Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery

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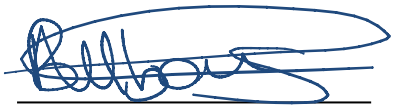
DEDICATION

In loving memory of my father, Ernest Ishmael Raowesi Motladiile (“Mdakes”), and my mother Onkabetse Mmasetshwanaka Motladiile (“Mma Mdakes”)

DECLARATION

I, Bontle Mbongwe, declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy in the University of Pretoria. It has not been submitted before for any degree or examination at this or any other tertiary institution.



Bontle Mbongwe — January 30, 2013

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Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery

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Submitted in fulfillment of the requirements for the degree

Doctor of Philosophy

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SUMMARY

Lead is a toxic heavy metal associated with adverse health effects ranging from developmental neurotoxicity to reproductive effects. While lead affects people of all ages, infants and children are the most vulnerable and susceptible to the neuro-developmental effects of lead exposure. Maternal blood lead concentrations that do not produce clinical toxicity on pregnant women have been linked to adverse offspring development. Observed reproductive effects to low lead levels during pregnancy include the risk of spontaneous abortions, effects on birth weight and preterm birth. There are particular concerns with regard to reductions in IQ scores. Research evidence suggests that an incremental increase in blood lead levels of 1 µg/dL is associated with approximately 1 IQ point deficit. Of particular concern is that currently no threshold has been observed or exists for developmental neurotoxicity to the chronic low lead exposures levels. While the developed countries have built evidence for lead exposure sources, have identified the most vulnerable groups to lead exposure, and have instituted control actions for lead exposure, it is not the case in developing countries such as Botswana. Currently, there is very little knowledge about the potential sources of lead exposure among different population groups not only in Botswana but also in most developing nations. There is also an evident limited knowledge on the behaviours and practices of different population groups that could potentially expose them to lead in developing countries.

This thesis explores the following questions: i) Are there specific risk behaviours and practices peculiar to pregnant women in Botswana that could potentially expose them to lead? ii) What are the environmental lead concentration levels and their potential to expose pregnant women? iii)What are the blood lead concentrations at each stage of pregnancy and after delivery in Botswana and, iv) Can we use the information from these three questions to predict lead exposure levels during pregnancy and after delivery? v) Can we use the new information to a develop a policy dissemination brief to inform policy on lead exposure sources in Botswana, develop guidelines for health professionals for assessing and screening lead exposure levels during pregnancy and after delivery, develop an awareness leaflet for lead education?

To address the specific risk behaviour and practices of pregnant women, a comprehensive validated risk assessment questionnaire was administered among 142 pregnant women during the first trimester of pregnancy (defined as 8-12 weeks) in four villages of different geographical settings and nomenclature (small/rural, major and semi urban). For purposes of this work the validation process involved obtaining information (from experts in the field and communities)

relevant to the purposes of the study and to confirm that the tools employed for collection of data in all trimesters were suitable in terms of both construct and content. Data was collected between September 2009 and February 2010.

To address potential environmental sources of lead exposure during pregnancy soil (n=28), water (n=28) and traditional cosmetic clay - *letsoku* (n=3) samples were collected in November 2010, February 2011 and May 2011 from the homes and in the vicinity of the study population to determine lead concentrations.

To know baseline blood lead levels at each stage of pregnancy, blood samples were collected from September 2009 to February 2011 from pregnant women between weeks 8-12 (first trimester, n=137), 20-24 (second trimester n=126) and weeks 34-36 (third trimester n=106). Blood lead levels of women who completed the entire study from trimester on until after delivery (n=63) were then used to construct blood lead prediction models using statistical models.

Pregnant women in the study area ingested non-food items such as soil, match sticks, pencil, chalk and animal feed such as bone meal (86%). Women applied used and unused car oils (in particular brake fluid) and other harmful substances for "treatment of skin conditions and for beautification purposes (74%). Older women (defined as >35 years in this study) were at a significantly higher risk to ingest soils ($p<0.01$). Mean (±SEM) lead concentrations in water exceeded the WHO drinking water quality standards nineteen fold (0.19±0.019 ppm (n=28) Major villages, had significantly higher Pb concentrations ($p<0.05$) in soils and water compared to small villages. Mean blood lead levels (±SEM) for the first, second and third trimesters were 1.96(±0.14)µg/dL, 2.49(±0.17) µg/dL, 2.66(±0.19) µg/dL respectively. Blood lead levels increases from the first to third trimester ranged from 1.6-5%. Blood lead concentrations significantly differed among locations ($p<0.01$). The highest concentrations were observed in women from smaller villages that were poorer ($p<0.02$).

Pica, multiple risk behaviours/practices (engaging in two or more risk behaviours/practices), trimester of pregnancy, poor food supplementation and diet were predictors of blood lead levels ≥ 2µg/dL. There was a dose response relationship between supplement intake and an increase in blood lead levels.

These findings suggest that pregnant women and their unborn babies could potentially be exposed to lead because of the environment in which they live, their economic status, lifestyle, behaviors and practices. Drinking water is a potential threat for lead exposure, not only among pregnant women, but other vulnerable groups such as infants and children. This study is the first in Botswana and one of the few in Africa to investigate lead exposure sources at each stage of pregnancy and after delivery. It is also the first to identify new potential lead exposure behaviors and practices such as the application of auto oils by pregnant women for treatment of skin diseases. The findings suggest the need to train health workers and equip them with the skills and knowledge to assess and screen women who could potentially be exposed to lead. Further, pregnant women need to be sensitized on potential lead exposure sources, to prevent lead poisoning. This study has been able to use the results to develop a policy brief for disseminating the results to decision makers, guidelines for utilization by health workers to screen lead exposure levels and an awareness leaflet for pregnant women. These have been validated and pretested at community and Government levels.

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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.

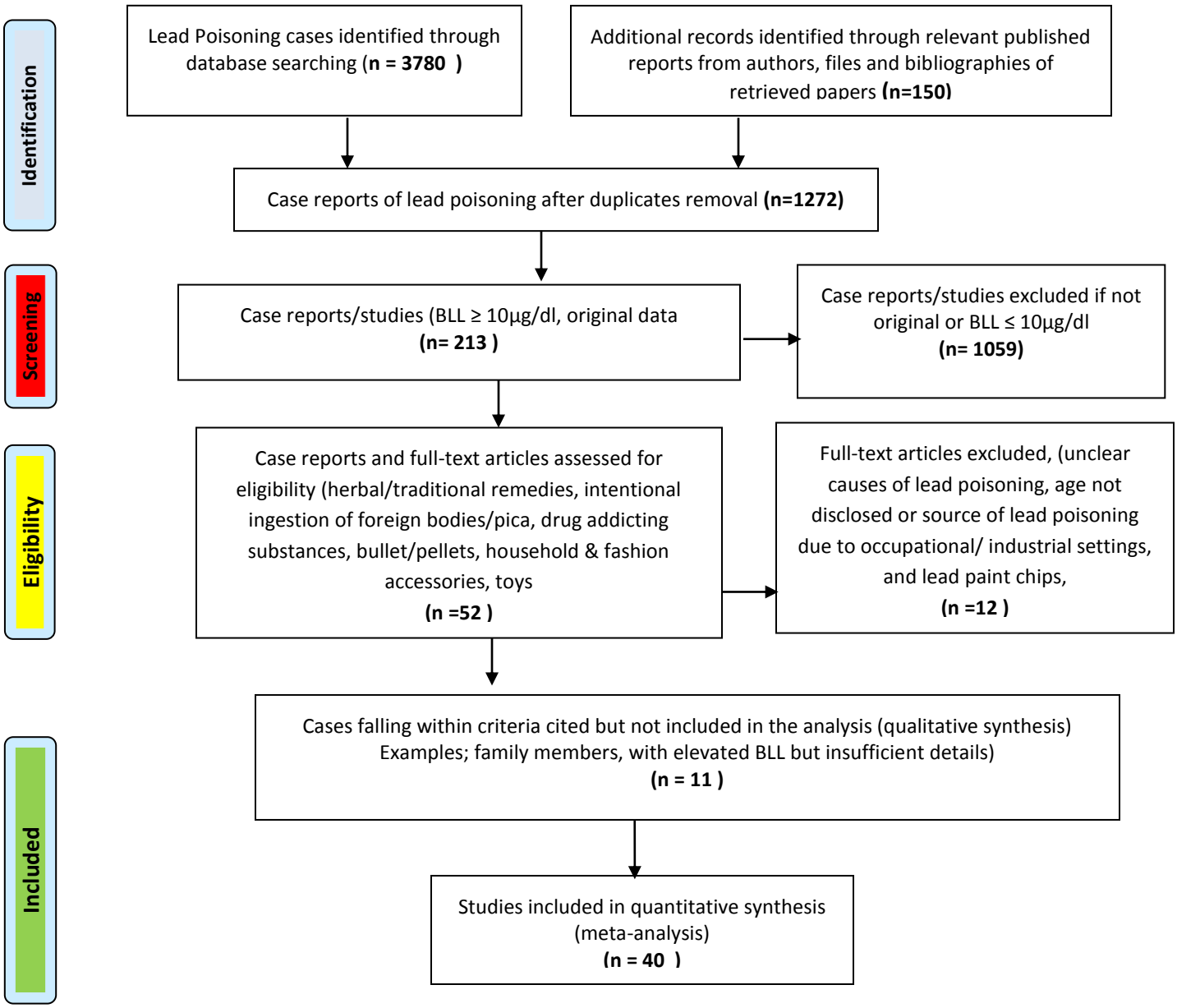

Figure 2.1: Schematic diagram of the systematic selection of lead poisoning incidents

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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Chapter 3:

Prevalence and Predictors of Risk Behaviors and Practices for Lead Exposure during the First Trimester of Pregnancy in the Central District, Botswana.

3.1 Abstract

Objectives: Lifestyle, environmental and cultural behaviours of pregnant women have been associated with lead exposure and elevated blood-lead levels (PbB). This study determines the prevalence and predictors of health risk behaviours and practices for prenatal exposure to lead in the Central District of Botswana. The study further looks at socioeconomic and demographic factors influential to such behaviours during the first trimester of pregnancy.

Methods: Interviews were conducted among 142 pregnant women (73% participation rate) attending antenatal care in hospitals and clinics in the study areas.

Results: Ingestion of non-food items was the most commonly practiced risk behaviour (86%) followed by the use of brake fluid oils, torch batteries, light brown shoe polish and traditional cosmetic clays (*letsoku)*) for skin treatment (74%). Alcohol consumption, tobacco and traditional medicines use were practiced by 31%, 8% and 11% of participants, respectively. Multiple risk behaviours (two or more risk behaviours) were practiced by 62% of women. Overall, age, employment and parity were significant predictors of whether a woman would engage in a risky behaviour or not.

Conclusion: These findings highlight the importance of monitoring and surveillance of behaviors and practices of pregnant women in order to understand potential prenatal exposure sources of lead. Inclusion of these behaviors in the Botswana Obstetrics Record booklet is recommended to allow midwives, obstetricians, gynecologists and family physicians to manage the risk behaviors and prevent potential adverse pregnancy outcomes. Development of awareness materials for pregnant women on the potential negative impacts of these habits and practices is recommended.

Key words: Risk behaviours, prevalence, pregnant women, lead exposure, Central District, Botswana

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3.2 Introduction

Lifestyle, cultural, environmental and other behaviors of pregnant women such as pica, the use of certain cosmetics, traditional remedies, alcohol and tobacco use have been identified as potential exposure sources for lead exposure during pregnancy.[1-3] Prenatal exposure to lead is increasingly becoming an issue of concern due to severity of lead toxicity even at very low concentrations. In addition, substantial fetal lead exposure can occur during pregnancy because of the ability of lead to transfer across the blood placenta barrier. Furthermore, during some health episodes, mobilization of maternal skeletal lead stores can occur thereby increasing fetal exposure.[4,5] Another concern is that the fetal nervous system is extremely sensitive to neurotoxins including lead.[6]

Exposure to lead during pregnancy is influenced not only by the health status of the pregnant women, but also by environmental, occupational and behavioural factors. Pregnant women may have additional sources of lead exposure which often involve habits or practices such as pica - an intentional ingestion of non-food items, very common in pregnant women. Shannon (2003) and Klitzman *et al*. (2002) have reported that severe lead poisoning resulting in blood-lead (PbB) levels equal to or exceeding 45µg/dL in pregnant women are more likely to occur due to intentional pica.[7,8] In these studies, most pregnant women with elevated PbB levels ingested soil, clay or pottery (known as geophagia) with very few cases of ingested paint chips. According to Shannon (2003) home renovation and the use of crushed bone meal (usually considered animal feed) were additional sources of lead exposure.[7] Lifestyle habits such as alcohol consumption, tobacco and traditional medicine use have been linked to lead and present yet additional exposure sources of lead poisoning during pregnancy. Alcohol has been reported to increase the absorption of lead in the gastrointestinal tract.[9,10] Acetaldehyde formed from alcohol may inhibit δ-aminolaevulinic dehydratase.[11] Severe lead poisoning has also been reported as a result of lead contaminated traditional/folk remedies.[12] Smoking of cigarettes is estimated to increase PbB by 0.33 µg/l for every cigarette smoked.[10]

Attention on lead and pregnancy is motivated by reports that pregnancy accelerates the release of lead stored in the woman's bones and therefore raise not only

circulating maternal PbB, but also PbB of the umbilical cord at term as well as raise postpartum PbB of the mother.[13,14] Heavy metals, including lead have been shown to cross the barrier of the placenta and transported to the fetus during pregnancy.[15] Bone lead is believed to follow the same kinetic pathway as calcium and therefore presents a potential source of lead for the fetus.[16] Miller (1983), has concluded in his study that kinetic studies during pregnancy must take into account the complex relationship between the mother, the fetus and the placenta.[17] Investigations further show that physiological factors may modulate the movement of lead from maternal bone to the growing fetus. Total lead exposure as well as the rate of lead exposure is reported to influence the concentration and location of maternal compartment, which in turn has an effect on the bioavailability and mobilization of lead into the placenta and fetus.[18]

Lead exposure plays a major role in the epidemiology of spontaneous abortion,[19] and hypertension.[20] It 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 outcomes, particularly in the form of retarded foetal growth that is in itself a risk factor for adverse developmental effects.[21,22]

Botswana is a landlocked, semi-arid country with an approximate area of 582 000 km^2 and has a population of 2,024,904.[23] It is located in the center of Southern Africa, bordered to the north by Zambia, to the northwest by Namibia, to the northeast by Zimbabwe and to the east and southeast by South Africa. The study area, Serowe Palapye, is located 22° 44' 53" S and 26° 47' 15" E in the Central Administrative District of Botswana with a total population of 180,500.[23] It is home to the only coal mine in Botswana, the Morupule Colliery, which supplies a coal-fired Murupule Power Station of the Botswana Power Corporation.

Published data on lead levels in air, blood, soil or water as well as paint used in Botswana is limited. A few published studies could however be sourced that focused on lead in soils and in blood. These studies were conducted in Gaborone (the capital City of Botswana) and in Palapye. Gaborone soils had lead levels as high as 222mg/kg compared to rural soils.[24] Zhai *et al.* (2009) further assessed the

distribution of heavy metals including lead near Palapye in the Serowe Palapye District and found lower lead values compared to Gaborone.[25] In terms of blood lead levels, the only study published in Botswana is that by Mbongwe *et al.* (2010) assessing PbB in children aged 1-6 years.[26] In this study 31% of children had PbB levels ≥10µg/dL with 5% of all study children having PbB levels ≥20µg/Dl.[26] In terms of behaviors and practices likely to expose the population to lead, there are currently no published studies in Botswana.

The goal of this study is to determine the prevalence of behaviors and practices among pregnant women that may contribute to exposure to lead. Specifically, this study determines the baseline characteristics of pregnant women and predicts prevalence rates and socioeconomic and demographic correlates of risk behaviors, separately and in combination during the first trimester of pregnancy in subjects residing in the Central District of Botswana (figure 3.1).

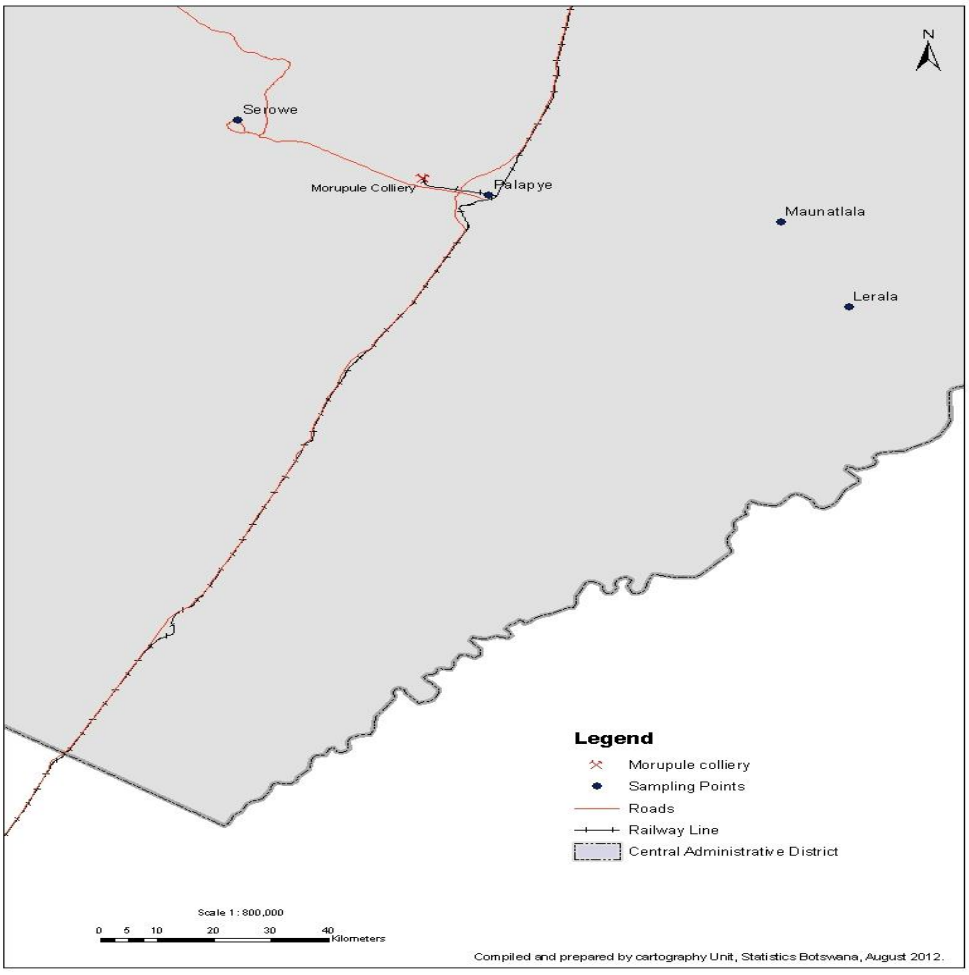

Figure 3.1 Sampling Locations, Central District

3.3 Methods

3.3.1 Study area and population

The eligible target population in this study was pregnant women aged 18 to 49 years attending antenatal clinic services at any public clinic or hospital in the Serowe/Palapye District. While the reproductive age is 15 to 49 years, for ethical requirements in Botswana and the University of Pretoria informed consent could only be given by persons 18 and above. Specifically the women were recruited from Serowe, Palapye, Maunatlala and Lerala villages. Serowe is the largest of the villages with a population about 52,000,[23] a typical major village in Botswana with minimal industrial activity but moderate traffic volume. Palapye is a moderately industrial major village (equated to a town due to the extent of industrial activity). Palapye population is approximately 37,000,[23] and is located about 5-7 kilometres from Morupule coal mine and the Morupule Power Station, with a major railway station and a major highway passing through the village from Gaborone to Francistown. Major villages are designated in terms of infrastructural developments, population size as well availability of services. Maunatlala and Lerala with populations 4,552,[23] and 687, [23] respectively, represent a typical small, rural villages in Botswana with no industrial activities and extremely minimal traffic volume.

3.3.2 Participation, recruitment and informed consent

All pregnant women registering for prenatal clinic between September 2009 and February 2010 who were between 0 and 12 weeks of pregnancy were invited to take part in the study. All eligible women were issued a letter containing a statement of consent and a leaflet describing the study and its protocols. Of the 200 women deemed eligible, 17 were not reached. Informed consent was given by 147 women, however out of these 5 women were below the age of 18 and therefore excluded from the study, making eligible women 195 instead of 200. Overall participation rate was therefore 73%.

3.3.3 Research Instrument

Validated risk assessment questionnaires were administered after the consent forms were signed by study participants. Prior to the interviews, the questionnaire was pretested and validated in a workshop attended by research experts from the

University of Botswana and Pretoria, statisticians as well as members of the Ministry of Health Research Ethics Committee (see appendix 8). Individual interviews were conducted by eight trained interviewers who recorded data directly into the questionnaires. Any additional information was recorded in a notebook to elaborate certain behaviours and practices. Interviews were conducted in a reasonably quiet location to ensure privacy but in close proximity to the queue so that participants retained their positions in the queue. All interviews were conducted in Setswana. Information was collected on the behaviours and practices of pregnant women in relation to lead hazards. Participants were asked about their personal habits during the first trimester of pregnancy such as alcohol consumption, tobacco use and traditional medicine and whether they have pica behaviour. In terms of practices, women were asked what substances they use to treat skin or other health related problems during pregnancy.

3.3.4 Alcohol and tobacco use

Women were asked on the number of alcoholic drinks they consume every day. Alcohol consumption was then estimated by a modification of the methods suggested by Miller *et al.* (1991), to calculate standard drink units.[27] For each type of alcoholic drink (beer, wine, spirits, etc.), respondents reported their usual quantity and frequency of intake. Average daily volume (AVD) scores were then calculated for those who were specific on the number of drinks taken daily. Only alcohol users included in this study were those who had quit after becoming pregnant provided they quit between 8 and 10 weeks after their last menstrual period.[28] AVDs were not calculated for binge drinkers and for traditional brews. Participants were also asked whether they currently use tobacco products and to state the type of tobacco they were using.

3.3.5 Pica behaviour

Women were asked to indicate if they currently ingested non-food items. The women were further asked to indicate the type of non-food items that they ingest from a list provided as well as any other not listed in the questionnaire.

3.3.6 Unconventional skin disease treatments and complexion solutions

Study participants were specifically asked about the use of traditional cosmetic clays (*letsoku*), dry cell batteries and brake fluid. Women were further asked to state the specific use of such products. It is traditional practice for women to use *letsoku* for skin smoothing purposes. The use of used brake fluid oil has also been observed in the general public for treatment of skin related problems as well as dry cell batteries. The dry cell battery would normally be crushed and the powdery content of it mixed with petroleum jelly and applied in the skin, particularly for ringworm treatment. These practices have not been studied in pregnant women and their impact on health.

3.3.7 Data Analysis

Data was "double punched" using a Microsoft Excel software package, and subsequently transferred to STATA 11.0 statistical programme using Stattransfer. Bivariate analysis was used to test associations between risk behaviours and practices during pregnancy and socio-demographic variables (Chi-square statistics). Logistic regression analysis was then conducted to examine the multivariate relationships between the socio-demographic variables and each risk behaviour or practice. This method of analysis was chosen because it provides an interpretable linear model for a categorical dependent variable. Additionally, logistic regression allows for testing of significance of a given predictor whilst controlling for all other predictors in the model.[29] Each behaviour or practice was coded as a dichotomous variable with those women having engaged in behaviour coded as 1 and those who did not engage in the behaviour or practice (abstainers) coded as zero. Dummy variable coding was used for categorical independent variables with the references category chosen to represent the lowest expected risk behaviour. The assumption of linear relationships between each risk behaviour and independent variables was examined using the -2 log-likelihood chi-square statistic, and where applicable the final models were re-estimated using the correct scale of the variables. Normalized sample weights were used in the analysis of the data. The sampling weight is the inverse of the probability of selection, which is represented by the proportion of the actual number of respondents in each age category among the total targeted population in that same age category. Sample weights assigned to each respondent were divided by the mean sample weight to adjust for differing sampling probabilities. This procedure has the

effect of reweighting the sample to approximate the population distribution, while maintaining the study sample size as the total number of observations used in the analysis.

