.[44] Of concern is the fact that because lead freely crosses the placenta, neonatal lead poisoning can always be expected from pregnant women.[45,119] Practices such as pica during pregnancy worsen the situation. These findings call for targeted lead screening in pregnant women as well as identification of uncommon sources of lead exposure. This review also points to elevated BLLs in newborns,[60,61,63] and support existing literature.[120] In one of the studies, it was observed that infants with blood lead concentration above 10 µg/dl experienced a 142g lower weight gain from birth to the first month of life compared to infants with lower blood lead levels at birth.[120] In a similar study by Sanin *et al* (2001), it was concluded that lead exposure during early postnatal period has adverse effects on early weight gain among healthy breast fed infants.[121] Maternal blood lead was strongly associated with infant blood lead levels confirming a previous study by Rothenberg *et al* findings that maternal lead burden is an important determinant of infants lead levels at birth and at 1 month of age.[122] During pregnancy, even lower lead levels are of serious concern because of their potentially adverse effects on the foetus, including developmental delays, low birth weight, and miscarriage.[123] Findings of this review suggest a shift from what was known as common sources of lead poisoning to a prompt identification of uncommon lead exposure sources that may potentially pose a threat to the health of the general population, particularly women and children. Foetal development in women with low current lead exposure may still be a risk for lead toxicity from long-lived maternal bone lead stores acquired from previous lead stores.

Medical literature also continues to point to lead poisoning as a result of sniffing and ingesting drugs such as heroin,[124] marijuana,[125,126] and practices such as sniffing or huffing petrol.[127] This paper supports this trend and the results are a cause for concern particularly that BLLs as a result of opium ingestion are extremely high among young men.[71,92] These results are consistent with the results of a retrospective survey of lead poisoning due to adulterated marijuana in Germany where 35 relatively young patients involving 7 females were treated for lead poisoning with BLLs as high as

1063±864 µg/dl.[126] It must however be pointed out that the case of petrol siphoning in this review, which resulted with lead poisoning was not intentional.[91] There are, however, reported cases of intentional petrol sniffing,[127-130] which cannot be ignored.

Finally, this review has observed that the diagnosis of lead poisoning is challenging due to its vague symptoms. Only in high dose lead poisoning can severe abdominal pain, irritability, decreased consciousness, motor, and sensory deficits raise enough diagnostic suspicion of lead toxicity. Chronic low dose exposure may manifest with non-specific gastrointestinal disturbances, subtle neurologic and subclinical cognitive deficits.[23] Overt poisoning with high doses of lead may pose a problem for both developed and developing countries. For developed countries, medical literature points to the fact that clinicians may have misdiagnosed lead toxicity in their patients.[59] The case of developing countries is more challenging because the clinicians may have never attended to a lead poisoned individual because lead screening may have never been done. Evidence to this is provided by misdiagnosed cases which resulted with death or adverse consequences.[70,131] The treatment of lead poisoning by chelation is not necessarily the best option. In the majority of cases the simple removal of the lead sources may be sufficient provided BLL were not too high. In cases where chelation therapy was applied without the removal of the source of exposure, the relieve of lead poisoning impacts became temporary.[84,131]

2.6 LIMITATIONS

Most of the cases identified in this review were retrieved from research carried out in developed countries. The data may therefore be misinterpreted to believe that lead poisoning occurs only in the developed world. However, from the data, the identified cases were from subjects originating from developing countries.

The sample size of the lead poisoning cases reviewed is small, many cases were excluded because sufficient details were not provided. However, the cases identified here could be used to inform future research on uncommon sources of lead poisoning.

2.7 CONCLUSIONS

This review reveals that despite the overall declines in BLLs in developed countries, lead exposure due to the not so common sources of lead exposure continue to be a risk to public health. The extremely high BLLs as a result of exposure to uncommon lead sources are a cause for concern as they are likely to result with life-long negative public health consequences. These trends call for changes in the approaches to detect and prevent lead poisoning where the global community can no longer afford to focus on children and on the traditional sources of lead poisoning such as lead-based paint solely. This is of particular concern to developing countries where the resources to screen and treat lead poisoning are limited. The review further shows that due to the lack of capacity particularly in developing nations, there is potential that several lead poisoning cases may have gone undetected particularly for women of reproductive age resulting with detrimental health effects for the mother, the baby and future generations. The identification, recognition and removal of uncommon sources of lead exposure sources during prenatal period can therefore, be useful in preventing maternal and neonatal morbidity and mortality. An important finding of this review is that the removal of the source of exposure is crucial in keeping blood lead levels low.

Despite the limitations noted in this review such as non-availability of data on the types and quantities of lead exposure in some of the cases, some key public health implications on the life-long consequences of lead exposure from uncommon sources have been identified. While such exposures cut across the general public, there is an additional need to develop public health interventions for pregnant women. Such interventions should include guidelines that would enable the identification of cases that may not have otherwise become known.

The following is recommend:

a) The need to train health professionals in the identification of lead poisoning symptoms, particularly in countries where lead screening is not available.
b) There is need to expand the scope of lead poisoning sources from the traditional lead–based paint and occupational sources and develop screening questionnaires that will incorporate practices and items that are uncommon but likely to expose the general population to lead poisoning. Particular attention

should be paid to women of reproductive age who have the potential to accumulate lead, store it in their bones and transfer it to the next generation.

c) Country specific baseline surveys on potential lead poisoning sources are crucial in recognition of the different socio-economic levels and cultural practices prevalent globally. This will identify specific lead poisoning sources and facilitate prompt treatment

d) Public awareness on lead and lead poisoning sources is necessary to sensitize members of the public on potential lead poisoning sources.

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