3.4 Ethical Approval

This study obtained unconditional ethical approval from the Research Ethics Committee, Faculty of Health Sciences, University of Pretoria, South Africa (reference 110/2009, appendices 1 & 2) and endorsement by the Ministry of Health Research and Ethics Committee, Gaborone, Botswana in 2009.

3.5 Results

3.5.1 Socioeconomic and demographic characteristics of study population

Table 3.1 shows the socio-demographic characteristics of pregnant women enrolled in the study.

Table 3.1
Socio-demographic Characteristics of the Study Population

Age (years)	**Number**	**Percent (%)**
≤19	13	(9.2)
20-24	49	(34.5)
25-29	32	(22.5)
30-34	28	(19.7)
35+	20	(14.1)
Employment		
Employed	61	(43.3)
Unemployed	80	(56.7)
Educational Status (in Years)		
Primary Education (1-7 Years)	19	(13.4)
Secondary Education (8-12 years)	92	(64.8)
Post-Secondary(13+years)	31	(21.8)
Income adequacy		
Lowest (P 0.00-P3000)	132	(93.6)
Lower Middle (P3001-6000)	7	(5)
Middle (P6001-9000)	1	(0.7)
Upper Middle (P9001-12000)	1	(0.7)
Parity		
Primipara	54	(38)
Multipara	88	(62)
Location		
Serowe (major village)	66	(46.5)
Palapye (major village)	48	(33.8)
Maunatlala (small village)	14	(9.9)
Lerala (small village)	14	(9.9)
Recruitment Facility type		
Hospital	104	(73.2)
Clinic	38	(26.8)

Note: One subject had missing values for employment and income variable

The income reported in this study indicates the total monthly household income as reported by the respondents. At the time of data collection 10 categories were created ranging from BWP <1 500 to BWP >9 500. However, upon analysis data was pooled into four groupings (Table 3.5.1). Since these were self-reported, there is a possibility that most of the respondents withheld the information. In this study, we define employment as having a paid salary at the end of each month.

Of the participants, 9% were found to be under the age of 20 years, with more than half (57%) being aged 20-29 years and 34% being above the age of 30 years. The majority of the women (89%) were not married. The low prevalence of marriage cut across all the study areas, however the majority of the unmarried (63%) was aged between 18-29 years and came from Maunatlala (100%) and Lerala (92.8%), both of which are small villages. About 57% of the women were unemployed in spite of more than 75% attaining secondary education level (matric) with 92% of the women falling in the lowest income adequacy group. Multiple parity was prevalent in 62% of the women overall, but more prevalent in Maunatlala (78%) and Lerala villages (92%) compared to Serowe and Palapye which both had 56% of multiparous women. The majority of the women were recruited from clinics (73%).

3.5.2 Prevalence and level of risk behavior

Table 3.2 shows prevalence of pica behavior. It is apparent that a substantial proportion of women overall reported ingesting non-food items (86%, n=142) which encompass a habitual ingestion of a variety of surface soils, crushed pottery and clays.

Table 3.2
Prevalence of Pica Behaviour By Age During the First Trimester of Pregnancy

	% ΣSoil Pica*		% Matches Pica		% Pencil Pica		% Paint Chips Pica		% Bone meal Pica		% Chalk Pica	
	No	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**	**No**	**Yes**
Age (Years)												
≤19	38.5	61.5	92.3	7.7	100	-	100	-	100	-	100	-
20-24	51	49	91.8	8.2	89.8	10.2	98	2.0	98	2.0	98	2.0
25-29	43.8	56.2	75	25	81.2	18.8	96.9	3.1	100	-	100	-
30-34	21.4	78.6	92.9	7.1	96.4	3.6	96.4	3.6	100	-	100	-
≥35	70	30	80	20	90	10	90	10	100	-	100	-
Overall %	45.1	54.9	86.6	13.4	90.1	9.9	96.5	3.5	99.3	0.7	99.3	0.7

***Chi-square test, p< 0.05**

(ΣSoils), unused matches heads, chewing pencil, ingesting paint chips from both furniture and peeling walls, bone meal and chalk The most frequently ingested item at the time of the study was soils about (55%) referred to as the sum of all soils (ΣS) in this paper. The ΣS ingested included termite mounds (n=56:39%), soils from pits and other surfaces (n=49:35%), river clay (n=16:11%) and crushed traditional clay pot (n=3:2.1%). Habitual soil ingestion was followed by habitual ingestion of unused matchstick heads and pencil chewing. Crushed bone meal, chalk and paint chips were the least ingested. Figure 3.2 characterizes ΣS by type and use by age. Women aged 30-34 years consumed more soil than all other age groups. Soil pica was less prevalent in the over 35 years age group.

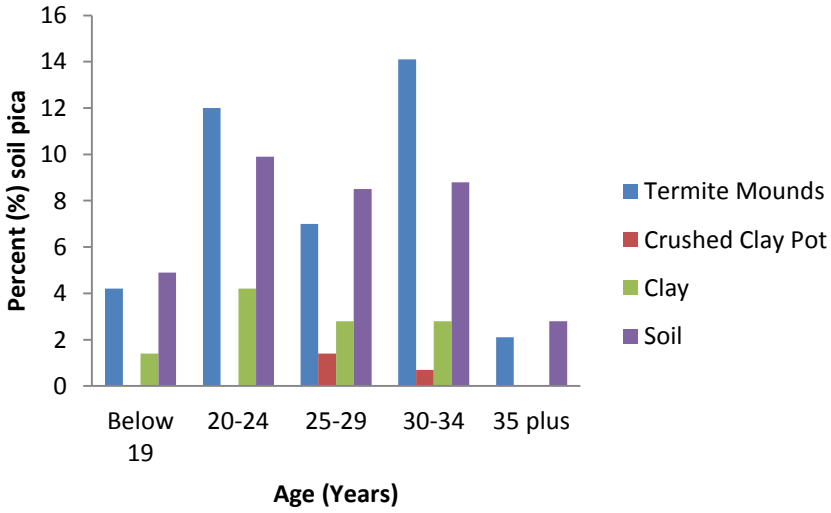

Figure 3.2 Characterization of ∑S Pica by type and Age (n=142)

Table 3.3 shows that 31% of women reported consuming alcohol. Out of these women, over 90% reported consuming alcohol 8-12 weeks before finding out they were pregnant (8 weeks: 53.5%; 12 weeks: 40.8%). Almost three quarters of the women had fewer than two drinks per week on average. Binge drinking was more prevalent among younger women while heavy drinking was observed in older women. Relatively fewer women (8%) reported using tobacco products. Out of the women only 2 smoked cigarettes whilst the rest used smokeless tobacco (snuff). Traditional medicines use was reported by 11% of women and was more prevalent in women aged 30 years and above.

Table 3.3
Prevalence of Alcohol, Tobacco and Folk Remedies Use By Age During the First Trimester of Pregnancy

	%Alcohol Use*¶					%Tobacco Use		% Traditional Medicine Use	
	None	Light (AVD 0.01-0.39)	Moderate (AVD 0.40-0.89)	Heavy (AVD 0.90+)	Binge	None	Yes	None	Yes
Age (Years)									
≤19	46.2	15.4	15.4	-	23.1	100	-	92.3	7.7
20-24	57.1	20.4	2.0	2.0	18.4	93.9	6.1	93.9	6.1
25-29	40.6	31.2	6.2	-	21.9	84.4	15.6	87.5	12.5
30-34	50	28.6	7.1	3.6	10.7	96.4	3.6	89.3	10.7
≥35	60	-	10	20	10	90	10	75	25
Overall %	51	21	6.3	4.2	16.9	92.3	7.7	88.7	11.3

***Average Daily volume (ADV):**0.01-0.39: equivalent to ≤ 2 drinks per week; 0.4-0.89: equivalent to 3-6 drinks per week; 0.90+: equivalent to ≥ 7 drinks per week. A standard drink is defined as 340ml can of beer(3.5% alcohol) or 105 ml wine (12% alcohol) or 30ml distilled spirits(43% alcohol)[27]
¶Chi-square test, p< 0.05

Table 3.4 shows unconventional skin practices among pregnant women. Used brake fluid oil was unanimously used treatment of psoriasis (referred to as *madi* or blood) by the women) and was prevalent in 30% of pregnant women overall. Approximately 20% of these women also reported using brake fluid for wound treatment and ringworm. Compared with younger women, older women (30 years and above) were more likely to use brake fluid. About 8% of women used torch battery contents for treatment of ring worm specifically. This practice was more prevalent in younger women than older women (above 34 years).

Table 3.4
Prevalence of Unconventional Skin Treatment Solutions By Age During the First Trimester of Pregnancy

	% Brake fluid Use For Treatment of Psoriasis		%Torch Battery Use for Ringworm Treatment		% *Letsoku* (Clay powder) Use for Vanishing		% Shoe Polish Use for Skin Vanishing	
	No	Yes	No	Yes	No	Yes	No	Yes
Age (Years)								
≤19	69.2	30.8	92.3	7.7	92.3	7.7	84.6	15.4
20-24	81.6	18.4	87.8	12.2	87.8	12.2	75.5	24.5
25-29	71.9	28.1	93.8	6.2	78.1	21.9	87.5	12.5
30-34	53.6	46.4	96.4	3.6	75	25	92.9	7.1
≥35	60	40	95	5	75	25	75	25
Overall %	**69.7**	**30.3**	**92.3**	**7.7**	**81.7**	**18.3**	**82.4**	**17.6**

Letsoku, was used for different purposes including cosmetic use and was reported overall by 18% of women. All of the women said they used *letsoku* as a facial powder with 60% and 20% using it for skin acne treatment (or skin smoothing) and for treatment of stomach ache respectively. Light brown shoe polish was also reported by 18% of women for skin smoothing and vanishing. The use of *Letsoku* was more prevalent in women aged >30 years whilst light-brown shoe polish cut across all age groups with a higher prevalence among the older (≥ 35) and the age 20-24 years category. The prevalence of each risk behavior did not vary with age with the exception of ΣS pica (p=0.01) and alcohol consumption (p=0.03). ΣS pica by age had a somewhat U-shape distribution being more likely among the less than 19 years and the 30-34 years age groups. However when termite mounds ingestion was compared with all other soils separately, termite mounds alone had a stronger association with age (p=0.001) with the age group 30-34 years more likely to ingest termite mounds than most of other age groups. Compared with older women, younger women (below 34 years) were more likely to drink alcohol; however older women (35 plus years) tended to drink more heavily.

Figure 3.3 shows the distribution of risk behaviours by location. A significant difference in the prevalence of risk behaviour by locations was observed (Chi square test, p<0.05).

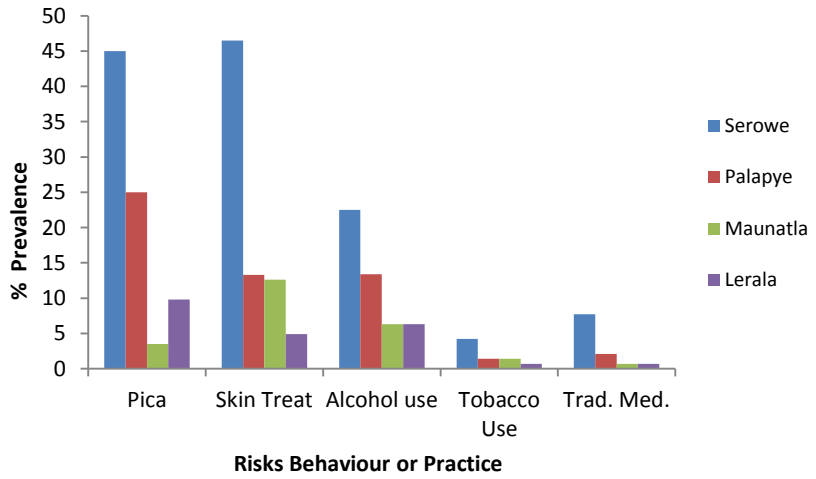

Figure 3.3: Percent Prevalence of Risk Behaviour/ Practice by Location (n=142)

Pica, skin treatment interventions and alcohol consumption were more prevalent in the major villages (Serowe and Palapye) compared to smaller villages (Maunatlala and Lerala). Tobacco use and traditional medicines were reported in all areas, but slightly higher in Serowe.

3.5.3 Socio-demographic correlates of risk behavior

Table 3.5 shows that age was an important predictor of the ingestion of non-food items such as soil, matches, brake fluid and folk remedies. Those at ages 30-34 were at a significantly higher risk of engaging in geophagy (ingestion of soils) than other age groups ($p<0.01$).

Table 3.5
Significant Socio-demographic Predictors of Risk Behaviors During the First Trimester of Pregnancy

	ΣSoils Pica OR(95%CI)	Pica Matchsticks OR(95%CI)	Pica Pencil Lead	Brake fluid	Folk Remedies
Age (Years)					0.62(0.39,0.98)**
18-19		22.70(1.2,458.04)**		1.00 Reference	
20-24		15.0(1.7,29.96)**		0.23(0.05,1.01)**	
25-29					
30-34	0.12(0.03,0.54)***				
≥35	1.00 Reference	1.00 Reference			
Employment					
Employed					1.00 Reference
Unemployed					0.25(0.07,0.99)**
Parity					
Primipara		1.00 Reference	1.00 Reference		
Multipara		0.16(0.04,0.66)**	0.17(0.04,0.77)**		

*****p<0.01; **p<0.05;**
OR=Odd Ratio; CI = Confidence interval

Additionally, the odds of predicting correctly who eats soils improved by 64% (1.64 – 1) (OR 1.64;CI:50,5.40) if one knew respondents marital status and 46% (1.46–1) if one knew respondents income categories. Younger women aged 18-24 and multiparous women were at a significantly higher risk for ingesting matches than older and primiparous women respectively. Multiparous women were at a greater risk of ingesting pencil ($p<0.05$) than primiparous women. Age was positively associated with pencil ingestion.

3.5.4 Unconventional skin treatment solutions

No significant differences were observed among the predictor variables for unconventional skin treatment products ($\chi^2 = 6.20, df = 6, N = 142, \rho > 0.05$). The odds ratio which suggest that the odds of predicting correctly who uses all the skin products improve by 29% (1.29 – 1) if one knew respondents age whilst it was 19% (1.19 -1) and 20% (1.99 -1) if one knew respondents marital status and level of education respectively. Women aged 20-24 years were at a higher risk of using brake fluid (OR=0.23: p<0.05).

3.5.5 Traditional medicines use

The use of traditional medicines or folk remedies was predicted by all the six predictor variables when considered together (χ = 9.609, df = 3, N= 142, ρ < 0.05). However employment and age were significantly better predictors of traditional medicine use. Women who were unemployed were at a significantly higher risk of using folk remedies than those who were employed (p<0.05).

3.5.6 Alcohol consumption and tobacco use

Alcohol consumption and tobacco use were positively associated with all the six predictor variables (p>0.05).

3.5.7 Multiple risk behaviours

Table 3.6 presents the proportions of women engaging in each possible combination of risk behaviours. About a quarter (26.7%) of the respondents reported two risk behaviours with alcohol and soil pica as the most common combination (8.5%). About 35% of the women engaged in three or more risk behaviours with no specific common risk behaviour combinations but rather varied alcohol and soil pica combinations.

Table 3.6
Multiple Risk Behavior During the First Trimester

	No.	%
One Risk Behavior (n=39; 27.5%)		
Pica Soils	13	9.2
Alcohol use	9	6.3
Brake fluid use	6	4.2
Letsoku application	3	2.1
Two Risk Behaviors (n=38; 26.8%)		
Alcohol use and soil pica	12	8.5
Alcohol use and matchstick pica	3	2.1
Alcohol use and tobacco use	1	0.7
Alcohol use and pencil lead pica	1	0.7
Alcohol use and torch battery contents application	1	0.7
Alcohol use and shoe polish application	1	0.7
Alcohol use and paint chip pica	1	0.7
Brake fluid and torch battery contents application	2	1.4
Brake fluid and shoe polish applications	2	1.4
Brake fluid and pencil lead pica	1	0.7
Brake fluid and matchstick pica	1	0.7
Matchstick and pencil lead pica	1	0.7
Shoe polish and *Letsoku* applications	1	0.7
Soil pica and brake fluid application	8	5.6
Soil pica and matchstick pica	2	1.4
Three Risk Behaviors (n=28;19.7%)		
Alcohol use, soil pica and brake fluid application	4	2.8
Alcohol use, soil pica and shoe polish application	4	2.8
Alcohol use, soil pica and *letsoku* application	4	2.8
alcohol use, soil pica and tobacco use	1	0.7
Alcohol use, soil pica and torch battery contents application	1	0.7
Alcohol use, soil and paint chips pica	1	0.7
Alcohol use, tobacco use and chalk pica	1	0.7
Alcohol use, shoe polish and *letsoku* applications	2	1.4
Alcohol use, *letsoku* and brake fluid application	1	0.7
Soil pica, brake fluid and *letsoku* application	3	2.1
Soil pica, shoe polish and torch battery contents application	1	0.7
Soil pica brake fluid and torch batteries contents application	1	0.7
Soil pica, shoe polish and brake fluid application	1	0.7
Soil pica, pencil pica and brake fluid application	1	0.7
Bone meal pica, torch battery contents and brake fluid application	1	0.7
Tobacco use, alcohol and brake fluid application	1	0.7
Four and above risk factors (n=22;15.5%)		
Alcohol use, shoe polish, *letsoku* and brake fluid application	1	0.7
Alcohol use, soil pica, torch batteries *Letsoku* and brake fluid application	1	0.7
Alcohol use, soil pica, pencil lead pica, torch batteries and brake fluid applications	1	0.7
Alcohol use, soil pica, *letsoku* and brake fluid application	2	1.4
Alcohol use, soil pica, matchstick pica, shoe polish, *letsoku* and brake fluid application	1	0.7
Alcohol use, soil pica, matchstick pica, *letsoku* and brake fluid application	1	0.7
Alcohol use soil pica, matchstick pica, pencil lead pica *letsoku* and brake fluid application	1	0.7
Alcohol use, soil pica, match stick pica, pencil lead pica and *Letsoku* application	1	0.7
Alcohol use , soil pica, shoe polish, *letsoku* and brake fluid applications	2	1.4
Alcohol use, soil pica, tobacco use letsoku and shoe polish application	1	0.7
Alcohol use, soil pica, tobacco use *letsoku* and chalk pica	1	0.7
Alcohol use, soil pica, tobacco use, paint chips pica, matchstick pica, pencil lead pica, shoe polish and torch battery content applications	1	0.7
Alcohol use, matchstick and pencil lead pica, shoe polish and *letsoku* application	1	0.7
Alcohol use, tobacco use, matchstick, paint chips and pencil lead pica	1	0.7
Alcohol use, tobacco use, matchstick and pencil lead pica, shoe polish and brake fluid application	1	0.7
Soil pica, matchstick pica, pencil lead pica, *letsoku*, shoe polish and torch battery contents applications	1	0.7
Soil pica, matchstick pica, pencil lead pica *letsoku* and brake fluid application	1	0.7
Soil pica, matchstick, pencil lead pica and *letsoku* application	1	0.7
Soil pica, bone meal pica, paint chip pica and brake fluid application	2	1.4
Soil pica, recreational drugs, shoe polish and *letsoku* applications	1	0.7
Abstainer from all risk factors	**15**	**10.6**

Employment was a better predictor of two or more risk behaviours than all other predictor variables (OR=1.43: CI=0.66,2.86). Not being married and being

multiparous were 1.5 times (OR=1.52:CI=0.45,4.74) and 1.3 times (OR=1.34:CI=0.53,3.35) as likely as women who were married or primiparous respectively to engage in two or more risk behaviours or practices.

3.6 Discussion:

This study has identified health risk behaviors among pregnant women in the Central District of Botswana during the first trimester of pregnancy. Pregnant women engage in behaviors such as pica, skin application of auto oils and other substances with a potential to expose them to lead and other hazardous substances. Socio-demographic factors such as age, employment and multigravida have an influence on pregnant women engaging in risky lead exposure behaviors during the first trimester of pregnancy.

3.6.1 Ingestion of Non-food items as a potential source of lead poisoning among pregnant women

Pica is described as the craving and subsequent purposive consumption of non-food substances for more than one month. Among the most prominent forms of pica in this study is geophagia, the intentional ingestion of earths or soils.[30] While this practice is prominent in countries of the African region, it has been observed in other regions as well as in nationalities which have immigrated to the developed countries.[8,31] Observations of women ingesting surface soil, particularly from anthills, have been noted in urban areas as well in Botswana and this is consistent with studies elsewhere. [32] In a related New York study women were likely to purchase such soils from areas where they were reared that was brought by visiting relatives. [33] In Kenya, more than half of pregnant women practice geophagy.[34] Our results show a similar pattern where approximately, 55% of women ingested different types of soils ranging from clays to termite mounds during their first trimester of pregnancy. Ingestion of paint was less of a problem and this is consistent with Shannon's findings where she reports more women engaging in geophagia compared to paint ingestion.[7] Soil and dust have been identified as dominant pathways for human lead exposure and that these pose a greater risk than lead-based paint to children who engage in hand-to-mouth and pica behavior.[35] In a literature review of 25 years, Shannon (2003) identified pregnant women who experienced severe lead poisoning as a result of ingestion of soil, clay or

pottery.[7] Reported adverse health effects as a result of geophagia during pregnancy include hypokalemic quadriparesis as well as death.[7,36] It is more concerning that pregnant women in this study have engaged in other forms of pica such sucking heads of match sticks, chewing pencil (likely to be painted with lead containing paint), ingesting paint chips from peeling wall paints and furniture paint, bone-meal and chalk. While paint-chips, chalk and bone-meal ingestion during pregnancy have been reported by other studies.[37-39] Studies of women chewing pencil have not been reported. This type of practice has generally been reported in children ingesting pencil paint that contains lead. [40] A study carried out in South Africa by Okonkwo (2004) identified pencils painted with lead paint.[41] Pencil chewing as a pica habit by pregnant women in this study therefore presents a potential lead exposure source. Ingestion of matches by pregnant women has been reported in other studies, however, these were burnt matches women habitually ingested.[39] In this study, pregnant women sucked the heads of unused matches. While it is not established if such a practice can predispose women to lead exposure, matches has previously contained lead pyrophorus from roasted lead tartrate and the modern matches has a variety of chemicals which may present harm if ingested such as ammonium phosphate, borax, paraffin, potassium chlorate, sulphur, zinc oxide, glass powder and many other substances.[42]

3.6.2 Use of nonconventional skin treatment solutions

Used brake fluid was reported to treat psoriasis, ringworm and applied on wounds including open wounds. Car lubricants, known to contain lead and its derivatives such as lead naphthenate were used. [43,44] Lead has been determined from various used and unused oils ranging from 4.6 to 928ppm lead.[43] Such oils include gear oils, brake washing oil, lockhead brake oils, tyre cleaners and many other used motor oils. In their study, among autoworkers, Claussen and Rastogi (1977) concluded that inadequate protection of workers might allow organic lead to be taken up by the body through direct skin contact.[43] Cutaneous application of lead naphthenate solution has been found to produce chronic lead toxicity in rats.[45] This therefore places women who apply oils such as brake on their skin, including on open wounds, at a much greater risk for lead exposure. It is not understood why women engage in using car lubricants for treatment of skin infections of conditions. However lubricants containing lead naphthenate have been used elsewhere for cleaning hands in auto

workshops for their apparent effectiveness in removing carbon particles due to their apparent detergent content.[45] Of major concern is that in studies of auto workers who used car oils for cleaning hands, high blood-lead levels have been observed (mean 57.4µg/dL) yet the workers were not aware of the risks from such practices.[45] In other non-human studies car oils have been identified as an important cause of lead toxicity for cattle in countries such as Australia where cattle drank it. [46] Auto oils are also used in South Africa as an acaricide even though there has been no report of lead poisoning as a result of such practice by small scale farmers.[47] This study reveals that while the use of brake fluid is prevalent in all age groups, women aged 20-24 years are at a significantly higher risk of using brake fluid compared to other women. These women may not be aware of the hazards presented by using brake fluid and exposure at such a young age might present lifelong lead exposure source for them and generations to come.

Light brown shoe polish was used as a "cosmetic" for smoothing and vanishing skin. This is a new phenomenon identified by this study. Shoe polish contains high concentrations of solvents and the solvents contained in shoe polish, just like lead, cause adverse effects on the central nervous system which may result with brain damage.[48,49] Other effects of solvents from shoe polish similar to those caused by lead found in animal studies include anemia and embryo-toxic effects such as significant reduction in fetus weight.[50] While solvents in shoe polish may not be a direct exposure source of lead in pregnancy, the solvent concentrations in it need to be taken into consideration as potentially powerful confounding factors in lead studies.

The prevalence of torch batteries used for the treatment of ringworm and other skin conditions was low (8%) compared to that of brake fluid (30%) and shoe polish (18%), but it is yet another new finding by this study. While it is not known how these women identified torch batteries as a treatment option for ringworm and found it effective, it is suspected that its effectiveness stems from the high zinc content in dry cell batteries. Studies that have characterized dry cell batteries have found large amounts zinc in dry cell batteries. In one study the total amount of zinc per AA alkaline household battery was 3418 mg.[51] The same study however reported total lead in one battery to be 1.2 mg.[51] Even though lead concentrations in dry cell

batteries are reported in trace amounts and the levels may even fall within the recommended standards, the application of contents of dry cell batteries on skin cannot be ignored because dry cell batteries contain other hazardous substances such as arsenic, cadmium and mercury. [51,52] On the other hand one may also argue that the standards were not set with the application of dry cell battery contents on human skin. This practice therefore, may still pose yet another new exposure source for lead not only for pregnant women, but for children and other adults who have been observed using dry cell batteries for treatment of ringworm in Botswana. This argument is supported by a body of literature which confirms that there is no threshold for lead toxicity. [21,22]

The use of clays as cosmetic and medicinal products (known as *letsoku* in Botswana) has extensively been studied in many parts of Africa including Botswana.[53,54] They are well known for their cleansing, sunscreen and body beautification properties due to their high mineral content.[55] However, heavy metals including lead have been detected in these clays.[56] In this study, women use *letsoku* for beautifying purposes (as a facial powder and acne treatment) but they also reported using it for treatment of stomach-ache. These practices therefore create another exposure source for lead in pregnant women through skin or the gastrointestinal tract particularly that some of the clays have been found to be acidic.[53-56]

3.6.3 Alcohol and tobacco use

In humans, the intake of about 1 drink/day or more has consistently been shown to be associated with a large number of adverse pregnancy outcomes.[57] A number of population based studies have also identified lifestyle factors such as smoking and alcohol consumption as potential avoidable sources of lead exposure.[58] Cigarettes contain varying amounts of lead and a person who smokes 20 cigarettes a day has been estimated to inhale an approximate amount of 1-5µg of lead daily.[59] Maternal drinking and smoking during pregnancy and prenatal exposure to low doses of lead have been associated with reduced gestational age and weight at birth. A dose response relationship was found between cigarette smoking and alcohol consumption of mothers and cord blood lead levels. An average increase of about 15% (0.013µmol/litre) in cord blood lead levels was estimated for every 10 cigarettes

smoked per day.[60] Mean blood lead levels in babies whose mothers did not smoke during pregnancy but who drank alcohol moderately was 17% higher than those of non-smoking mothers who abstained from alcohol intake.[60] Rhainds and Levallois concluded that the lifestyle of pregnant women play an important role in the prenatal lead exposure of newborns.[60] While the majority of women used smokeless tobacco in this study, it is noted that such a practice is a potential confounder for lead exposure, as it has been associated with poor birth outcomes such as stillbirth.

3.6.4 Traditional medicine

Traditional medicine was used for different purposes which ranged from pain relief to blood cleansing by pregnant women in this study. The greatest concern with the use of traditional medications during pregnancy is that such medications may be contaminated with heavy metals including lead.[61] The Centers for Disease Control (2004) has reported severe lead poisoning as a result of traditional medications use??resulting with detrimental health effects such as brain damage.[12] Adverse pregnancy outcomes such as lead poisoned infants, encephalopathy, ante-partum hemorrhage, and elevated cord blood lead levels have been reported as a result of the use of traditional remedies.[3] The use of traditional medications and lack of monitoring thereof during pregnancy have serious implications on the health of pregnant women and the expected infants. This practice by pregnant women, require not only strict control measures but public awareness among health care providers and the public.

3.6.5 Predictors of risk behaviours:

In terms of predictors of risky behaviours, age, employment and parity were significant predictors of whether a woman would engage in a risky behaviour or not. Pregnant women aged 30-34 years were at a significantly higher risk of geophagy than all the other age groups. Multiparours women were at a significantly higher risk of engaging in pencil and matchstick pica than all other women. In this study, this has implications on women living in rural areas (small villages) who had the highest number of children compared to women in larger, semi-urban villages. Studies are not conclusive on predisposing factors in terms of geophagy and socioeconomic status. However, this study has similarities with that carried out in Kenya in terms of age as a

predictor of geophagy.[62] Even though the differences were not statistically different, Luoba and others (2004) also found unemployment and education as predictors of geophagy among pregnant women.[62] The findings of this study are also generally similar in many respects with studies that concluded that pica of any sort is not limited to socioeconomic background.[30,34] Predictor factors for traditional medicines were limited to employment. Unemployed women were at a significantly higher risk of using traditional medicines than those employed. The use of brake fluid was significantly predicted by age with the 20-25 years age category at a significantly higher risk to use brake fluid than other age groups. Interestingly, though not significant, employment and marital status were better predictors of two or more risk behaviors than all other predictor variables.

3.7 Limitations

The sample size of this study was not entirely representative of all pregnant women in Botswana but was heterogeneous in terms of demographic characteristics as well as risk behaviours. For this reason, the findings can be applied to many districts and therefore make findings of this study relevant to other settings.

Another limitation of this study is that respondents felt that the questionnaire was too long and the additional waiting to receive the services compounded this. It is the view of the author that some of the critical behaviour were under reported. The behaviours that are normally observed in these communities, for example, tobacco use do not generally reflect the actual observations with regard to snuff used by many women.

Alcohol use in this study did not take account of traditional brews, which are common in villages (major and small). This may therefore have an effect on the number of women who used traditional brews.

The majority of the women were reluctant to reveal their income. The author therefore feels income was under reported.

3.8 Conclusions and policy implications

The results of this study have brought out important lifestyle, environmental and cultural behaviors of pregnant women in the Central District of Botswana. Most importantly, these findings have been observed in other parts of Botswana including urban areas. These behaviors and practices have a potential to adversely affect pregnant women and their expected infants. While the current Botswana Obstetric Record booklet, [63] lists alcohol and smoking as risk factors for adverse effects during pregnancy, it is however silent on the behaviors reported in this study such as pica, the use of traditional medications, and hazardous skin treatment interventions such as auto oils, torch batteries, shoe polish and traditional clay cosmetics. This study highlights the need to enquire whether pregnant women engage in these practices during history taking and report these in the obstetrics record booklet. Most importantly this study highlights the need for obstetricians, gynecologists and family practitioners or physicians to be sensitized on these habits and practices through workshops to enable them to analyze the prevalence of the risk behaviors and practices within their communities; identify risk factors for such behaviors and practices, assess potential adverse effects on pregnancy outcomes and develop interventions to manage the risk behaviors and practices. Education and awareness of pregnant women on the potential negative impacts of these habits and practices is recommended.

Finally, the inclusion of these risk behaviors and practices on the Botswana Obstetric Record booklet is recommended. This will allow family physicians, gynecologists and obstetricians to be aware of the potential risks to lead and other hazardous substances. This will enable timely behavior risk management and the interventions such as education and awareness. Such an inclusion will also allow continuous screening of pregnant women for risky lead exposure behaviors during antenatal visits as this will provide a more systematic and a less expensive way of establishing the epidemiological status of such behaviors and practices. Additionally baseline lead exposure studies are recommended to establish if there is a link between these habits and lead exposure in Botswana.

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Chapter 4

Potential Environmental Sources of Lead Exposure to Pregnant Women in the Serowe Palapye District, Botswana

4.1 Abstract

The study aims to determine lead (Pb) concentrations in water (PbW), soil (PbS) and in clays (PbC) in the Serowe Palapye District and compare lead levels between major villages and small rural villages. Pb levels were also compared to international maximum permissible standards to assess potential health impacts on pregnant women. Samples were collected in two major villages (Palapye and Serowe) and two small villages (Lerala and Maunatla). Three cosmetic clays, 28 surface soils (top 2-5cm) and drinking water samples (the first flush water from drinking water taps) were collected and analysed using Varian AAS. The mean PbC (±SEM) was 3.99±0.41ppm compared to 0.27±0.03ppm and 0.19±0.02ppm in soil and water respectively. Mean PbS (±SEM) in Palapye, Serowe and small villages (Maunatlala and Lerala) were 0.57±0.068ppm, 0.28 ±0.049ppm and 0.22±0.019ppm respectively below the recommended international residential permissible soil standards. Mean PbW (±SEM) in Palapye, Serowe and small villages were 0.32±0.01 ppm, 0.25±0.010 ppm and 0.12±0.025ppm respectively, all in excess of the WHO drinking water quality permissible Pb concentration of 0.01ppm. Major villages, had significantly higher Pb concentrations ($p<0.05$) in soils and water compared to small rural villages. PbW concentrations by far exceed permissible WHO drinking water-quality standards and therefore present a potential exposure source for pregnant women. Measurement of blood lead levels (PbB) among pregnant women are recommended to assess potential relationship between BLL and environmental levels. Assessment of plumbing materials used in household and communal drinking water taps and the lining of communal water storage tanks is recommended. Educating the public on potential environmental sources of lead exposure including policy makers in order to influence policy change in addressing Pb pollution issues is needed.

Keywords—Lead; Drinking water, Soil, Central District, Botswana

4.2 Introduction

Lead, occurring in various concentrations in rocks and soils, is one of the most pervasive and persistent heavy metals posing threats to the environment, soil quality and human health.[1-6] In the environment, lead occurs both naturally and from human activities such as mining, smelting, production, processing, recycling and waste disposal activities as well as emissions from auto exhausts.[7,8]

ATSDR (2010) has identified six major environmental sources of lead which include leaded paint, leaded petrol, stationary sources, dust/soil, food and water.[9] There is consensus in scientific and medical literature that the primary route of exposure to lead in children is oral ingestion of lead-based paint and lead contaminated dust and soil. For adults, the primary route of exposure is inhalation of lead containing dust and fumes from occupational settings. There is also mounting evidence that population groups are exposed to lead through many other unconventional sources such as traditional medicines,[10,11] adult soil ingestion (geophagia),[12,13] cosmetics,[14] and many other sources.[15]

Lead polluted soils constitute a major environmental problem. In recent years, there has been an increased recognition that lead contaminated soils are an exposure source to humans. Soil can enter the human body through inhalation,[16] eating soil (geophagia),[17] and through skin lesions[18]. Lead has been reported as a greater risk factor for elevated blood lead levels than lead-based paint not only to children engaging in hand-to-mouth and pica behaviour, but also to pregnant women who engage in geophagia.[19-23] Women of reproductive age who have had significant lead exposures may experience decrease in fertility,[5,24] hypertension,[25,26] preterm delivery and low birth weight.[27,28] Pregnancy may accelerate the release of lead stored in the woman's bones to other parts of the body.[29,30] Because lead is freely transported across the placenta, fetuses of mothers with high body lead burden are potentially exposed to significant concentrations of lead during the course of the pregnancy[31]. This may result with damage to the developing fetus in any trimester, in part due to the placental permeability and immature fetal blood–brain barrier and may have lifelong negative impacts on the woman and the unborn child.[32]

Clays, naturally occurring inorganic components of soil, have traditionally been used by humans for different purposes ranging from cosmetics to medicinal use. Clay slurries have often been used for beautification purposes and applied to the face or body or even drunk to cure systemic problems[33]. In a recent study by Mbongwe et al. (2012) (unpublished), 18% of pregnant women used traditional clays for beautification and medicinal purposes[34]. These clays are rich in minerals and often contain hazardous heavy metals including,[35] lead hence in developed nations, compositional, technical and specifications of clays to be used for pharmaceutical and cosmetic purposes have been developed[36].

Lead in water (PbW) is an important pathway for lead exposure for several reasons. First water lead levels can vary from dwelling to dwelling due to the variations in plumbing types as well as social factors.[37-39] Pockock *et al*. (1983) and Elwood *et al*. (1984) further report that even in areas where there is non-plumbosolvent water, appreciable lead levels have been observed.[40,41] For example, relatively high water lead levels have been observed in hard water, which is normally considered to have low lead levels compared to soft water.[41] The second, and probably the most important reason why PbW is an important pathway for lead exposure is due to its relatively efficient absorption by the body compared to other sources. A study by Heard (1983) found that volunteers retained 40-50% of radioactive lead marker added to water[42]. Additionally, lead is adsorbed from water onto vegetables during cooking[43]. In the United Kingdom, where more studies have been conducted in water more than in any other source, it is further estimated that water, both in its direct form and indirectly through adsorption contributes on average to at least 10% of dietary lead.[44] Pocock *et al*. (1983) and Elwood *et al*. (1984) similarly estimated that about 7% and 23% respectively, of the variance in blood lead levels could be attributed to PbW[40]. A more than doubling effect on mean blood lead levels has been reported by other studies in areas of plumbosolvency and old pipes.[38,45] The third reason why PbW must receive close attention is because high lead levels occur more often in older housing properties as well as in less privileged areas.[46]

4.2.1 Study area overview and context

Botswana is a landlocked, semi-arid country with an approximate area of 582 000 km^2 and has a population of 2,024,904.[47] It is located in the centre of Southern Africa, bordered to the north by Zambia, to the northwest by Namibia, to the northeast by Zimbabwe and to the east and southeast by South Africa. The country is an almost plateau with an average altitude of 1 000m; elevation ranges between 700m and 1300m. The lowest parts of the plateau surface are Ngami area and swamps of the Okavango River in the northwest (Figure 1), the salty pans of Makgadikgadi in the northeast and the area between the Shashe and the Limpopo Rivers in the east (Figure 1). The Okavango and Chobe Rivers are the only perennial rivers with their sources outside the country (Figure1). Most of the rivers and valleys are ephemeral and usually dry except after rains.

The study area, Serowe Palapye, is located 22° 44' 53" S and 26° 47' 15" E in the Central Administrative District of Botswana (Figure 1) with a total population of 180,500.[47] It is home to the only coal mine in Botswana, the Morupule Colliery, which supplies a coal-fired Murupule Power Station of the Botswana Power Corporation. According to Central Statistics Office (2007), Botswana has over 212,383 million tonnes of coal resources out of which 48,576 million tonnes are classified as measured, indicated or inferred reserves and the rest is of either hypothetical or speculative resources[48]. More than half of the locally produced coal (60% in both 2004 and 2005) is used to fire the BPC thermal plant.[48]

Toxic elements maybe released during mining, beneficiation and usage of coal operations. There is an increasing concern for the effects of toxic elements associated with power plant residues from bottom ash and fly ash as well as emissions.[49,50] Lead is of environmental concern because it is dispersed from power plant emissions.[50] It is recognised that during combustion of coal, the redistribution of trace elements into fly ash and bottom ash should be ascertained for each power plant to ensure that relevant decisions are made about the management of the residues.[49,50] It is on this basis necessary to assess trace elements in the environment around power stations at least about 20 km from power stations to ensure that trace elements from coal mining and usage are not harmful to the environment and human health.[50,51]

Currently, very little work has been done in the Serowe Palapye District and near the Morupule Power Station on trace elements contamination on soils or water. Zhai *et al.* 2009 assessed the distribution of heavy metals including lead near Palapye and found moderate contamination of soils around Palapye area.[52] No studies have been conducted to assess lead concentrations in water.[53,54] The relevance of this research in the context of coal mining in the Serowe Palapye area can therefore not be overemphasized with particular reference to pregnant women who have a tendency to engage in geophagea which in turn may result with undesirable birth outcomes.

This study is part of a study to develop a clinical assessment tool for assessing lead exposure during pregnancy. The goal of this study is to determine lead levels in environmental samples from selected villages of Serowe Palapye Administrative District. Specifically the study seeks to determine the distribution of lead levels in soils, cosmetic clays and drinking water from Serowe, Palapye, Lerala and Maunatlala villages. The study further seeks to compare lead levels in each of the environmental sample matrices by location and assess potential impact on pregnant women based on soil and water standards. The standards and specifications (maximum allowable limits) are shown on page Table 4.1.

Table 4.1: Standards/specifications for cosmetic clays, soils and water (ppm)

Environmental medium	Standard	Source
Cosmetic/medicinal clays (kaolinite)	≤10	USP[55]
Soil (Residential)	140	CCME[56]
Water (drinking water)	0.01	World Health Organization[57]

4.3 Materials and Methods

4.3.1 Topograpy of the study site

To study the distribution of lead in soils and water from the Serowe Palapye District, we sectioned the study area to distinguish areas in the vicinity of the coal mining area and the power station and those further away. Figure 1 shows the study areas. Serowe, a major village with a population of 50,820 is located approximately 30 kilometres west of the Morupule Colliery. Palapye, a moderately industrial major village, is

situated approximately 7 km to the east of the Morupule Colliery with the main road between Palapye and Serowe (A14) lying south of the mine and a major highway lying west of the village. Highway A1 from Gaborone to Francistown runs between Palapye village and Morupule Colliery. Two small villages, Maunatlala with a population of 4552[47], and Lerala with a slightly higher population of 6871[47] were chosen and are approximately 65 km and 93 km respectively east of Palapye, the mine and the power station.

Table 4.2 classifies and describes the soils and topography of the sampling areas as laid out in the soil map (Figure 2). According to the Land Utilization Division of the Ministry of Agriculture (1985), Serowe is dominated by B1-B6 and R soils; Palapye is characterized by A13a and D1a soils while Maunatlala and Lerala are dominated by A11a and A4b soils (Figure 2, Table 1)[58]. Serowe Palapye district is therefore generally dominated by a low relief plain and featureless veldt with the major soil groups being mostly Arenosols and Luvisols, with small areas of Lixisols[48,59,60], mostly found on fine-grained and coarse-grained sedimentary rocks e.g. sandstone[61]. Luvisols of the Karoo super-group are known for the accumulation of clay (15-25%) and a higher fertility[62], while Arenosols made up of sandy soils with weak structure and low fertility[59,60]. In general the soils are sandy with a low clay content (<10%) the result of which is high water infiltration rates, low water holding capacity and fairly poor fertility[53,61,62]. Around the Colliery, the dominant soil types are Ferralic Arenosols and Arenic Ferric Luvisols (<3% clay)[53]. The pH of the soils generally ranges from 6.7 to 9.1[62].

On average, the temperature ranges between 2.65°C in winter and up to 41.35°C in summer. Rainfall occurs between the months of October and March, with the dry season commencing in mid-April continuing until September. The annual average rainfall recorded for the study area is 445 mm with the annual total evaporation estimated at ~2 520mm[48].

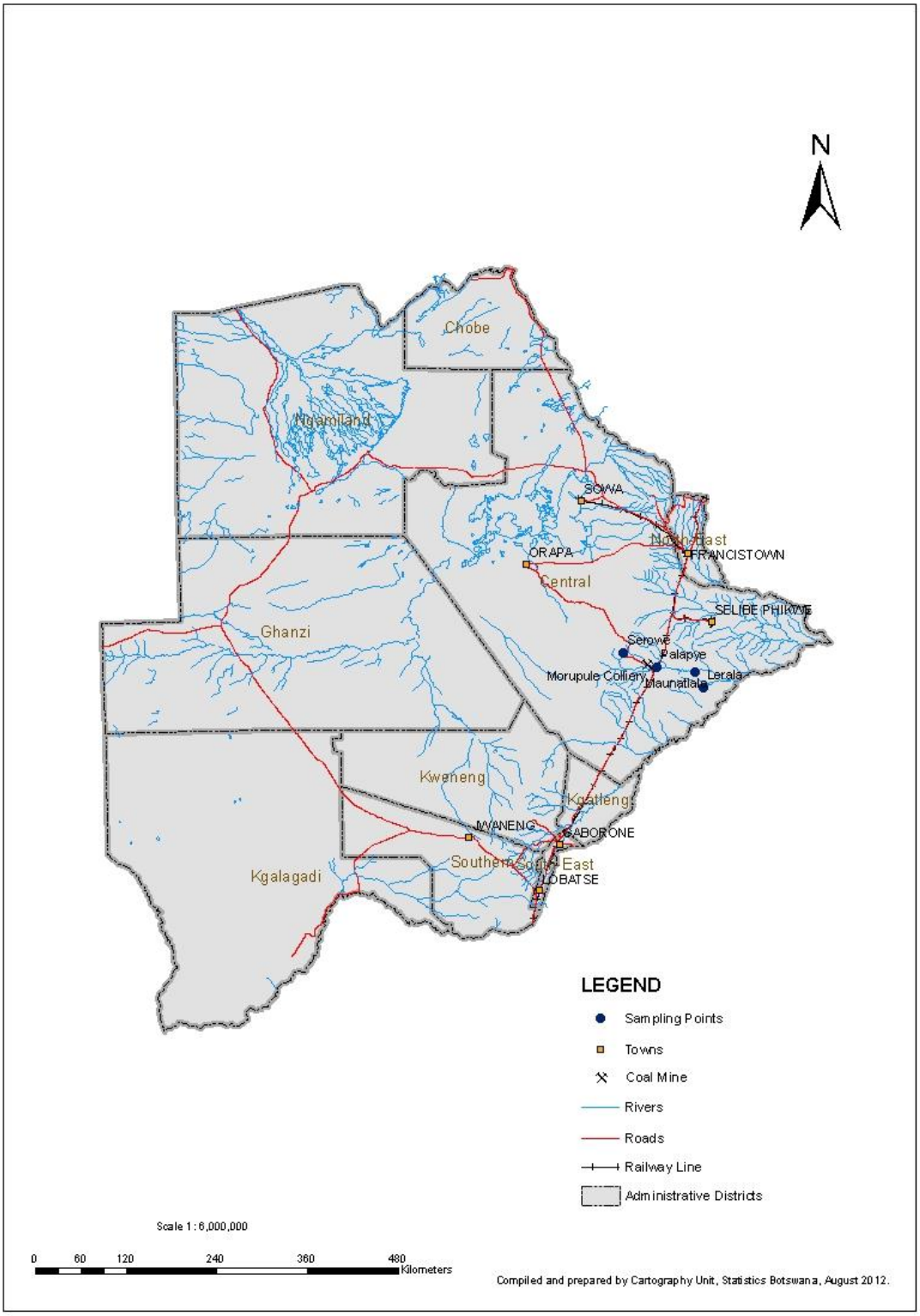

Figure 4.1 Map of Botswana Showing Administrative Districts and sampling locations

Table 4.2: Sampling Area Soil Description and Classification

Location	Soil Symbol	Soil Description and Topography	Soil Classification
Lerala and Maunatlala	A4b	Moderately deep to very deep, imperfectly drained, massive, gray to greyish brown to brown clay loam to clay	Calcic Cambisol
	A11a	Moderately deep to deep, moderately well drained, red to brown sandy loam to sandy loam	Ferric Luvisol, petric, petroferric
Palapye	A13a	Moderately deep to deep, moderately well drained, dark red to strong brown massive sandy clay loam to sandy clay	Chomic Luvisol
	D1a	Very shallow to moderately deep, well drained, yellowish brown, to reddish brown sandy loam to clay loam, undulating to hilly	Dystric Regosol. petric, partly lithic
Serowe	RR	Very shallow soils on steep hills, ridges and escarpments	
	B1	Very shallow to shallow, well to somewhat well drained, reddish brown to dark brown sandy loam to clay loam, undulating to hilly	Eutric Regosol lithic
	B1a	As B1 but almost flat	Eutric Regosol
	B1b	As B1 but calcareous	Calcaric Regosol
	B2	Shallow to moderate deep, well drained, red to strong brown sandy loam to clay loam	Chromic Luvisol, partly petric and lithic
	B3	Moderately deep to deep, moderately well to well drained, red to strong brown sandy loam to clay loam, almost flat to undulating (on dolerites)	Chromic Luvisol
	B4	Moderately deep to deep, moderately well to well drained, reddish brown to red sandy clay loam, almost flat to undulating (on dolerites)	Chromic Calcic Luvisol
	B5	Moderately deep to deep, moderately well to well drained reddish brown to strong brown sandy clay loam to clay. Undulating to rolling (on basalt)	Chromic Luvisol
	B5a	Shallow to moderately deep, well drained reddish brown to strong brown sandy clay loam to sandy clay. Undulating to rolling (mainly on basalt)	Chromic Luvisol, partly petric, some lithic
	B5b	As B5a, but with Cambic horizon	Chromic Cambisol
	B5c	As B5a, but with aridic moisture regime	Luvic Xerosol
	B5d	As 5b, but with aridic moisture regime	Calcic Luvisol
	B6	Moderately deep to deep, moderately well to well drained, dark brown to reddish brown clay loam to clay. Undulating to rolling (on basalt)	Calcic luvisol
	B6a	Shallow to moderately deep, well drained dark brown to reddish brown sandy clay loam to clay. Undulating to rolling (mainly on basalt)	Calcic luvisol, partly petric, some lithic
	B6b	As B6a, but with cambic horizon	Calcic Cambisol, partly petric, some lithic
	B6c	As B6a, but with aridic moisture regime	Calcic luvic, Xerosol, partly petric, some lithic
	B6d	As B6b, but with aridic moisture regime	Calcic Xerosol, partly petric, some lithic

Source: **Land Utilization Division of the Ministry of Agriculture (1985)**[58]

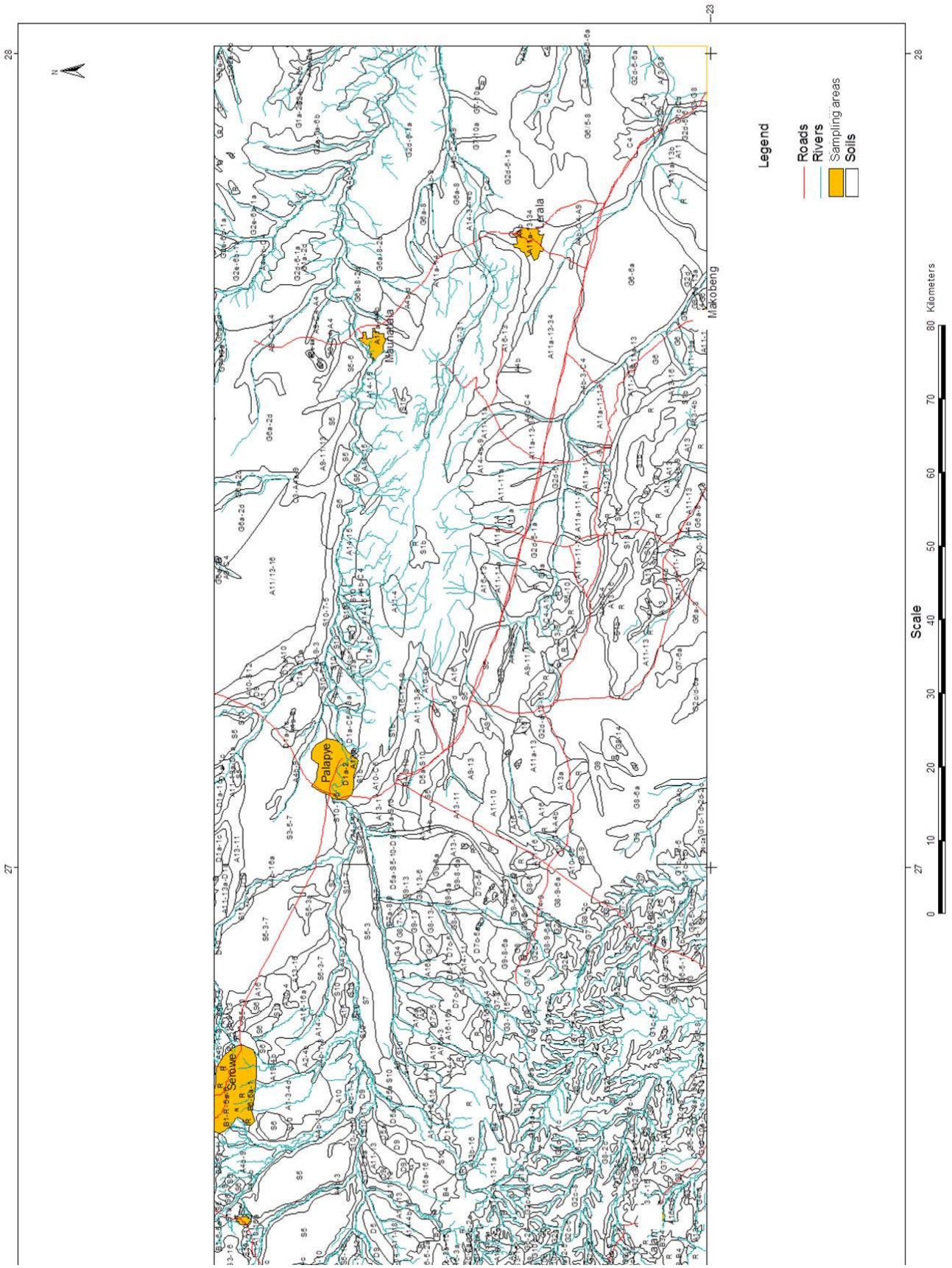

Figure 4.2: Geographical map of the Study Area Showing Soil Types

4.3.2Drinking water supply sources

Botswana is generally an arid country, with approximately 34% of the total water supply sources from surface water and 66% from groundwater[54]. Drinking water from the study area is solely supplied by means of underground borehole water through communal standpipes and private household tap water.[54] Table 3 presents average Total Dissolved Solids (TDS), total hardness (measured as $CaCO_3$), pH and selected minerals in water from the two major villages.[54]

Table 4.3:Average pH, total Hardness, Total dissolved Solids, and minerals in water from Serowe and Palapye

Location	pH	Total Hardness (as $CaCO_3$)	TDS (ppm)	Manganese (ppm)	Magnesium (ppm)	Phosphorus (ppm)	Calcium (ppm)	Chloride (ppm)	Iron (ppm)	Nitrate	Chlorine residual (ppm)
Palapye	6.52	268.87	350	2.128	38.01	2.13	56.94	91.7	11.72	5.94	0.71
Serowe	7.54	317.92	518	0.02	82.90	NQ	75.2	41.56	0.22	47.81	NQ
Maunatlala/ Lerala	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ	NQ

NQ=Not Quantified
Source: Department of Water Affairs[54]

4.3.3 Sampling:

Sampling was conducted in November 2010 and February 2011 with a few additional clay cosmetic powders purchased from vendors in May 2011. In total 28 water and soil samples each and 3 cosmetic clay powders were collected. Throughout this paper Serowe and Palapye are referred to as major villages and Maunatlala and Lerala are referred to as small villages.

4.3.4 Soil and clay sampling, preparation and analysis

The 28 soil samples were collected from Serowe, a major village (N=12), Palapye, a major but semi industrial village (N=5), Maunatlala a small rural village (N=4) and Lerala, a small rural village (N=7). In line with the objectives of the study, sampling was confined and restricted to the vicinity of household dwellings. The general soil types of the sampling areas are elaborated in Table 1. Samples were collected from the top 2-5 cm of the surface within residential clusters (referred to as *kgotlas*). All samples were air dried for 24 hours and passed through a 53 µm-nylon sieve to separate and remove unwanted debris and coarse material. The <53µm fraction was retained as a working sample whereas the rest of the sample was discarded. To ascertain a representative sample, subsamples were collected at distances of 2, 10, 20, 50 and 100 m intervals and combined into a composite sample of approximately 3-5

kg. Samples were collected into air tight self-sealing Ziploc bags and transported to the University of Botswana (Department of Chemistry) for analysis.

Three samples of cosmetic clays were bought from a vendor in Palapye. The samples consisted of red, brown and yellow clay from Makoro.

The soils and clays were assayed for pseudo-total Lead (Pb) content following the conventional method by Tessier *et al.* (1979),[63] however, though this method is widely used for sequential extraction of heavy metals in soils, for purposes of this study the method was used to determine pseudo-total metal content which recommends extraction of metals by digestion with aqua regia solution. Extraction of lead (Pb) was achieved by weighing 1g of soil into a 250mL borosilicate beaker to which 8mL of aqua regia (HCl and HNO3, 3+1 v/v) was added. The suspension was subsequently digested by heating at 120˚C for 2h, using a Labcon laboratory heater. The digests were then quantitatively put into 100 ml volumetric flasks followed by assaying using a flame atomic absorption spectrophotometer (Varian-FS220, SpectrAA, Australia).

4.3.5 Water sampling and analysis

Water samples (100 ml) were collected in Nalgene® plastic bottles at the same time the soil samples were collected in the sampling areas. The samples were collected from public standpipes (60%) and residential homes (40%). The general characteristics of the water in the two major villages are described in Table 4. Temperature, pH and Total Dissolved Solids (TDS) were measured at each sampling point. To be realistic we did not flush the taps prior to water collection[46,64]. Samples were acidified with 1ml of nitric acid (1 M) and the bottles sealed immediately and stored in ice while in the field. Upon arrival at the laboratory the samples were stored in a refrigerator at 4°C prior to analysis at the University of Botswana, Department of Chemistry. To a 200mL borosilicate beaker, 50ml sample aliquot was combined with 50mL aqua regia reagent (HCl and HNO3, 3+1 v/v) and heated in a Laboratory heater for 2h to solubilize the metallic ions. The digest was then poured in a 100 ml volumetric flask and diluted to the mark using ultra-pure water followed by assaying for pseudo-total Pb content using the Varian AAS (SpetrAA FS220).

4.3.6 Reagents and standard solutions

Analytical-reagent grade hydrochloric acid, nitric acid and lead nitrate salt were obtained from Sigma-Aldrich, South Africa. A stock standard lead solution (1000 mg l^{-1}) was prepared by dissolving 1.5985g lead in a 500mL beaker followed by adding 5 ml concentrated nitric acid to ensure solubility of the salt and diluted to the mark in a 1L volumetric flask with distilled, de-ionised water. Calibration standards were obtained by appropriate dilution of this stock standard solution.

4.3.7 Data Treatment and Statistical Analysis:

Data were analysed using SPSS 20.0.0. The collected samples from Maunatlala and Lerala were pooled to make one small village instead of two. The rationale follows that the two villages are approximate from one another and that they had similar characteristics in terms of soil (Figure 2, Table 1). Clay samples were not included in the analysis but reported separately. The rationale for this is that these samples were collected in Palapye only.

To achieve the study objective, ANOVA was used to compare mean Pb levels in soils and water between the major villages (Serowe and Palapye) and small villages (Maunatlala and Lerala combined). When the assumptions of normality, homogeneity and independence of residuals were not met, a nonparametric analysis (Kruskal Wallis) was used.

4.4 Results

4.4.1 Pb Concentrations in clay, soils and water:

Table 4.4 shows lead values in clays, soil and water in parts per million (ppm), water pH, temperature and Total Dissolved Solids (TDS) measured in parts per million. Pb concentrations ranged from 0.02 ppm in water to 4.53ppm in cosmetic clays. Lead concentrations in cosmetic clays were on average 15 and 21 times higher than concentrations in soil and water respectively. The mean Pb concentration in cosmetic clays (±SEM) was 3.99±0.41ppm compared to 0.27±0.03ppm and 0.19±0.02ppm in soil and water respectively.

Table 4.4: pH, Temperature (°C), Conductivity (µS/cm), Total Dissolved Solids (TDS), Pb (ppm)

Location	Location Type	Type of sample	Sample ID	pH	Temp. °C	Conductivity µS/cm	TDS	Pb (ppm)
Lerala	Small Village	Soil	MpeoLS1	_	_	_	_	0.22
Lerala	Small Village	Soil	MpeoLS2	_	_	_	_	0.10
Lerala	Small Village	Soil	MoatsheLS3	_	_	_	_	0.21
Lerala	Small Village	Soil	MonnengLS4	_	_	_	_	0.22
Lerala	Small Village	Soil	MothalaganeLS5	_	_	_	_	0.16
Lerala	Small Village	Soil	SegoleLS6	_	_	_	_	0.23
Lerala	Small Village	Soil	SegoleLS7	_	_	_	_	0.23
Lerala	Small village	Water	MpeoLW1	7.3	28.1	219	153	0.16
Lerala	Small village	Water	MpeoLW2	7.5	32.8	214	150	0.18
Lerala	Small village	Water	MoatsheLW3	7.4	28.5	215	151	0.17
Lerala	Small village	Water	MonnengLW4	7.4	31.6	220	167	0.21
Lerala	Small village	Water	MothalaganeLW5	7.3	28.2	215	150	0.14
Lerala	Small village	Water	SegoleLW6	7.4	28.2	217	158	0.20
Lerala	Small village	Water	SegoleLW7	7.3	28.3	214	150	0.13
Maunatlala	Small Village	Soil	ThamagaMS1	_	_	_	_	0.32
Maunatlala	Small Village	Soil	RaphiriMS2	_	_	_	_	0.27
Maunatlala	Small Village	Soil	MokueleloMS3	_	_	_	_	0.24
Maunatlala	Small Village	Soil	MagadingwaneMS4	_	_	_	_	0.20
Maunatlala	Small Village	Water	ThamagaMW1	6.9	36.6	99.2	69.4	0.03
Maunatlala	Small Village	Water	RaphiriMW2	6.1	33.6	75.1	52.5	0.04
Maunatlala	Small Village	Water	MokueleloMW3	6.7	29.6	99.2	69.4	NQ*
Maunatlala	Small Village	Water	MagadingwaneMW4	6.4	33.2	106.1	58.5	0.04
Palapye	Major Village	Soil	SeroromePS1	_	_	_	_	0.49
Palapye	Major Village	Soil	Serorome PS2	_	_	_	_	0.50
Palapye	Major Village	Soil	Extention8PS3	_	_	_	_	0.08
Palapye	Major Village	Soil	Extention1PS4	_	_	_	_	0.50
Palapye	Major Village	Soil	OldMallPS5	_	_	_	_	0.77
Palapye	Major Village	Water	SeroromePW1	6.7	31.4	366	253	0.30
Palapye	Major Village	Water	Serorome PW2	6.4	29.0	246	287	0.32
Palapye	Major Village	Water	Extention8PW3	6.5	32.9	333	245	0.29
Palapye	Major Village	Water	Extention1PW4	6.5	35.0	409	294	0.30
Palapye	Major Village	Water	OldMallPW5	6.7	32.9	321	223	0.34
Palapye	Major Village	Red cosmetic clay (*letsoku*)	LetsoRed	_	_	_	_	3.18¶
Palapye	Major Village	Brown cosmetic clay *(letsoku)*	LetsoBrwn	_	_	_	_	4.53¶
Palapye	Major village	Yellow cosmetic clay *(letsoku)*	LetsoYell	_	_	_	_	4.26¶
Serowe	Major village	Soil	MokolojnSS1	_	_	_	_	0.35
Serowe	Major village	Soil	GoosesmoSS2	_	_	_	_	0.22
Serowe	Major village	Soil	MokwenaSS3	_	_	_	_	0.02
Serowe	Major village	Soil	NewTwnSS4	_	_	_	_	0.27
Serowe	Major village	Soil	SebinanyaneSS5	_	_	_	_	0.5
Serowe	Major village	Soil	BokhurutsheSS6	_	_	_	_	0.21
Serowe	Major village	Soil	MogorosiSS7	_	_	_	_	0.07
Serowe	Major village	Soil	BotalaoSS8	_	_	_	_	0.26
Serowe	Major village	Soil	GooleinaSS9	_	_	_	_	0.28
Serowe	Major village	Soil	MorwamokwnSS10	_	_	_	_	NQ
Serowe	Major village	Soil	PhokelaSS11	_	_	_	_	0.47
Serowe	Major village	Soil	TalaojnSS12	_	_	_	_	0.07
Serowe	Major village	Water	MokolojnSW1	7.7	34.0	523	376	0.27
Serowe	Major village	Water	DinokwaneSW2	7.7	31.0	476	333	0.26
Serowe	Major village	Water	MokwenaSW3	7.7	31.5	473	329	0.20
Serowe	Major village	Water	MorwamokwenSW4	7.8	29.5	489	333	0.27
Serowe	Major village	Water	RakgomoeSW5	7.5	28.4	465	325	0.25
Serowe	Major village	Water	MogorosiSW6	7.3	28.7	652	465	0.21
Serowe	Major village	Water	BrigadeSW7	7.4	28.2	462	324	0.13
Serowe	Major village	Water	MMualfPrimSW8	7.4	27.6	569	396	0.3
Serowe	Major village	Water	BokhurutsheSW9	7.5	29.2	458	316	0.24
Serowe	Major village	Water	NewtownSW10	7.4	27.7	480	331	NQ
Serowe	Major village	Water	PhokelaSW11	7.6	29.4	489	392	0.25
Serowe	Major village	Water	TalaojnSW12	7.5	28.5	473	387	0.10

***NQ – Not Quantified**
¶Not included in the statistical analysis

Table 4.5 shows Pb concentrations between and within locations. Within locations Pb concentrations were compared between old and new settlements (areas where

communities were recently allocated land in ≤ 1 year ago). Mean PbS (±SEM) in older settlements were 0.31± 0.035 ppm compared to 0.13±0.034 ppm in newer settlements (p=0.03). No significant difference (p>0.05) was observed in PbW concentrations despite higher absolute values found in older settlements (mean PbW (±SEM) 0.20 ±0.020ppm in older settlements compares to 0.13± 0.047ppm).

Table 4.5: Mean±SEM of Lead concentration between locations and between old and new settlements within the locations

Location	Sample type	Pb (Old settlement)	Pb (New settlement)	Total Pb	% greater* than recommended standard
Palapye	Soil	0.57±0.068 (n=4)	0.08 (n=1)	0.47±0.111 (n=5)	0
	Water	0.32±0.01 (n=4)	0.29 (n=1)	0.31±0.009 (n=5)	100
Serowe	Soil	0.28 ±0.049 (n=9)	0.11± 0.040 (n=3)	0.24±0.431 (n=12)	0
	Water	0.25±0.010 (n=9)	0.077±0.039(n=3)	0.21±0.11 (n=12)	91
Small Villages (Maunatlala/Leral)	Soil	0.22±0.019 (n=10)	0.23 (n=1)	0.22±0.017 (n=11)	0
	Water	0.12±0.025(n=10)	0.13 (n=1)	0.12±0.023 (n=11)	64
All locations	Soil	0.31 ±0.035 (n=23)	0.13± 0.034 (n=5)	0.27±0.032 (n=28)	0
	Water	0.20 ±0.020 (n=23)	0.13± 0.047 (n=5)	0.19±0.019 (n=28)	82

***Recommended standard =0.05ppm**[65]

When PbS and PbW from major and small villages were compared (after pooling the data for small villages - Lerala and Maunatlala), a significant difference was observed (p=0.009 and p=000 for PbS and PbW respectively). Mean PbS concentrations from Palapye were twofold compared to values from Serowe and from small villages. With respect to PbW concentrations, Palapye had the highest values (three to fourfold than small villages) followed by Serowe (Table 4 &5). Figure 3 shows a graphical view of mean PbS and PbW concentrations by location.

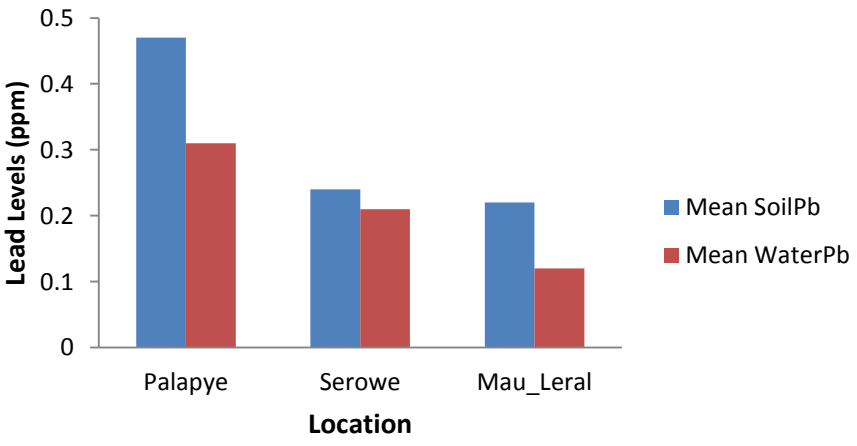

Figure 4.3: Mean soil and water lead levels by location

4.4.2 Associations between Pb concentrations and location

Figure 4.4 is a scatter plot showing the relationship between the PbS and PbW. There was a significant relationship between PbW and PbS (p=0.028) and the linear regression model for the correlation between PbW levels and soil lead levels:

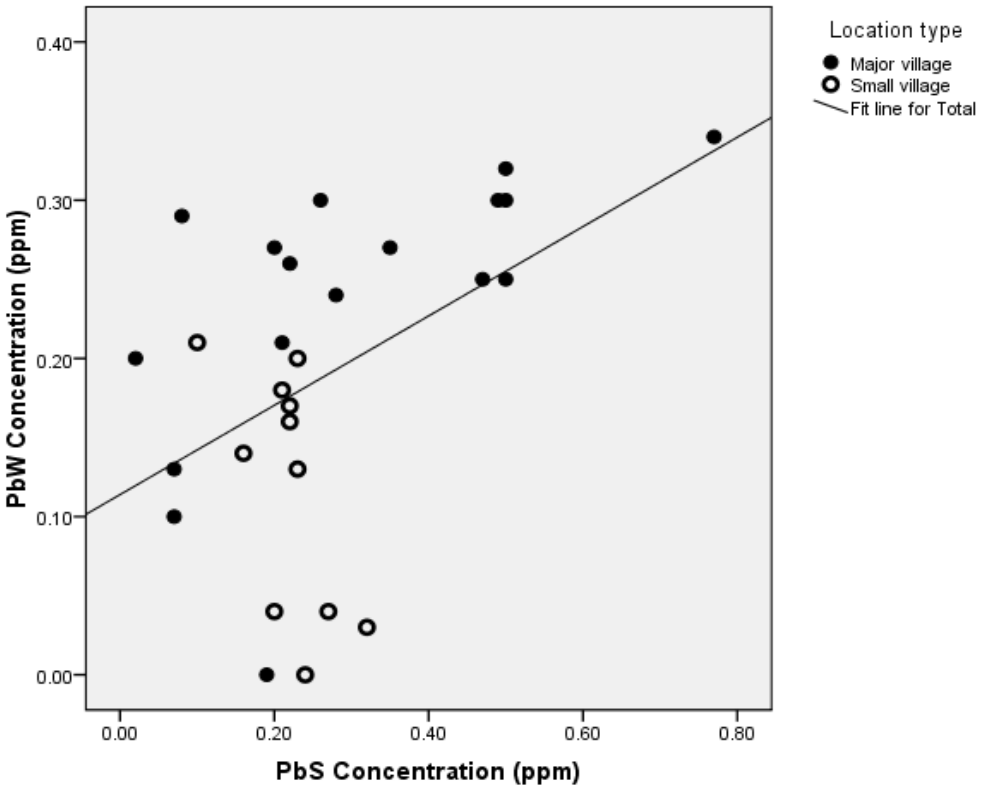

Figure 4.4 Relationship between the soil lead levels and water lead levels

Table 4.6 shows the results of analysis of covariance to establish a relationship between lead levels and location (major village vs small village). The strongest relationship was observed in PbW and PbS between Palapye, a major village and Maunatlala /Lerala (small village). No relationship was observed between Serowe and Maunatlala/Lerala (p>0.05) in terms of PbW. However, a significant relationship was observed between PbS in Serowe and Maunatlala/Lerala.

Table 4.6: Correlation coefficients of major and small villages

	Maunatlala/Lerala (Small Village	Maunatlala/Lerala (Small Village)
Palapye (Major village)		
	-0.24982(S)*	
	-0.19182(W)**	
Serowe (Major village)		
		-0.01848(S)
		-0.08848(W)*

***p<0.05; **p<0.001**
S= Soil
W=Water

4.5 Discussion

4.5.1 Lead in soils and clay:

Soil lead levels were detected in trace amounts and were well below the set soil standard limits of 140ppm.[56] These low Pb levels may be attributed to the soil types in the study area, particularly in Serowe and Paplapye which are generally of a sandy nature and therefore moderately to well drained as reflected in Table 3. There is evidence that atmospheric lead enters the soil as lead sulphate or is converted rapidly to lead sulphate at the soil surface. EPA (2006) estimates that soils with a pH of ≥5 and with at least 5% organic matter atmospheric lead is retained in the upper 2-5 cm of undisturbed soil.[66] The movement of lead from soil by leaching is also observed to be slow under natural conditions therefore making lead persistent in the soils. The soil characteristics of Serowe Palapye fit this description with a pH greater than 5 and an organic content of approximately 10% except around the coal mining area where the soils are only 3% clay.[53] These types of soils may facilitate the removal of lead from surface soils by leaching and by run-off. Some of the conditions which could induce leaching are the presence of lead that either approach or exceed the sorption capacity of the soil, the presence in the soil of materials that are capable of forming soluble chelates with lead, and therefore a decrease in pH of the leaching solution such as acid rain[67]. Zhai *et al.* (2009) also observed Pb levels lower than the set standards (1.00-35ppm) in bedrock samples from Palapye.[52] He further reported low Pb levels in the range of 19.4-21.9ppm; 81.6—101.4ppm and 16.2-19.2ppm in bottom ash, inlet fly ash and coal respectively[52]. Our values are generally lower (0.04-0.77ppm) than those of the study by Zhai et al (2009).[52] This however can be expected due to the variability of the distribution of lead in soils. Chaney (1984) examined soil lead concentrations in urban Baltimore gardens and found that soil Pb concentrations

varied more than 10 fold within a single garden.[68] On the other hand, we are exercising some caution in comparing these results because of the sampling design, chemical extractions and analytical techniques used to measure lead levels in the two studies. Our study focussed on residential areas without particular attention to areas of intense pollution, whereas the study by Zhai et al. (2009) focussed on Palapye and the coal mining area. Our results are however comparable to those of Okonkwo and Maribe (2004) who measured lead levels in soils in Thohoyandou, a remote area in South Africa. Their mean Pb concentrations mean (±SD) ranged from 0.205±0.09 – 0.312±0.08.[69]

While Zhai *et al.* (2009) results did not find significant differences on Pb concentrations in the mine plant soils, intermediate soils and rural soils,[52] our study found a significant difference in concentrations between rural soils and soils from major villages. Palapye soil Pb concentrations were three to fourfold higher than rural small village soils (even though all levels were near detection limit values). The low lead levels in the small villages are consistent with studies elsewhere which have shown low Pb levels in soils from rural areas compared to urban areas[70,71]. To further strengthen this finding, a further comparison of older settlements versus new settlements in all locations showed a significant difference with older settlements having higher soil lead levels. The difference could be attributed to activities such as waste disposal, auto workshops and gas stations etc, which are less prevalent in newer settlements and in smaller villages. In the case of Palapye, which is near a major highway and a railroad line, these could be contributing factors. Zhai et al. 2009, found Pb concentrations near the highway significantly higher than concentrations in other locations further away from the highway suggesting automobile related pollution (Zhai, 2009).[52]

Environmental heavy metal contamination, especially by lead in soil (including clays) and sediments, has become increasingly recognised as a significant problem in public health. As a result of this recognition, the developed world has come up with comprehensive and complex environmental legislation and associated guidelines,[72] to safeguard public health. There is a strong positive correlation between exposure to lead contaminated soils and blood lead levels. CDC (1991) reports a 3-7µg/dl for

every 1000ppm increase in soil or dust lead concentrations[73]. Although the PbS levels in this study are extremely low, soil impact as an exposure source for pregnant women cannot be ruled out for several reasons;1) Studies have found that human absorption and retention of Pb as a function of both particle size and chemical species.[74] The smaller the particle, the more easily it will be absorbed by the digestive system. This observation is derived from studies that have observed that almost half exhaust particles emitted from petrol was less than 0.25µm in size with most of the remaining emissions between 10 and 20µm[66]; 2) High dose source does not always mean greater risk.[19] The bioavailable fraction of lead in soil or dust is generally defined as that fraction that can be absorbed into the blood stream.[72] Although there is a general notion that lead based-paint poses the greatest risk because it is a high dose lead source, Mielke and others(1998) argues that paint has larger particle size (from 200-300µm) to the visible range, hence they are less easily absorbed and therefore less bioavailable[19,72]; 3) There is evidence of non-uniformity of lead distribution in soils from the same location[68]. It is therefore possible that some areas may have soil lead levels greater than the current levels; 4) The low lead in soils, particularly for pregnant women who ingest soil will add to the lead load from other sources.[57,66]

In terms of cosmetic clays, the current levels may add up to the lead load in pregnant women through skin absorption.[33-36]

4.5.2 Lead in water

Pb levels in water exceeded the WHO permissible concentrations of 0.01ppm.[57] Our overall PbW mean concentration (±SEM) was 0.19±0.019ppm (190±19µg/l) which is nineteen times higher than the permissible concentrations safe for human consumption in drinking water. Compared to PbW levels in rural South Africa, the levels are approximately 10 times higher.[69] These levels are comparable to levels in the developed world in the 1990s prior to restrictions on plumbing materials containing[75]. This finding is a course for concern and presents a potential risk for lead exposure to pregnant women and other vulnerable groups such as children. Mathew (1981) has estimated that water lead level of 50µg l^{-1} would yield average intake of lead from water alone for an average adult at about 60 µg $dayl^{-1}$[76] While this estimate may be small for adults, the relative intake of lead from water is estimated to be seven

and half times for children who are bottle-fed and dependent on tap water compared to that of adults.[76]

Palapye, had significantly higher PbW levels compared to other locations. One assumption for the higher PbW is the soil setting of the study area, which is mainly aeolian, derived from the weathering of the Ntane Sandstone Formation.[58] These are moderately to high vulnerability and additionally they do not contain any significant clayey material (or organic material) likely to prevent the downward migration of contaminants.[53] This situation has contributed to a number of boreholes in the Palapye area being closed down due to high nitrate levels as a result of soil pollution.[53] Palapye underground water sources are therefore prone to industrial pollution as it is a moderately industrial village compared to the other study villages. In support of this, our results showed a relationship between PbS and PbW concentrations, particularly in Palapye which had the highest PbS and PbW levels. That is, an increase in PbS concentrations resulted with an increase in PbW concentrations. Additionally, Palapye is in the vicinity of Morupule coal mine and power station. There is therefore a highly likely possibility of Pb lechachates from ash disposal ponds into underground water.[50] It should also be noted that the water in Palapye is slightly more acidic than the water in Serowe and this could be the result of some materials in the soils capable of forming chelates with lead and therefore decrease the pH of the water.[67] A pH of <7 would also cause more corrosion in plumbing systems. It is desirable to have pH levels of 8-9 to reduce corrosion from plumbing systems.[77,78] All of the samples collected from Palapye were from indoor household taps.

Other than the soil types and pH, several reasons may help explain the generally high concentrations of PbW in the Serowe Palapye villages. Currently, all drinking water is from boreholes and is stored in steel tanks and then distributed to public standpipes and households through polyvinyl chloride (PVC) pipes which then connect with interior plumbing. At household level, interior plumbing is mostly copper pipes with lead solder in joints between copper pipes. At public standpipes the standpipe material is mostly steel. The presence of lead in water is generally a result of its dissolution from natural sources but primarily from plumbing systems within residences which including brass fittings and lead solder[79]. Soldered connections in recently built homes

fitted with copper piping have been reported to release enough lead to cause intoxication (210-390µg/l) that may cause intoxication in children.[80] It is also reported that PVC pipes contain lead compounds that can be leached from them resulting with high lead concentrations in drinking water[57].The amount of Pb dissolved from plumbing is however influenced by factors such as the presence of chloride and dissolved oxygen, pH, temperature, water softness and standing time of water. Soft and acidic water is reported to be the most plumbosolvent.[81,82] Research also points elevated PbW levels in drinking water to certain types of faucets and certain types of water meters[78]. Our study analysed the first flush water from communal and residential tap water for practical reasons that people would not normally flush their system before they collect their drinking water. Our results are comparable with those of Gulson (1997). In his study he compared variations in lead concentrations for water samples collected at hourly intervals from the kitchen tap in one house. Lead concentrations of the first flush were 119µg/l compared to a fully flushed tap which had PbW of 1.7µg/L).[64] In his conclusion Gulson (1997) observed that a pregnant woman who consumes 0.5 L of water a day of first flush water could be at a greater risk of exposure than one who consumes water from a fully flushed system.[64] He further observes that if more than 0.5 l of water was consumed in drinks and formulae using first flush water, then the blood lead levels could exceed the recommended CDC action blood lead level of 10µg/dL.[64,83] A Boston men normative aging study concluded that ingestion of first morning tap water contaminated with Pb was an important predictor of elevated bone lead levels(Vijayalakshmi et al. 1999). Men who lived in households with ≥ 50ugPb/L of first morning tap water (water that has been standing overnight in the plumbing), who ingested ≥ 1glass /day had progressively higher patella lead levels than did those with low water consumption (< 1 glass per day).[84] This finding is important for women of reproductive age who have exposure to Pb levels in water as this would not only contribute to elevated Pb levels later in life, but would have Pb released from bone during pregnancy and thus result with undesirable birth outcomes.[85]

Social factors are also reported by studies to affect lead levels in water and some of these factors include spending time away from home by being at work during the day thereby creating lead to leach from the tap and thereby increasing the lead load.[64]

Most households would generally use more water in the morning before going to work and in the evening when they come back from work and school. In the case of households using public standpipe the same situation can apply. In this study 60% and 40% of tap water was from indoor and outdoor taps respectively. The mean temperature of the water at the time of collection was above 30^{o}C. Levin (1990) has attributed day-time leachability of lead to exceed that of overnight because plumbosolvency is temperature dependent.[37] It is also important to note cultural factors in the context of developing countries. It is generally accepted that storing water in clay pots will keep the water cooler in the rural areas where most people do not own refrigerators. This, depending on the water acidity and whether the clay pot is made out of material that contains lead or not may contribute an additional lead load to water at the household level. In one study, clay pot water storage was correlated to elevated blood lead levels.[86] Even though the authors related this to be an indicator for lower socio economic status, rather than a risk factor itself, it cannot be entirely ruled out that clay pots used for storage of water may be a source of lead exposure depending on the water pH, as well as whether the pot itself was made up of clay that is contaminated with lead.

Elwood, in his critical review of sources of lead in blood,[46] concludes that while water may be considered a relatively minor source in people exposed to high levels from other sources, it should be of greater importance and should generate greater attention if other sources are low. He further notes that as higher PbW levels are likely to be associated with older housing in inner city areas with dust and air lead levels, the potential for bias in the event of ignoring water may turn out to be considerable. In our study we observed no significant differences between PbW in older and newer settlements. This is explained by the fact that unlike soil, variations in the types of materials used in lead pipes are not dependent on how old the residence.[87] It is also an indication of possible contamination of the water from the source water tanks or from soil leaching.

4.6 Limitations:

The number of clay samples was extremely small to be included in the analysis. The limitation was a result of non- availability of *letsoku* at the time of sampling in the

study areas. Only 3 samples were bought in the market. Despite this limitation, it could be confirmed that *letsoku* may pose a potential exposure source for women who apply it on their skin as well as ingest it. Additionally, due to limited resources we restricted our sample size to 28, for both water and soils. A larger sample size would be beneficial in future to compare these results. The limited resources also deviated us from collecting water from a city, which does not use borehole water. This therefore limited our capacity to be able to apply the findings of this study nationally. The results of the study however create an opportunity for further research on drinking water quality.

4.7 Conclusions:

While soil Pb levels were at trace levels and lower than the set maximum Pb limits, Pb levels in water were in excess of the set drinking water-quality standards. It is important to highlight that even though the soil Pb levels are low the combined influences of other environmental sources of exposure to lead in pregnant women have to be taken into consideration. In assessing the risk of exposure for pregnant women in the Serowe Palapye it is necessary to look at other factors which may be economic, social as well as lead levels from air, dust, water, food, paint, cosmetics and others. This is particularly so for pregnant women who are geophagic and may be using traditional clay cosmetics to apply on their skins. Irrespective of the low lead levels, pregnant women need to be sensitized on geophagy and the use of traditional clay for cosmetic and pharmaceutical purposes.

To determine the public health impact of environmental lead contamination, a biomarker should be available and one of the most commonly recommended biomarkers in any population is the measurement of blood lead levels (PbB). The need to measure PbB of pregnant women and other vulnerable groups such as children in the Central and other districts is recommended to assess if there is a relationship in blood lead levels and water lead levels. In doing so, other potential confounders will need to be taken into consideration such as the behaviours and other practices of pregnant women during pregnancy. Such behaviours will include but not limited to geophagia, lifestyle behaviours such as alcohol and tobacco use, and the use of traditional and other cosmetic products.

There is need to assess the types of plumbing materials used in household and communal drinking water taps as well educating the public and in particular women of reproductive age on the importance of flushing the first draw of water in the mornings as well as later in the evening if the tap was not used frequently during the day.

4.8 References

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Chapter 5

Levels of Lead Across Pregnancy in Women from Major and Small Villages in the Central District, Botswana

5.1 Abstract

Blood lead (PbB) levels were measured in a prospective cohort study of pregnant women living in selected villages in the Central Administrative District of Botswana to characterize PbB changes during pregnancy and investigate if PbB levels differed by location. PbB were measured at weeks 8-12, 20-24 and 34-36 respectively among women aged 18-44 years. A total of 137, 126 and 106 women were enrolled at the first, second and third trimesters respectively from four locations of varying socioeconomic and environmental status. PbB concentrations ranged from 0.5-12.90µg/dL with an overall mean (±SEM) of 2.34(±0.098)µg/dL. PbB concentrations of ≥5µg/dL were observed in 5.5%,5.6% and 3.1% during the first, second and third trimesters of pregnancy. A significant increase in PbB levels was observed between the first and third trimester (p=0.01). Mean PbB (±SEM) for the first, second and third trimesters were 1.96(±0.14)µg/dL, 2.49(±0.17) µg/dL, 2.66±0.19)µg/dL respectively. Increases from first to third trimester ranged from 1.6-5%. PbB concentrations significantly differed with location (p=0.01). Location mean (±SEM) was 2.27(±0.13) µg/dL, 2.06(±0.14) µg/dL, 2.18(±0.30) µg/dL and 3.60(±0.48) µg/dL in Serowe, Palapye, Maunatlala and Lerala respectively. The highest concentrations were observed in women from Lerala compared to Serowe (p=0.02) and Palaye (p=0.01). Mean (±SEM) values of women from Lerala were 3.33(±0.86), 3.78(±0.896) and 3.84(±0.82) in the first, second and trimesters respectively. The increase in PbB levels was more a function of the socioeconomic status of women in Lerala village than a function of location. To the best of our knowledge this is the first study to measure PbB concentrations in pregnant women in Botswana. The significant increase in blood levels during the different stages of pregnancy in this study is of clinical importance and emphasizes the need for primary prevention interventions of exposure sources for lead during pregnancy to reduce lifetime lead exposure and decrease the risk for fetal lead exposure.

Key words: Blood-lead levels; pregnant women; Exposure; Central District; Botswana

5.2 Introduction

Lead is exclusively toxic to living organisms, including humans and as a result is associated with a range of adverse health effects to different segments of the population. Human exposure to lead can be from anthropogenic and natural sources. In addition life style, behavioural and occupational activities can be a contributing factor. Once in the blood stream, lead binds directly to erythrocytes, accumulates in the renal tubules, hepatocytes and eventually deposited in bone and teeth. It is estimated that 95% of the total lead burden in the body is stored in bone and that the half-life of lead in bone is 20-30 years while it is 1-2 months in blood[14]. Blood lead levels therefore only reflect the active, toxic fraction of lead and may be indicative of acute intoxication.[15] Studies have estimated that mild mental retardation and cardiovascular outcomes resulting from exposure to lead amount to almost 1% of the global burden of disease, with the highest burden in developing regions.[1] Evidence also exists that lead contributes to mental retardation and neurotoxicity.[2,3] Gastrointestinal effects and anemia are some of the earliest toxic effects of lead to be recognized; however, over the years it has become increasingly evident that the nervous system is the principal target for lead among others.[4-7] Lower levels of lead decrease reaction time,[8,9] cause deficits in hand-eye co-ordination,[10] and decreased nerve conduction velocities.[11,12] Severe lead poisoning results in adverse effects such as encephalopathy which can be followed by coma and death.[13]

Of major concern is lead exposure in pregnant women and risk of passing on the lead to the fetus. During pregnancy, a considerable blood exchange occurs between the mother and the fetus as the placenta does not provide sufficient protection from fetal exposure to lead and other toxic chemicals.[16-18] Lead crosses the placenta through gestation and the correlation between maternal and umbilical cord -blood is estimated at 0.55 to 0.92.[15,19] Studies have further found higher concentrations of lead in amniotic fluid than in cord blood suggesting that fetal membranes, which in these studies showed high concentrations of lead, may be absorbing lead from amniotic fluid.[20]

5.3 Possible lead exposure sources in Botswana

Botswana, a mineral-rich country located in Southern Africa and a fast growing country is of particular importance to the assessment of highly ubiquitous heavy metals such as lead. Botswana only stopped the use of leaded petrol in 2005. In 1999, lead in fuel was estimated at 106 tons per year.[21] Lead imported to Botswana is mainly in the form of lead oxides. It is also used as a stabilizer in PVC-manufacturing. The main distributors of paint in Botswana report that they do not use lead-based paint pigments currently. However, it is not clear when these distributors stopped using lead based paint pigments in particular because South Africa, (where most of the paints used in Botswana originate from), "white lead" in paint was abolished in the 1940s and a voluntary agreement reached with the paint industry to limit the use of leaded pigments in the 1970s. However, researchers in South Africa have detected lead in paint at levels above the set standards and report that legislation to regulate lead in paint has been introduced.[22-24] Lead has also been detected in peeling paint in the city of Gaborone, Botswana.[25]

Like many other developing nations, Botswana is burdened with infectious diseases such as TB, HIV/AIDS as well as malaria and other epidemics. These, combined with socioeconomic related issues, make populations in developing nations, more vulnerable to the toxic effects of pollutants in their living environments.[23] In 2009, the first ever study performed in Botswana on children lead exposure found that 31% of children in the city of Gaborone had blood lead levels ≥10µg/dL.[25] The contribution of lead to the burden of disease in Botswana is currently unknown. Potential sources of lead exposure in the general population are also not known.

This study is part of a broader research assessing lead levels in pregnant women from the first trimester until six weeks after delivery. It aims to determine and measure the variation in blood lead levels at each stage of pregnancy in a randomly selected sample of pregnant women in four villages of different socioeconomic and environmental background. The study further establishes whether the levels of lead will be influenced by the type of location. A manuscript that will assess correlates of

blood lead levels from the first trimester until parturition is in preparation. The study area was selected deliberately because of its significance as a coal mining district.

5.4 Materials and methods

5.4.1Study sites and participants

Women were recruited from Serowe, Palapye, Maunatlala and Lerala villages. Serowe is the largest of the villages with a population approximately 52,000,[26] a typical major village in Botswana with minimal industrial activity but moderate traffic volume. Palapye is a moderately to high industrial major village with a population of approximately 37,000,[26] located about 5-7 kilometers from Morupule coal mine and the Morupule Power Station, with a major railway station and a major highway passing through the village from Gaborone to Francistown (Figure 1). Maunatlala and Lerala with populations 4,552[26] and 687[26] respectively are classified as small rural villages in Botswana with no industrial activities and minimal traffic volume. Figure 5.1 shows the location of the study area.

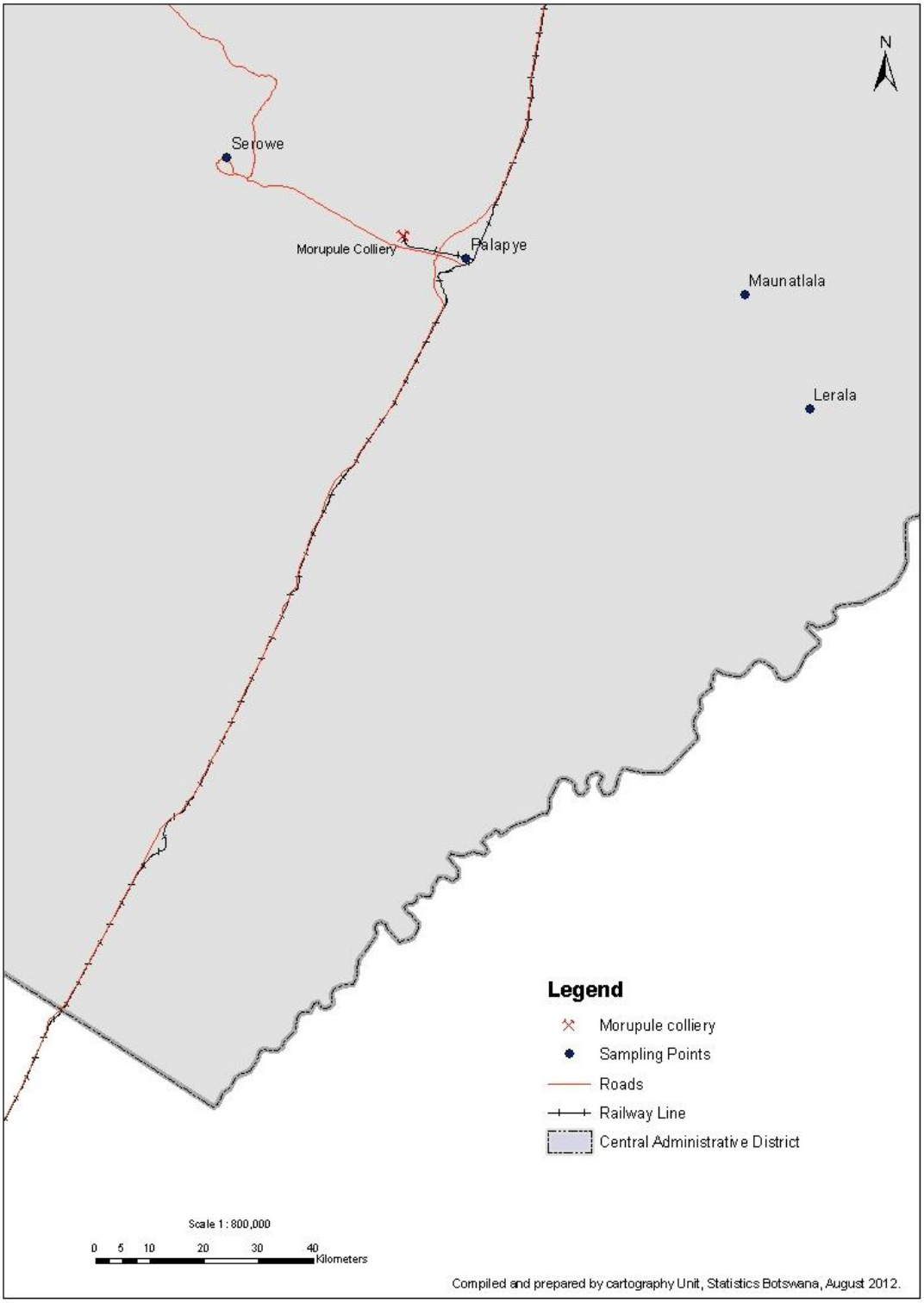

Figure 5.1: Central district sampling locations

5.4.2 Participation, recruitment and informed consent

All pregnant women registering for prenatal clinic between September 2009 and February 2010 who were between 0 and 12 weeks of pregnancy were invited to take part in the study through information leaflets developed specifically for the study and

through public addresses at the participating facilities whilst the women were waiting to be served. A *priori* exclusion criteria for the study were: 1) younger than 18 and not older than 49 years; 2) active diabetes 3) hypertension that was managed with medication and 4) any medical problem known to the health worker screening the pregnant woman that would compromise their health if they took part in the study. Women read, or were read the informed consent and agreed to participate.

The original population for the study comprised of 200 pregnant women who expressed interests to donate blood at each trimester of pregnancy and six weeks after delivery. Of these 200, 36 were not eligible and therefore excluded from the outset of the study. From the 164 eligible women, 28(17%) could not donate blood at the first trimester due to medical reasons (21%) or showing up at the health facility after 12 weeks had elapsed (60%) or discovered to be under-age upon age verification at the time of the first blood draw (18%). Overall a total of 137, 126 and 106 women enrolled and continued with the study on the first, second and third trimesters respectively as elaborated on Figure 2. Once having consented, outpatient staff screened the women to assess if their health will allow a blood draw. A midwife was employed to follow up the pregnant women and liaise with participating facilities. A qualified phlebotomist was also employed for the study to ensure the safety of the pregnant women and quality control issues in blood samples collected for the study.

5.4.3 Ethical Considerations

This study obtained unconditional ethical approval from the Research Ethics Committee, Faculty of Health Sciences, University of Pretoria, South Africa (reference 110/2009) and endorsement by the Ministry of Health Research and Ethics Committee, Gaborone, Botswana in 2009

5.4.4 Research Instrument

Validated risk assessment questionnaires were administered after the consent forms were signed by study participants. Participants were asked about their personal habits during the first trimester of pregnancy such as alcohol consumption, tobacco use and traditional medicine and whether they have pica behavior. In terms of practices, women were asked what substances they use to treat skin or other health related

problems during pregnancy. Follow up question on personal habits, diet or health status were asked when the women came for subsequent blood samples. To promote trust among the research participants and create a sense of ownership to the study, a feedback workshop was held with all study participants after the first draw of blood. The workshop was intended to inform the participating women on the progress of the study and emphasize the importance of the study on potential benefits not only to their health but the health of other women in reproductive age. This helped in maintaining the women in the study as can be observed in figure 5.2 that the loss to follow up rate was less than in any other trimester.

5.4.5 Sample collection and analysis

5.4.5.1 Maternal blood collection

Blood samples were drawn by venipuncture at intervals of 8-12 weeks, 20-24 weeks, and 34-36 weeks of pregnancy. The final sample was collected six weeks after delivery (data reported in Chapter 6). Each participant was given a unique identifying number in a sticker placed on their obstetric record booklet for easy identification by the outpatient staff when the patient comes for follow up. The same number was placed on the consent form for identification purpose of the results. The timing for the blood draw was synchronized with the schedule for follow up in the obstetrics record as well as the timing for risk assessment. Each pregnant woman donated 15 ml of blood consisting of 2 venous samples of 7.5 mL each (Venipuncture Needle-Pro, SIMS Portex, Inc, Keene, NH). Each venous blood sample was drawn into a Vacutainer tube (K_3 EDTA, BD 36-9651; Becton Dickinson, Rutherford, NJ) labeled with a code for identification. The sampling procedures followed the protocols prescribed by the National Institute of Occupational Health (NIOH), Johannesburg, South Africa where analysis was done.

5.4.5.2 Determination of lead in maternal blood

The analyses for lead content in whole blood were performed using graphite furnace spectrometry (Perkin-Elmer AAnalyst – 600) instrument. Contamination free vessels and certified reference standards were used throughout the analyses.

Briefly, blood samples diluted ten times with Triton X (0.1%), and mixed on a vibration mixer. The preparation of calibration standards included the addition of a

1ppm lead standard to ox blood and Triton-X to a final volume of 5 ml. The range of the calibration standards prepared was 5 – 80 µg/dl. The standards (10µl), samples (10 µl) and quality controls (10 µl) were analysed on a Perkin-Elmer AAnalyst – 600. The instrument parameters include: wavelength 283.3, the furnace temperature was set initially at 50^{o}C and then ramped to 2500^{o}C, run time: 2 min. Certified Reference Material, Nycomed Seronorm Trace Element control level 1 and 2 as well as in-house prepared reference controls were analyzed after every 10 samples. The detection limit for the blood lead analysis was 1 µg/dl. The coefficient of variation for Seronorm level 1 was 14.02 % and level 2 was 10.86%.

5.4.6 Statistical Analysis

Data was "double punched" using a Microsoft Excel software package, and subsequently transferred to STATA 11.0 statistical programme using Stattransfer. Statistical analysis was performed separately for each trimester and on the entire data set. This was to enable us to determine significant changes as well as trends in lead through pregnancy. This approach also allowed us to account for intrinsic variables associated with lead at each trimester of pregnancy. Descriptive statistic was calculated for lead which included the mean and Standard Error of Mean (SEM), the median and the range. We used Kruskal Wallis and Dunn tests for multiple comparisons. A significant difference was defined by a p value of <0.05.

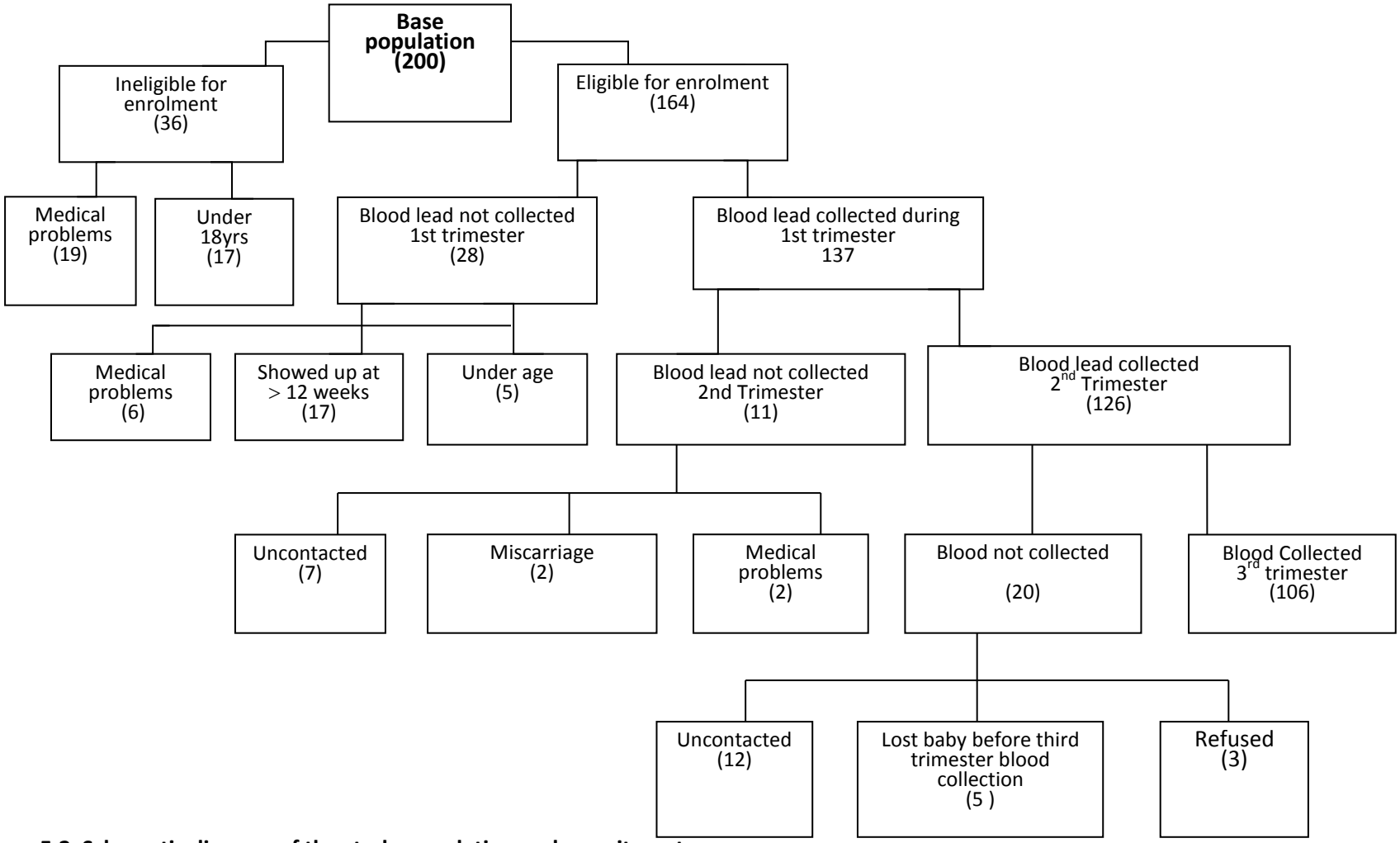

Figure 5.2 Schematic diagram of the study population and recruitment process

5.5 Results

5.5.1 Socioeconomic and demographic characteristics of participants

Table 5.1 summarizes socioeconomic and demographic characteristics of the women who continued with the study at each trimester (n= 137, 126 and 106 fist, second and third trimesters respectively). The mean age of women was 27 years (range 18-44 years). Most of the study participants were young in their early to late 20s (approximately 57% across all trimesters). Approximately 34% of the women were 30 years and above and 9% aged below 20 years. Over 50% of the women were unemployed and relied on social grants or support from their partners or family members. The majority of women (62%) had 2-4 children.

Table 5.1 Socioeconomic characteristics of women by trimester (%)

Statistic	Trimester 1	Trimester 2	Trimester 3
Age (Years)	n=137	n=126	n=106
≤19	9.5	10.3	8.5
20-24	34.3	34.9	35.8
25-29	22.6	21.4	21.7
30-34	19.0	19.0	18.9
35 plus	14.6	14.3	15.1
Marital Status			
Single	88.3	89.7	88.7
Married	11.7	10.3	11.3
Educational status (in years)			
Primary Education (1-7 years)	13.1	13.5	15.1
Secondary Education (8-12)	64.2	65.1	64.2
Post-Secondary (13+years)	22.6	21.4	20.8
Employment			
Employed‡	43.1	42.1	42.5
Unemployed	56.2	57.1	56.6
Income adequacy‡			
Lowest (P 0.00-P3000)	93	93.7	92.5
Lower Middle(P3001-6000)	4.4	4.0	4.7
Middle (P6001-9000)	1	1	1
Upper Middle(9001-12000)	1	1	1
Parity			
Primipara	39.4	38.9	36.8
Multipara	60.6	61.1	63.2
Site			
Serowe (Major Village)	44.4	46.0	45.3
Palapye (Major village with industrial activity)	34.3	34.1	32.1
Maunatlala (Small rural Village)	8.8	9.5	10.4
Lerala (Small rural village)	9.5	10.3	12.3
Recruitment Facility type			
Hospital	27.7	26.2	27.4
Clinic	72.3	73.8	72.6

‡One participant did not indicate their employment status

It must be noted that the socioeconomic characteristics reported here differ with the one on chapter 3 as we wanted to establish the characteristics of women who donated blood from trimester 1 to 3.

Women from Lerala (a small village) had the most children (92%) compared to women from Maunatlala (a small village - 72%) and major villages (Serowe and Palapye - approximately 45%). Compared to major villages, women from small villages were significantly multiparous (p=0.05). Employment rate was significantly different between major villages and small villages (p<0.001) with Lerala having 80% of women employed compared to major villages. However, the employed women from Lerala earned between Botswana Pula 500 (USD71) and 1500 (USD214), which placed them in the lowest income adequacy grouping. Only one woman was employed from Maunatlala. Income adequacy was not significantly different between small and major villages even though major villages had higher absolute values compared to small villages.

5.5.2 Housing and living environment of participants

Table 5.2 summarizes housing and environmental characteristics of the women. The type of fuel used for cooking and lighting is significantly different among locations. Women in small rural villages predominantly use wood than women in major villages (p=0.003).

Table 5.2: Housing Characteristics by Site (%)

Statistic	Serowe (n=65)	Palapye (n=47)	Maunatlala (n=12)	Lerala (n=13)
Home Ownership	67	66	100	84
Heating**				
Electricity	12.3	8.5	-	7.7
Paraffin	4.6	-	-	-
Gas	18.5	38.3	-	1.0
Wood	27.7	17.0	66.6	76.9
Car battery	1.5	2.1	0	-
Gas/wood	18.5	27.7	25	-
Electricity/gas	16.9	6.4	8.3	7.7
Water Source				
Indoor tap	26.2	29.8	10	-
Outdoor tap	66.2	68.1	81.7	100
Rainwater	3.1	-	-	-
Outdoor/indoor tap	4.6	2.1	8.3	-
Type of plumbing				
Plastic	23.1	31.9	-	7.7
Metal	20	59.6	91.7	92.2

Palapye women used gas more and less of wood than all other areas depicting its semi urban nature. Home ownership was higher in small villages. Compared to all villages, women from Lerala relied solely on outdoor public taps for their water supply.

5.5.3 Behaviors and practices of participants

Table 5.3 summarizes behavioral characteristics of the women by site. The general characteristics of the women who participated in the study were proportional throughout the three trimesters..

Table 5.3 Behaviour and Practices of Participants

Statistic	Trimester 1 (%)	Trimester2 (%)	Trimester 3 (%)
Alcohol Consumption			
Serowe (T1, N=65; T2,N=58; T3, N=48)	47.7	46.6	47.9
Palapye (T1, N=47; T2,N=43; T3, N=34)	40.8	39.5	44.1
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	66.7	66.7	63.6
Lerala (N=13 all trimesters)	61.5	61.5	61.5
Tobacco Use¶			
Serowe (T1, N=65; T2,N=58; T3, N=48)	9.2	10.3	10.4
Palapye (T1, N=47; T2,N=43; T3, N=34)	4.3	4.7	5.9
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	8.3	8.3	9.1
Lerala (N=13 all trimesters)	7.7	7.7	7.7
Geophagia			
Serowe (T1, N=65; T2,N=58; T3, N=48)	60	58.6	56.2
Palapye (T1, N=47; T2,N=43; T3, N=34)	46.8	44.2	47.1
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	33	33	27.3
Lerala (N=13 all trimesters)	76.9	76.9	76.9
Paint Chip Pica			
Serowe (T1, N=65; T2,N=58; T3, N=48)	3.1	1.7	2.1
Palapye (T1, N=47; T2,N=43; T3, N=34)	6.4	7.0	8.8
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	NR	NR	NR
Lerala (N=13 all trimesters)	NR	NR	NR
Matchstick sucking pica			
Serowe (T1, N=65; T2,N=58; T3, N=48)	15.4	15.5	14.6
Palapye (T1, N=47; T2,N=43; T3, N=34)	14.9	16.3	14.7
Lerala (N=13 all trimesters)	15.4	15.4	15.4
Pencil Pica			
Serowe (T1, N=65; T2,N=58; T3, N=48)	13.8	13.8	10.4
Palapye (T1, N=47; T2,N=43; T3, N=34)	8.5	9.3	8.8
Lerala (N=13 all trimesters)	7.7	7.7	7.7
Chalk Pica			

Serowe (T1, N=65; T2,N=58; T3, N=48)	1.5	1.7	2.1
Pica Bone Meal Pica			
Serowe (T1, N=65; T2,N=58; T3, N=48)	3.1	1.7	2.1
Brake Fluid Use for Psoriasis, ringworm treatment			
Serowe (T1, N=65; T2,N=58; T3, N=48)	40.0	37.9	35.4
Palapye (T1, N=47; T2,N=43; T3, N=34)	19.1	18.6	17.6
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	33.3	33.3	36.4
Lerala (N=13 all trimesters)	30.8	30.8	30.8
Use of Traditional Cosmetic Clays (Letsoku) for skin Smoothing **			
Serowe (T1, N=65; T2,N=58; T3, N=48)	23.1	22.4	20.8
Palapye (T1, N=47; T2,N=43; T3, N=34)	10.6	9.3	11.8
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	33.3	33.3	36.4
Use of light brown shoe-polish for skin smoothing and vanishing*			
Serowe (T1, N=65; T2,N=58; T3, N=48)	26.2	29.3	31.2
Palapye (T1, N=47; T2,N=43; T3, N=34)	6.4	7.0	8.8
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	16.7	16.7	18.2
Lerala (N=13 all trimesters)	23.1	23.1	23.1
Use of Torch Battery contents to treat ringworm			
Serowe (T1, N=65; T2,N=58; T3, N=48)	12.3	13.8	16.7
Palapye (T1, N=47; T2,N=43; T3, N=34)	2.1	2.3	2.9
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	8.3	8.3	9.1
Lerala (N=13 all trimesters)	7.7	7.7	7.1
Use of Traditional Herbs			
Serowe (T1, N=65; T2,N=58; T3, N=48)	18.8	15.5	16.9
Palapye (T1, N=47; T2,N=43; T3, N=34)	5.9	7.0	6.4
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	9.1	8.3	8.3
Lerala (N=13 all trimesters)	7.7	7.7	7.7
Use of over the Counter Drugs			
Serowe (T1, N=65; T2,N=58; T3, N=48)	27.1	22.4	21.5
Palapye (T1, N=47; T2,N=43; T3, N=34)	23.5	27.9	27.7
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	9.1	8.3	8.3
Fasting During Pregnancy***			
Serowe (T1, N=65; T2,N=58; T3, N=48)	22.9	25.9	24.6
Palapye (T1, N=47; T2,N=43; T3, N=34)	2.1	4.7	4.3
Maunatlala (T1, N=12; T2,N=12; T3, N=11)	9.1	8.3	8.3
Lerala (N=13 all trimesters)	NR	NR	NR

T1=Trimester 1;T2=Trimester 2;T3=Trimester 3
¶Only one woman from Palapye reported smoking. The rest were using snuff
*******Significant difference observed in all trimesters ($p<0.05$)
****** Significant difference observed in trimesters 1 and 2 only ($p<0.05$)
*Significant difference observed in the second trimester only ($p<0.05$)

**Significantly different (p=0.003)

There were generally no significant differences in the behaviors of women by site with the exception of the use of *letsoku*, a traditional clay cosmetic, the use of shoe polish for skin smoothing, and fasting during pregnancy ($p<0.05$). In all cases women from Serowe were more likely than other women to engage the use of *letsoku*, shoe polish as a beautifying product and fasting during pregnancy. However, alcohol consumption was more prevalent in women from small rural villages compared to major villages. Geophagia (the intentional ingestion of soils) was the most reported practice across all locations, but highest in Lerala village (approximately 77%) even though the difference was not significant ($p>0.05$). Chalk, bone meal and paint chips pica were the least practiced habits, and mainly reported in Serowe. The ingestion of paint chips by pregnant women was only prevalent in major villages. Brake fluid, reported to be used for treatment of psoriasis and ringworm was evidently less prevalent in Palapye

5.5.4 Self-reported dietary intake of selected food items

Table 5.4 summarizes self-reported dietary intake frequency of selected iron, calcium and protein rich foods. Women in smaller villages consumed wholegrain foods more frequently than those in urban areas ($p<0.001$), while consumption of green leaf vegetable and meat cut across all sites except in Lerala where meat was consumed less. Generally, Lerala women performed poorly in terms of dietary requirements compared to all other villages. Maunatlala women generally reported a sufficient dietary intake compared to Lerala and the two major villages. The consumption of calcium rich food such as milk was highest in Maunatlala followed by Palapye on average. Calcium and iron supplement consumption was not reported by women in Lerala whilst it was highest in Palapye and Serowe (average 50%) and Maunatlala (average 40%).

Table 5.4: Self-reported information on dietary intake selected food items (%)

Statistic	Serowe (n=65)	Palapye (n=47)	Maunatlala (n=12)	Lerala (n=13)
Wholegrain**				
Daily	7.7	17	50	30.8
2-3X a week	30.8	17	25	0
1-4X a month	33.8	48.9	16.7	15.4
Green leaf vegetables				
Daily	50.8	29.8	58.3	38.5
2-3X a week	30.8	53.2	41.7	38.5
1-4X a month	13.8	10.6	0	23.1
Red Meat				
Daily	43.1	31.9	45.5	0
2-3X a week	21.5	38.3	27.3	60
1-4X a month	16.9	19.1	9.1	10
Milk				
Daily	26.2	34	41.7	15
2-3X a week	21.5	21.3	41.7	30.8
1-4X a month	21.5	25.5	8.3	0
Ice cream**				
Daily	9.4	10.6	8.3	7.7
2-3X a week	32.8	23.4	0	0
1-4X a month	32.8	53.2	75.0	15.4
Fish				
Daily	0	4.3	8.3	0
2-3X a week	30.8	36.2	50.0	0
1-4X a month	35.9	34.0	25.0	38.5
Yoghurt				
Daily	9.2	8.5	8.3	0
2-3X a week	30.8	29.8	25	1
1-4X a month	33.8	44.7	50	23.1
Dietary Supplements**	46.2	21.3	83,3	61.5
Type of Supplement taken**				
Iron	87.5	50	60	0
Calcium	12.5	50	20	0
Multivitamins	0	0	20	100

**** Significantly different (p<0.05)**

5.5.5 Blood lead levels of pregnant women across trimesters

Table 5.5 summarizes concentrations of lead in whole blood by site and trimester. PbB concentrations ranged from 0.5 to 12.90µg/dL with an overall mean (±SEM) of 2.34 (±0.098) µg/dL. PbB concentrations of ≥5µg/dL were observed in 5.5%, 5.6% and 3.1% of women during the first, second and third trimesters of pregnancy. PbB concentrations significantly differed among locations (p=0.01) (Figure 3). Overall mean (±SEM) were 2.27(±0.13) µg/dL, 2.06 (±0.14) µg/dL, 2.18(±0.30) µg/dL and 3.60(±0.48) µg/dL in Serowe, Palapye, Maunatlala and Lerala respectively. The highest concentrations were observed in women from Lerala compared to Serowe (p=0.02) and Palaye (p=0.01). No significant differences were observed between Lerala and Maunatlala. Mean (±SEM)

Table 5. 5 Blood lead levels by site and trimester (µg/dL)

Statistic	Serowe (T1, N=65; T2,N=58; T3, N=48)	Palapye (T1, N=47; T2,N=43; T3, n=34)	Maunatlala (T1, N=12; T2,N=12; T3, N=11)	Lerala (N=13 all trimesters)
Trimester 1				
Mean (SEM)	1.88(0.18)	1.75(0.19)	1.77(0.49)	3.33(0.86)
95% CI	1.53:2.23	1.38:2.13	0.69:2.84	1.46:5.20
Median	1.40	1.50	1.56	1.90
Range	0.50-5.40	0.50-5.60	0.50-6.80	0.50-11.80
Trimester 2				
Mean (SEM)	2.52(0.25)	2.16(0.26)	2.09(0.355)	3.78(0.896)
95% CI	2.03:3.01	1.64:2.68	1.31:2.87	1.83:5.74
Median	1.60	1.80	2.05	3.46
Range	0.50-7.50	0.50-8.40	0.50-4.40	0.50-12.90
Trimester 3				
Mean (SEM)	2.51(0.23)	2.38(0.32)	2.73(0.69)	3.84(0.82)
95% CI	2.05:2.91	1.74:3.02	1.20:4.27	2.04:5.62
Median	2.20	2.15	1.70	2.40
Range	0.50-8.50	0.50-10.30	0.50-6.80	1.00-9.80

SEM=Standard Error of Mean
95%CI =95% Confidence Interval
T1=Trimester 1;T2=Trimester 2; T3=Trimester 3

values of women from Lerala were 3.33(±0.86), 3.78(±0.896) and 3.84(±0.82) in the first, second and trimesters respectively. The range was 0.50- 12.90µg/dL.

Blood lead levels increased by trimester. A significant increase in PbB levels was observed between the first and third trimester (p=0.01) (Figure 4). However, no significant difference was observed between the first and second trimester (p=0.07). The mean PbB (±SEM) for the first, second and third trimesters were 1.96(±0.14) µg/dL, 2.49(±0.17) µg/dL, 2.66(±0.19) µg/dL respectively. The proportion of PbB between the first second and third trimester was 1.6%, 3.3%, 3.6% and 5.4% in Lerala, Serowe, Palapye and Maunatlala.

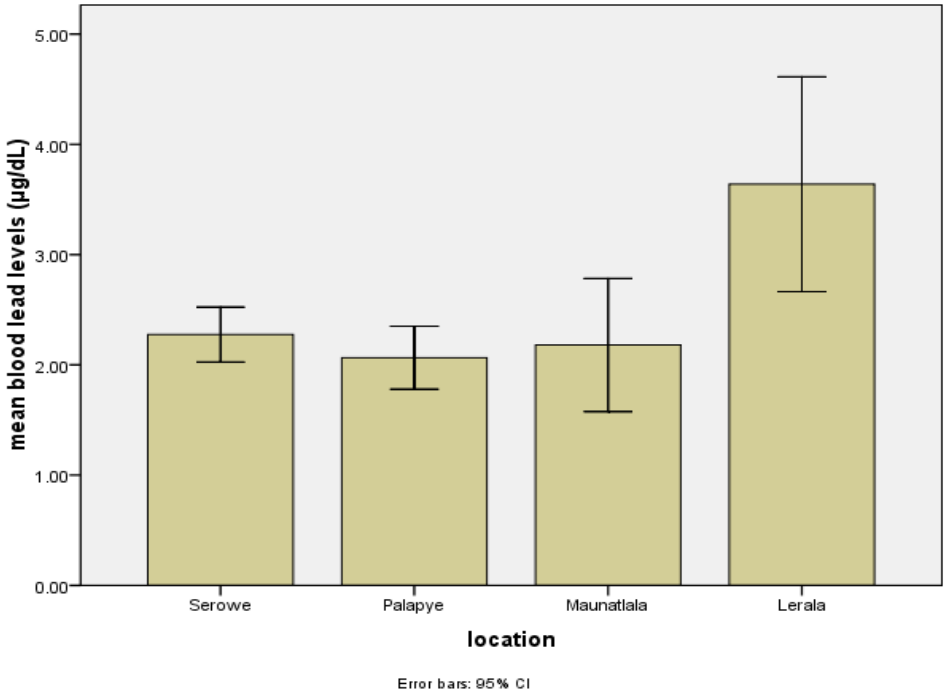

Figure 5.3 :Mean blood lead levels by location

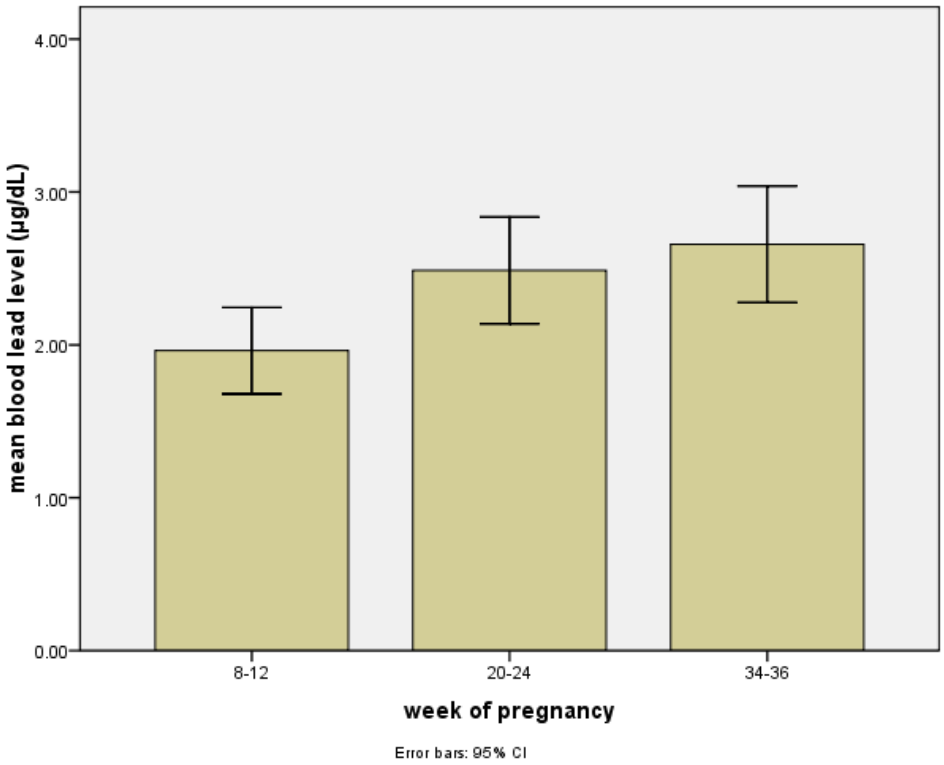

Figure 5. 4: Mean blood lead levels by week of pregnancy

5.6 Discussion

In this study we examined PbB concentrations among women aged 18 to 44 years to establish if women from areas of different socioeconomic and environmental background will have significant differences in PbB and to investigate if blood levels will differ by trimester in the Central Administrative District of Botswana. We found that there is a significant difference in blood lead concentrations between small and major villages. Interestingly, we have found that women from a poor small rural village in Botswana had significantly higher PbB levels compared to women from major villages where moderate to high industrial activity takes place. Overall we also found that women in their third trimester had significantly higher blood PbB compared to their first trimester.

The highest mean PbB concentrations among the study sites were recorded at Lerala followed by Maunatlala during the third trimester. These findings could be explained by several factors. These two villages are both categorized as small and rural villages with the lowest income adequacy. For example, unemployment was highest in Maunatlala, and, even though the women in Lerala reported being employed their income earnings placed them in the lowest income adequacy category. Women from the two small villages also have the highest number of children compared to women from major villages. Additionally, women from Lerala village generally had a low dietary intake of calcium and iron rich foods. Iron and calcium supplementation was also very poor in Lerala compared to Maunatlala and other villages. This is despite the fact that every pregnant woman attending antenatal clinics in Botswana are automatically supplied with iron, ferrous sulphate, calcium and vitamin C. Lerala women were further reliant on outdoor public standpipe a compound standpipes supplied from boreholes by the water authorities. This water is purified however, our suspicion is that lead leaches are higher due to the high water temperature as a result of exposure to high heat from the outdoor environment. This could also be reflection of women not affording a water connection fee to municipal water supply or not affording to install water fittings in their houses due to poverty. Geophagia, the intentional ingestion of soils, was highest in Lerala and

alcohol consumption highest in both Maunatlala and Lerala. Based on these factors, it can therefore be concluded that the higher PbB concentrations in small villages are a function of environmental, socioeconomic and lifestyle behaviors.

Although this is the first study investigating lead exposure among pregnant women in Botswana, a study carried out in 2010 found 31% of children aged 1-6 years having PbB levels equal to or exceeding the action level of 10 µg/dL. The main confounding factor was maternal unemployment.[25] Our results are consistent with the said study and studies conducted elsewhere which have found strong relationships between populations of poorer socioeconomic status and exposure to lead.[27-29]

Diet is an important component in the absorption of lead. Deficiencies of calcium and iron have been found to enhance the absorption of lead.[30,31] Evidently, women from Lerala had low dietary calcium and iron. As a result we suspect that the low calcium diet and not taking calcium supplements has contributed to the enhancement of gastrointestinal lead absorption. This is consistent with other studies.[31] It is worth noting that whilst the government provides supplements to pregnant women, we observed that many of the women collected the supplements but did not use them. Further probing of the women revealed the women said the supplements make them sick. This finding reveals the need for awareness and education of pregnant women on the importance of the supplements provided.

Women in small villages, Lerala and Maunatlala, are geophagic as well as consuming alcohol more than women from major villages. Studies have proven that infants born to women who smoke, drink and maintain a poor nutritional status for selected nutrients are at a greater risk of lead toxicity than those born to other women.[32] Severe lead poisoning has also been observed in women who are geophagic.[33,34]

Studies have reported a significant increase in maternal PbB during periods corresponding to 20-36 weeks.[35,36] This study has reflected a similar trend with a significant increase in blood lead levels between the first and the third trimester. An increase of PbB concentrations in the last half of pregnancy is reported to coincide with an increased fetal need for calcium as well as an increased maternal provision of calcium.[37] The resultant effect is that if the needed supply of calcium is supplied from the expectant woman's bone, then women with high loads of bone lead may transfer more lead to the bloodstream with calcium. In this study PbB concentrations increases from the first to the third trimester ranged from 1.6 to 5%. The lowest increase between trimester 1 and trimester 2 was observed in women from Lerala who had the highest number of children prior to the current pregnancy. There is evidence that if the fetus transports maternal lead from the mother's body (bone) stores, blood lead levels will be lowered in subsequent pregnancies.[35] A similar trend in is observed in this study using the example of Lerala women who starting off with significantly higher levels, but resulting with a small 1.6% increase in PbB on the third trimester compared to Maunatlala for example that started off with lower blood lead levels in the first trimester but ending with a 5% increase on the third trimester. These findings are similar to other studies that have found multigravida women to have lower PbB levels during the last trimester (relative to lead levels in the first trimester).[35]

5.7 Limitations:

As with any progressive cohort studies women were lost in each trimester of pregnancy. Additionally as in the previous chapters, the lack of resources could not allow sampling in an urban area. This could have provided a good comparison of trends among women in villages and urban areas.

The study did not assess knowledge and attitudes on lead exposure or lead exposure sources. This could have provided an insight as to whether women engage in the practices and behaviours knowingly. Future studies should assess such.

5.8 Conclusions

To the best of the author's knowledge, this is the first ever study conducted in Botswana that measured blood lead concentrations in pregnant women at each stage of their pregnancy. The results suggest that location and socioeconomic factors have an influence on PbB concentrations during pregnancy. Even though we did not investigate knowledge and health beliefs, the results further suggest that most women are ignorant of lead and its potential negative impacts on pregnancy outcomes. This was confirmed during workshops with study participants as well as during interactions with them through interviews. Most importantly, the results suggest that women who have been exposed to lead continuously may have higher PbB circulating in their blood.

Currently the Government of Botswana does not have in place any system to keep track of lead exposure. Such systems will be necessary to assess risks to health and to determine trends in exposure to lead over time. Public education and awareness is crucial in the prevention of lead exposure. It is important therefore for the Government to develop interventions that would reach most vulnerable population groups such as young children, young adults and women in reproductive age to prevent lead exposure in the early years of their lives and thus prevent fetal lead exposure.

Training and education of health care workers, parents and the communities at large should be intensified and food supplementation programmes should be promoted. Pregnant women should be made aware of lead and the importance of good nutrition practices, avoid potential lead containing substances to avert serious medical consequences to their health and that of their unborn children

5.9 References

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Chapter 6

A Model for Assessing Lead Exposure during Pregnancy and After Delivery

6.1 Abstract

This study identifies characteristics of pregnant women that can be used to predict blood lead levels ≥2µg/dL in order to develop a clinical assessment tool that will be used by health workers to screen lead exposure levels during pregnancy and after delivery. Blood lead levels of 63 pregnant women living in the Serowe Palapye Administrative District were analysed three times from week 8 to week 36 and again six weeks after delivery. The enrolled women were only those with uneventful pregnancies, and had normal babies. Blood lead levels were dichotomized into <2µg/dL and ≥2µg/dL. A logistic regression analysis was conducted to examine the association of the characteristics of pregnant women with blood lead levels≥2µg/dL using blood lead levels collected from the first to the third trimester and six weeks after delivery (n=63, total 252 repeated measures). The following variables were associated with increased risk of blood lead levels ≥2µg/dL, defined in this study as elevated: engaging in pica behaviour (OR, 6.7, CI,1.34-34.5); Using an outdoor drinking water tap (OR,4.4, CI,1.6-12.0); Trimester of pregnancy (OR 8.6, CI,1.4-52.4) and engaging in multiple risk behaviours during pregnancy such as traditional medicine use in combination with smoking, alcohol use, and so forth; (OR, 20.9,CI,4.5-95.8). Consumption of citrus fruits (OR 0.07, CI,0.01,CI,0.41-0.01) and supplements in the combination of calcium, folic acid and iron (OR 0.02,CI, 0.01-0.11) reduced the risk of elevated blood lead levels. These predictor variables can be used to identify women with blood lead levels ≥2µg/dL This data demonstrated that understanding the behaviours, practices, social and environmental characteristics of a population can be used to develop screening tools for lead exposure, and thus prevent lead poisoning from occurring.

Key words: Blood-lead levels; pregnant women; trimester; delivery, Botswana

6.2 INTRODUCTION

Lead is a recognised and well known neurotoxin that has been associated with adverse multiple health effects ranging from impaired cognitive behaviour to death. The most recent concerns raised by researchers is that the lowest blood lead concentrations associated with deficits in cognitive functioning as well as academic achievement is poorly defined.[1] Since the 1980's blood lead levels as low as 10µg/dL were associated with adverse effects on cognitive development, growth and behaviour among childen.[2-5]Recent research has revealed that the lead affects intelligence quotient (IQ) score at blood lead levels below 10µg/dL and that no single study has been able to identify a safe level of lead.[6] Bellinger (2008) states that "…. 10µg/dL has no special biological significance with regard to neurodevelopment…..the current screening guideline is best interpreted as a risk management tool".[7] These conclusions are based on cohort studies that have reported significant inverse relationships on most or all children with blood lead levels below 10µg/dL[8-10] including cohorts with mean blood lead levels as low as 1-2µg/dL.[11]

Another concern is that lead adversely impacts offspring development at maternal blood lead concentrations that do not in fact produce maternal clinical toxicity.[12] Some of the key reproductive effects observed in females associated with low- level exposure to lead include delays in sexual maturation, the risk of spontaneous abortion, effects on birth weight and pre-term birth. [12] There is evidence of delayed puberty in adolescent girls and blood lead concentrations as low as 3µg/dL[13] Inverse associations between blood lead levels and length of gestation have been reported with implications on increased prematurity.[14]have been reported

Chapter 5 reported blood lead levels from the first trimester of pregnancy to the third trimester with concentrations ranging from 0.5-12.90µg/dL with an overall mean (±SEM) of 2.34(±0.098)µg/dL. The studies reporting low lead levels just summarized in this introduction documented effects at blood lead levels ranging from 1 to 10µg/dL. The effects include developmental neurotoxicity and reproductive effects. Of major concern

is the strong weight of evidence for neurodevelopmental effects in infants and children. The lead levels in this study therefore present serious health implications for women of reproductive age, infants and children. Pregnant women are not only a source of exposure to the unborn infants, but are also a vulnerable group that requires attention in preventing the effects of low lead level. It is therefore logical to apply the principles of primary prevention in order to minimize the effects of lead poisoning on infants, children and pregnant women.

It is on this basis that the main objective of this study is to develop a clinical assessment tool for screening lead exposure levels during pregnancy and after delivery. The objective of this chapter is therefore to identify the characteristics of 63 pregnant women who completed the study from the first trimester (week 8-12) , second trimester (week 20-24), third trimester (week 34-36) and 6 weeks after delivery (weeks 42-44) which can predict blood lead levels ≥2µg/dL. The cut of point of ≥2µg/dL is based on the literature that has just been highlighted showing evidence that irreversible neurodevelopmental effects occur at levels lower than 2µg/dL. For our purpose an elevated blood lead level is ≥2µg/dL

6.3 PURPOSE OF THE TOOL

The tool will be used to guide health care workers in predicting whether a pregnant woman is at a greater risk of lead elevated blood lead level and therefore recommend educate, assess risks counsel and follow up. (Please see chapter 7)

6.4 METHODS

6.4.1 Data

Blood lead was analyzed from a total of 63 women living in the Central District of Botswana (Figure 1) who donated blood between weeks 08-12, 20-24 and 34-36 and again 6 weeks after delivery. The data was captured and cleaned in SPSS and converted to Stata version 12, where further data cleaning, data management and all statistical analyses were conducted.

6.4.2 Descriptive statistics

The outcome variable (lead measurement) was summarised first as a continuous variable (original data) and then as a binary variable. In the first instance, the outcome variable was summarised using numerical descriptive statistics. Prior to data description, three methods were used to determine the normality of the data:

1. Numerical - nearness of the mean to the median
2. Graphical - frequency distribution plot and
3. Statistical – statistical test for normality (Skewness-kurtosis and Shapiro-Wilk tests).

The lead measurement data was skewed. Data transformation, including log transformation, did not achieve normality. The data was therefore summarised using median and inter quartile range.

In the second instance, lead values were categorised as normal (<2ug/dL) and high (≥2ug/dL). The binary data was described using actual frequencies (numbers), proportions and 95% confidence intervals. Both sets of descriptive statistics were reported for all study participants and by key variables.

6.4.3 Explanatory variables modelling

Further analysis sought to determine the significant explanatory factors (risk factors and protective factors) of blood lead levels. The outcome variable for this analysis was the dichotomous lead levels data. Therefore logistic regression was used. The dichotomous lead variable was used for the modelling analysis because:

1. The original variable was not normally distributed
2. Transformation of the original variable did not achieve normality
3. Most explanatory variable binary or categorical
4. Categorized lead values would be easier for health professional to interpret.

Since the data contained repeated measures for each individual, classical statistical methods would not be appropriate as they would produce standard errors that are too small leading for false positive associations. Statistical methods that account for clustering were used for this analysis. Specifically, the generalised estimating equation (GEE) was used. The random effect approach was also explored but the results were very similar. Since the random effect method can be problematic for logit models, the GEE was preferred.

To fit the GEE models, the correlation between the repeated measures was first calculated. The correlation matrix was found to be an auto-regressive (order 1) correlation. This correlation (AR1) was therefore specified for the GEE models. To build the final model, univariate GEE logistic regression models were first built followed by a multivariate model.

First, the association between each exposure variable and the outcome variable was determined using univariate GEE logistic regression models. Variables were considered for inclusion in adjusted models on the basis of significant ($p<0.15$) univariate association with the outcome. A table of unadjusted odds ratios and 95% confidence intervals were presented for each univariate association.

Adjusted associations between significant exposure variables and outcome were then assessed using multivariate GEE logistic regression. The stepwise regression technique (forward then backward selection), starting with the most significant covariate, was used to determine the significant explanatory variables to be retained in the final adjusted model. The final model was selected from a family of models on the basis of parsimony and post-estimation model evaluation. The Wald test was used to determine if variables included in the model improved the model fit. Only variables which were significant at 0.05 were included in the model. Robust standard errors were also evaluated against the model standard errors. Tables of adjusted odds ratios and 95% confidence intervals were presented.

6.5 RESULTS

Table 6.1 summarizes the overall proportions of women with blood lead levels ≥2µg/dL. Overall 46% and 54% (n=252 repeated observations representing 63 pregnant women, C.I. 0.40:0.53) had blood lead levels <2µg/dL and ≥2µg/dL respectively.

Table 6.1 Blood lead levels (≥2µg/dL) of study participants by social, demographic and environmental status (n=252 observations (repeated measures), representing 63 women)

Characteristics	Median	Inter Quartile Range		Range		Blood lead ≥2µg/dL	
				Minimum	Maximum	No.	(%)
Age (years)							
18-25	2.25	1.65	3.37	0.5	6.55	71	57.26
26-33	2.19	1.42	2.9	0.5	4.43	40	50.00
34-42	2.1	0.85	3.74	0.73	11.1	24	50.00
Type of Location							
Major Village	2.05	1.125	3.0	0.5	4.83	80	51.28
Small Village	2.675	1.54	4.29	0.77	11.1	55	57.29
Current Location							
Lerala (small village)	3.5	1.925	4.43	0.8	11.1	34	65.38
Maunatlala(small)	2.63	1.05	3.35	0.77	5.45	21	47.73
Palapye(Major Village)	1.98	1.13	3.12	0.5	4.7	29	48.33
Serowe(Major Village)	2.18	1.35	2.94	0.5	4.83	51	53.13
Marital Status							
Married	1.63	1.025	2.8	0.8	2.88	10	35.71
Single	2.23	1.5	3.36	0.5	11.1	125	55.80
Parity							
Multipara	2.09	1.125	3.2	0.5	11.1	82	48.81
Primipara	2.25	1.75	3.38	0.5	5.45	53	63.10
Education							
Tertiary	2.175	1.57	2.63	1.13	4.68	31	58.49
Secondary	2.75	1.68	3.68	0.5	11.1	88	57.89
Primary	1.51	0.85	2.03	0.725	4.15	16	34.04
Income							
Lower	2.2	1.4	3.35	0.5	11.1	123	53.71
Middle	2.05	1.43	2.48	1.03	3.13	9	45.00
Upper	2.9	2.9	2.9	2.9	2.9	3	100.00
Home/ neighbour with backyard repair workshop							
No	1.6	1.025	2.23	0.5	4.9	40	28.57
Yes	3.2	2.48	4.68	1.05	11.1	95	84.82
Tobacco use or live with smoker							
No	1.4	0.88	1.88	0.5	2.73	25	20.49
Yes	3.22	2.71	4.55	1.58	11.1	110	84.62
Alcohol Consumption							
None	1.8	1.03	2.98	0.5	5.98	45	40.54
Light	1.73	1.4	2.48	0.75	4.15	23	40.35
Moderate	2.88	2.05	4.7	1.05	6.55	39	79.55
Heavy	3.63	2.65	4.68	1.93	11.1	32	80.00
Pica Behaviour							
No	1.58	1.03	2.25	0.5	3.35	30	27.78
Yes	2.94	1.95	4.29	0.73	11.1	105	72.92
Unconventional skin treatments							
No	1.78	1.13	3.13	0.5	11.1	69	42.33

Yes	2.84	2.18	3.5	0.73	5.98	66	74.16
Fuel for cooking							
Electricity	1.58	0.8	1.88	0.5	3.18	12	33.33
Gas	1.58	1.03	2.48	0.73	2.78	14	31.82
Elect-gas	2.21	1.75	3.38	1.03	4.89	34	60.71
Wood	2.96	1.89	4.29	0.75	11.1	74	66.07
Gas-wood	1.78	1.78	1.78	1.78	1.78	1	25.00
Traditional Medicine use and over the counter drugs							
No	1.75	1.05	2.78	0.5	11.1	71	40.11
Yes	3.1	2.64	3.74	1.63	5.45	64	85.33
Multiple risk behaviours/ practices							
0-1 risk behaviours	1.6	1.03	2.51	0.5	5.03	10	10.87
≥2 Risks risk behaviours	3.0	1.93	4.15	0.78	11.1	125	78.13
Water Source type							
Indoor	1.58	1.03	2.25	0.5	3.18	24	35.29
Outdoor	2.7	1.7	3.68	0.73	11.1	111	60.33
House paint type							
Water	2.3	0.83	3.2	0.5	4.83	19	47.50
Oil_h20	2.4	1.5	3.9	0.5	5.45	55	55.56
Oil	1.98	1.4	2.05	1.13	3.13	8	40.00
Pigment	2.25	1.525	3.44	0.76	11.1	53	56.99
Supplements							
Calcium	1.41	0.95	1.81	0.5	2.4	9	8.74
Other	2.56	1.35	3.19	0.78	5.01	14	50.00
None	3.35	2.78	4.68	2.05	11.1	111	92.50
Green veg consumption rate							
1-5xw	1.5	1.03	2.3	0.5	11.1	8	11.11
Weekly	1.93	1.58	2.48	0.5	4.68	42	51.85
None	3.3	2.9	4.43	0.8	6.55	85	85.86
Citrus fruit consumption							
1-5xw	1.58	0.89	1.93	0.5	5.03	11	11.96
Weekly	2.73	1.63	3.13	0.5	4.83	48	60.76
None	4.13	3.35	4.7	2.05	11.1	76	93.83
Peanut							
0	1.6	1.03	2.21	0.5	5.03	36	25.90
1	3.35	2.48	4.68	0.8	11.1	99	87.61
Milk consumption							
1-5xw	1.14	0.8	2.2	0.5	5.03	3	9.38
Weekly	1.73	1.9	2.15	0.5	5.03	26	26.80
None	3.25	2.78	4.43	0.75	11.1	106	86.18
Job or hobby involves paint							
No	1.65	1.05	2.63	0.5	6.55	54	35.76
Yes	3.19	2.2	4.15	1.025	11.1	81	80.20

The mean age (±SEM) of the women (n=63) was 27 (±0.39) years, range 18-42 years with 38% and 62% coming from small (rural) and major (semi-industrial) villages. Only 8% of the women were married. Median blood lead levels of women was 2.0µg/dL (CI;2.34-2.87) (Table 6.1). Women who lived in small villages (median 2.7 µg/dL) had higher blood lead levels compared to women who lived in major villages (median, 2.1 µg/dL). Consequently women from Lerala, a small village in the study area had a higher proportion of women with blood lead levels of 2 µg/dL or higher (n=13, 65%) compared

to Serowe (n= 24, 53%), Palapye (n=15, 48%) and Maunatlala (n=11, 47%) . A higher proportion of women who had backyard car repairs or a neighbour with a backyard car repair shop (n=28, 84%), using tobacco or living with a smoker (n=32,85%), engaging in pica behaviour(n=36, 73%) and using traditional medicines (n=19, 85%) and using unconventional skin treatments (n=23,74%) had blood lead levels greater or equal to 2µg/dL.

A higher proportion of women who did not use supplements during pregnancy (n=28, 93%), citrus (n=19, 86%) had blood lead levels ≥2µ/dL.

Figure 6.1 and Table 6.2 characterizes blood lead levels by trimester. The proportion of women having blood lead levels ≥2µg/dL was significantly different between

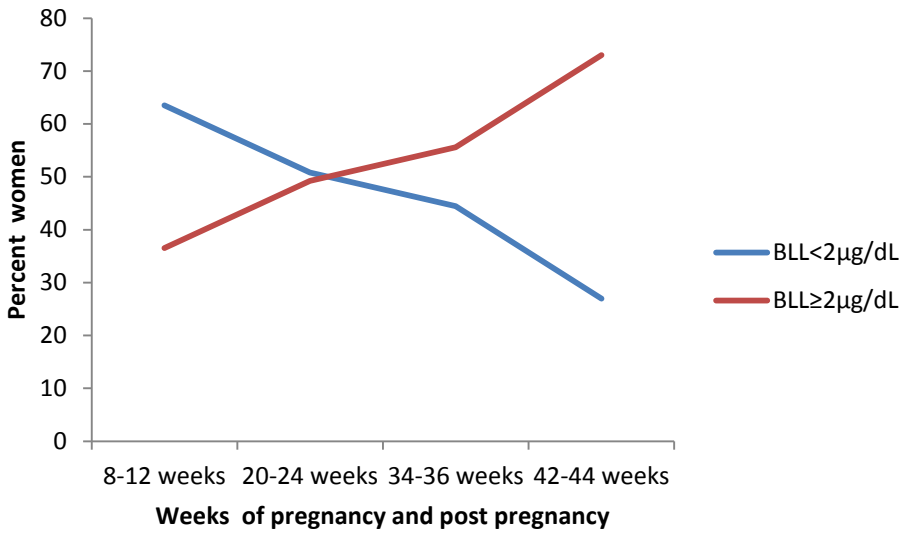

Figure 6.1 The time course of the proportion of women with blood lead levels <2µg/dL and ≥2µ/dL during pregnancy and after delivery

trimesters (between group difference p<0.01) with the first trimester (8-12 weeks) having the lowest number of women with blood lead levels ≥2µg/dL compared to post-delivery (42-44 weeks). No significant differences were observed in the proportion of women having blood lead levels ≥2µg/dL between major and small villages and the current

location of residence at the time of sampling (p>0.05). A higher proportion of younger women (57%) had blood lead levels ≥2 µg/dL compared to older women (+34 years), however the difference was not significant (p>0.05). Marriage, parity and level of education had significantly different proportions of blood lead levels (p<0.05).

Table 6.2 Distribution of blood lead levels by trimester and socioeconomic/ demographic factors

	Trimester 1		Trimester 2		Trimester 3		Trimester 4	
Characteristics	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**	**Median**	**IQR**
Age (years)								
18-25	1.8	1.1-3.0	2.0	1.1-3.6	2.1	1.4-3.4	3.2	1.6-4.8
26-33	1.5	0.8-2.1	1.6	1.15-2.55	2.2	1.35-2.6	2.6	1.6-4.4
34-42	1.45	0.5-3.75	1.6	0.5-2.75	1.8	1.15-3.45	2.85	1.2-5.15
Type of Location								
Major Village	1.4	0.5-2.3	1.6	1-2.7	2.1	1.3-2.6	2.4	1.2-4.4
Small Village	1.8	1.2-3.25	2.45	1.45-3.8	2.3	1.3-4.85	3.3	1.75-5.4
Current Location								
Lerala (small village)	1.9	1.5-3.9	3.0	1.6-4.5	2.4	1.7-5.1	4.2	2.4-5.4
Maunatlala(small)	1.4	0.5-1.9	2.2	1.0-3.3	1.7	1.0-3.7	2.2	1.4-5.4
Palapye(Major Village)	1.2	0.5-2.1	1.6	1.0-2.7	1.7	1.3-2.9	3.3	1.6-4.4
Serowe(Major Village)	1.5	1.05-2.6	1.6	1.0-2.65	2.1	1.35-2.6	2.25	1.15-4
Marital Status								
Married	1.5	1.1-2.9	1.4	1.0-2.1	1.5	1.0-2.5	1.2	0.5-4.4
Single	1.6	0.5-2.45	2.0	1.05-3.15	2.1	1.35-3.4	3.25	2.0-4.9
Parity								
Multipara	1.5	0.5-2.6	1.95	1.0-3.0	1.8	1.3-3.2	2.4	1.2-4.9
Primipara	1.6	1.0-2.3	1.7	1.2-3.0	2.4	1.7-3.4	3.3	2.2-4.4
Education								
Tertiary	1.3	0.5-2.3	1.7	1.2-2.9	2.1	1.4-2.5	2.4	2.1-3.2
Secondary	1.8	1.3-3.1	2.15	1.1-3.3	2.5	1.2-3.6	4.1	1.5-5.4
Primary	0.5	0.5-1.8	1.15	0.5-2.4	1.5	1.15-2.05	2.0	1.2-3.3
Income								
Lower	1.5	0.5-2.6	2.0	1.0-3.0	2.1	1.3-3.4	3.2	1.6-4.9
Middle	1.9	1.6-2.1	1.6	1.4-1.6	2.1	1.0-2.2	2.4	1.2-4.4
Upper			2.5	2.5-2.5	2.2	2.2-2.2	2.4	2.4-2.4
Home/ neighbour with backyard repair workshop								
No	1.2	0.5-1.8	1.2	1.0-1.95	1.4	1.0-2.1	2.0	0.5-3.3
Yes	2.45	1.55-4.05	3.0	2.4-4.8	2.6	2.2-4.75	4.4	2.6-5.4
Tobacco use or live with smoker								
No	1.0	0.5-1.5	1.1	0.5-1.6	1.3	1.0-1.7	1.5	0.5-2.4
Yes	2.25	1.8-4.05	2.8	2.25-4.45	3.3	2.2-4.6	4.4	2.6-5.4
Alcohol Consumption								
None	1.2	0.5-1.8	1.4	1.0-2.5	1.65	1.15-2.45	2.05	1.15-4.3
Light	1.5	0.5-2.0	1.45	1.0-2.2	1.5	1.0-2.6	2.85	1.4-4.4
Moderate	2.9	2.0-4.2	2.7	1.6-3.6	2.5	2.1-4.9	2.4	2.2-5.4
Heavy	2	1.5-4.5	3.15	2.1-4.8	3.3	2.4-5.1	4.6	3.6-5.4
Pica Behaviour								
No	1.1	0.5-1.55	1.1	1.0-1.6	1.4	1.0-1.7	2.15	1.2-4.8
Yes	2.1	1.3-3.9	2.65	2.0-4.1	2.55	2.05-3.95	3.3	2.4-4.8
Unconventional skin treatments								
No	1.4	0.5-2.1	1.6	1.0-3.15	1.6	1.0-2.6	2.4	1.2-4.4
Yes	1.9	1.2-4.2	2.5	1.0-4.3	2.6	2.15-3.4	3.4	2.2-4.9
Fuel for cooking								
Electricity	1.2	0.5-1.9	1.6	0.5-2.4	1.5	1.0-2.1	1.2	0.5-2.1
Gas	1.5	0.5-2.1	1.1	1.0-1.6	1.4	1.0-2.6	2.0	1.1-3.6

Elect-gas	1.75	1.1-3.1	1.85	1.1-2.9	2.25	1.3-3.2	3.7	2.4-4.9
Wood	1.8	0.8-3.75	2.8	1.35-4.45	2.45	1.7-4.6	3.75	2.15-5.4
Gas-wood	1.9	1.9-1.9	2.2	20.2-2.2	1.6	1.6-1.6	1.4	1.4-1.4
Traditional Medicine use and over the counter drugs								
No	1.25	0.5-2.05	1.45	1.0-2.5	1.6	1.0-2.4	2.2	1.2-4.3
Yes	2.3	1.8-4.4	2.7	2.1-4.4	3.05	2.4-3.7	4.4	2.6-5.4
Multiple risk behaviours/ practices								
0-1 risk behaviours	1.1	0.5-1.4	1.1	0.75-1.6	1.3	1.0-1.5	1.2	0.5-2.0
≥2 Risks risk behaviours	2.2	1.5-3.9	2.7	2.0-4.4	2.55	2.1-3.7	3.35	2.4-4.9
Water Source type								
Indoor	1.2	1-2	1.1	1.0-1.7	1.5	1.0-2.1	1.6	0.5-2.4
Outdoor	1.8	0.5-3.1	2.4	1.2-3.6	2.4	1.4-3.5	3.35	2.0-5.0
House paint type								
Water	1.65	0.5-3.6	1.75	1.0-2.6	1.8	1.2-3.4	2.0	0.5-4.9
Oil_h20	1.6	1.2-2.6	2.0	1.2-3.0	2.2	1.3-3.2	2.6	1.2-4.4
Oil	0.5	0.5-1.1	1.0	0.5-1.6	1.4	1.3-2.1	3.3	2.4-4.4
Pigment	1.7	0.5-2.5	2.4	1.0-3.3	2.4	1.5-3.5	3.3	2.0-5.4
Supplements								
Calcium	0.75	0.5-1.3	1.0	0.5-1.55	1.3	1.0-1.5	1.2	0.5-2.0
Other	1.6	1.4-2.2	1.8	1.5-3.15	1.5	0.5-2.1	2.2	0.5-2.4
None	3.0	2-4.5	3.0	2.5-4.5	2.9	2.4-4.6	4.4	3.3-5.4
Green veg consumption rate								
1-5xw	1.2	0.5-1.6	1.1	0.5-1.5	1.35	1.0-1.55	0.85	0.5-2.0
Weekly	1.35	0.5-2.2	1.6	1.1-2.4	2.0	1.3-2.75	2.4	1.5-3.6
None	2.75	1.8-4.4	3.0	2.5-4.5	2.6	2.2-4.6	4.9	3.3-5.4
Citrus fruit consumption								
1-5xw	1.1	0.5-1.6	1.1	0.5-1.5	1.1	1.0-1.6	1.2	0.5-2.0
Weekly	1.7	1.1-2.3	2.4	1.2-2.9	2.2	1.4-2.6	2.5	2.0-4.4
None	3.9	2.2-5.2	3.3	2.6-4.8	3.45	2.5-5.1	4.85	3.3-5.4
Peanut								
0	1.2	0.5-1.6	1.1	1.0-1.9	1.4	1.0-1.9	2.0	0.5-3.3
1	3.6	2.1-5.0	2.95	2.4-4.45	2.9	2.1-4.6	4.4	2.4-5.4
Milk consumption								
1-5xw	1.1	0.5-1.3	1.25	0.75-1.6	0.75	0.5-1.65	1.2	0.5-1.4
Weekly	1.35	0.5-1.6	1.1	1.0-1.9	1.3	1.0-1.7	2.0	1.2-3.2
None	3.05	1.95-4.45	2.95	2.4-4.5	2.9	2.2-4.6	4.4	2.6-5.4
Job or hobby involves paint								
No	1.2	0.5-2.1	1.35	1.0-2.2	1.45	1.0-2.2	2.0	1.1-4
Yes	1.85	1.3-3.6	2.7	2.0-4.4	2.6	2.2-4.2	4.4	2.6-5.4

Table 6.3: Univariate logistic regression using generalized estimating equation to adjust for intra-class correlation within repeated measures. Outcome variable is binary blood lead levels .

Sociodemographic Characteristic	Proportion (n=252 Observations)		Adjusted Odds Ration	95% Confidence Interval		*P* Value
	<2µg/dL (%)	≥2µg/dL %				
Age(years)						
18-25	(43)	(57)	1			
26-33	(50)	(50)	1	0.34	2.93	1.00
34-42	(50)	(50)	1.3	0.49	3.65	0.57
Marital Status						
Married	(64)	(36)	1			
Single	(55)	(57)	2.2	0.67	7.70	0.19
Parity						
Multipara	(51)	(49)	1			
Primipara	(37)	(63)	1.7	0.80	3.9	0.15
Education						
Tertiary	(42)	(58)	1			
Secondary	(42)	(58)	1.16	0.46	2.91	0.75
Primary	(65)	(34)	0.54	0.17	1.67	0.28
Income						
Upper Middle	46	53	1			
Middle	55	45	1.22	0.34	4.40	0.76
Lower	0	100	7.01			
Painting hobby or job						
No	64	36	1			
Yes	20	80	6.94	3.22	14.99	**<0.001**
Backyard repair workshop						
No	71	28	1			
Yes	15	85	15.72	6.96	35.50	**<0.001**
Live smoke						
No	80	20	1			
Yes	15	85	21.48	10.74	42.96	**<0.001**
Alcohol						
None	59	41	1			
Light	60	40	0.99	0.41	2.42	0.99
Moderate	20	80	5.70	1.80	18.03	**<0.0001**
Heavy	20	80	5.87	1.76	19.55	**<0.001**
Pica Behavior						
No	72	28	1			
Yes	27	53	4.40	2.52	7.70	**<0.001**
Skin applications						
No	58	42	1			
Yes	26	74	3.15	1.50	6.65	**<0.001**
Cooking						
Electricity	67	33	1			
Gas	68	32	0.93	0.24	3.60	0.92
Gas+electricity	39	61	3.1	0.88	10.90	0.08

Wood	34	66	3.90	1.24	12.22	**<0.05**
Gas-wood	75	25	0.67	0.02	20.02	0.82
Traditional Medicine Use						
No	60	40	1			
Yes	15	85	8.27	3.46	19.77	**<0.001**
Multiple Risk Behavior						
0-1 risk behaviors	89	11	1			
≥2 risks risk behaviors	22	78	29.59	12.76	68.60	**<0.001**
H20 sour						
No	65	35	1			
Yes	40	60	2.79	1.19	6.54	<0.05
House paint						
Water	53	48	1			
Oil and water	44	56	1.38	0.46	4.15	0.56
Oil	60	40	0.73	0.14	3.76	0.71
Pigment	43	57	1.46	0.48	4.44	0.50
Supplement						
Calcium +iron	91	9	1			
Other	50	50	10.30	3.64	29.13	**<0.001**
None	8	92	130.68	48.37	353.07	**<0.001**
Eat green Veggies						
1-5xweek	89	11	1			
Weekly	48	52	9.80	3.39	28.29	**<0.001**
None	14	86	67.08	20.80	216.36	**<0.001**
Eat citrus fruits						
1-5xweek	88	12	1			
Weekly	39	61	13.05	5.18	32.86	**<0.001**
None	6.7	94	152.89	39.43	592.87	**<0.001**
Peanut						
Yes	74	26	1			
None	12	88	25.93	10.92	61.60	**<0.001**
Drinking milk						
1-5xweek	91	9	1			
Weekly	73	27	3.94	0.91	17.16	0.1
None	14	86	64.95	0.03	298.1	**<0.00**

Table 6.4 shows characteristics of pregnant women that are associated with blood lead levels ≥2µg/dL. Having a job or hobby that involves paint (OR,6.7, CI,3.22-14.99); engaging in pica behaviour (OR, 4.4,CI,2.52-7.70), traditional medicine (OR, 8,(3.46-19.77); using unconventional skin products (OR, 3.1, CI,1.5-6.7); source of drinking water supply (OR, 3.0,CI,1.2-6.54) were independently associated with an increased risk of blood lead levels exceeding 2µg/dL. Additionally, living with a smoker and drinking moderately-heavy were risk factors for increased lead levels.

An intake of a combination of supplements which include calcium, multivitamins, folic acid and iron as well as frequent and regular consumption of citrus fruit had a protective effect on lead exposure risk (OR, 0.02, CI, 0.01-0.17).

Table 6.4. Multivariate semirobust regression model for blood lead levels during pregnancy and after delivery

Predictors	**Adjusted Odds Ratio**	**Standard Error**	**Lower 95% Limit**	**Upper 95% limit**	**P Value**
Water source	4.4	2.3	1.6	12.0	0.004
Pica behaviour	6.8	5.5	1.4	33.51	0.019
Multiple risk behaviours	20.0	15.1	4.5	88.32	<0.000 1
Trimester 2	12.1	12.2	1.7	87.12	0.013
Trimester 3	8.6	8.0	1.4	52.41	0.020
Post delivery	129.7	131.5	17.8	946.25	<0.0001
Citrus fruits ingestion	0.07	0.6	0.01	0.41	0.003
Calcium and multivitamin supplements	0.023	0.02	0.01	0.17	<0.0001

Table 6.5: Correlation among repeated lead (Pb) measurements

	Pb1	Pb2	Pb3	P4
Pb1	1.0000			
Pb2	0.7008	1.0000		
Pb3	0.5447	0.7914	1.0000	
Pb4	0.4385	0.6875	0.8890	1.0006

The final multivariate model for blood lead level prediction is shown in Table 6.4 and the correlations among repeated measures are presented on Table 6.5. The strongest significant predictors of blood lead levels ≥2µg/dL were multiple risk factors (engaging in two or more risks) stage of pregnancy and an intake of calcium in combination with other supplements such as folic acid and multivitamins ($p<0.001$). Ingesting non-food

items, pica and using an outdoor source of drinking water could be used to predict increased lead exposure levels during pregnancy ($p<0.01$ and $p<0.05$ respectively)

A dose response relationship was observed between lead exposure and ingestion of supplements and citrus fruits. Consuming more of vitamin supplements and citrus fruits had an effect on blood lead levels ≥2µg/dL.

6.6 DISCUSSION

This project has demonstrated that the behaviour, lifestyle, practices and environmental factors can be used to predict blood lead levels ≥2µg/dL in pregnant women and after delivery. This is an important undertaking in light of the mounting evidence that the toxic effects of lead occur at very low levels of lead. More and more researchers continue to prove that there is no level of lead that is safe. There is compelling evidence that low blood lead levels cause negative effects such as IQ deficits, attention-related behaviours, and poor academic achievement. A major concern among researchers is that the absence of an identified blood lead level without deleterious effects, combined with the evidence that these effects appear to be irreversible, provide good justification for the importance and critical role of primary prevention. This research was conducted in recognition of the lack of capacity for a country such as Botswana and many more countries to have the capacity for universal testing of pregnant women for lead exposure. Additionally, even if screening could be afforded by any country, the signs and symptoms of lead would usually show when detrimental effects have already occurred. Primary prevention of lead therefore aims at preventing lead exposure rather than responding after the exposure has taken place.

In this chapter, the behaviours and practices of pregnant women that have a potential to predict blood lead levels have been identified. These include pica, multiple risk behaviours, diet and nutrition. Two other predictors of blood lead levels are environmental factors (water source) and trimester of pregnancy.

6.6.1 Pica as a predictor of blood lead levels

Pregnant women in the study area ingest non-food items such as soil, bone meal, matchsticks and many other items. Women who engaged in pica were 7 times more likely to have increased lead levels that are equal to or greater than 2µg/dL (OR,6.9,CI, 1.3-34.5). Pica during pregnancy has been associated with severe lead poisoning which is not only detrimental to the mother, but to the infant.[15-17] The most important aspect in these studies however is that advising women to stop the behaviour (removal of the source) was the most important undertaking as it immediately reduced the lead load. In addition, improvements in nutrition contributed to the reduction on the lead load in the woman.[17] Multiple risk behaviours such as engaging in two or more lead exposure behaviours is yet another important predictor of lead exposure level risk. These behaviours, as discussed in chapter three include a combination of risk behaviours such as the use of traditional medicines, alcohol consumption, tobacco use as well as pica and are preventable. Education and awareness of the pregnant is an important approach in preventing lead exposure during pregnancy. It must however be noted that pica behaviour, the use of tobacco or alcohol could be difficult to stop immediately. Counselling and advise would therefore be necessary. Health workers /clinicians may therefore need to be sensitised

6.6.2 Diet and Nutrition as a predictor of lead exposure

Diet and nutrition are important strategies for preventing lead exposure and poisoning. Dietary calcium is for example known to lower lead levels in pregnancy and lactation[18]. Women who regularly consumed citrus fruits (OR, CI,0.07,CI,0.04-0.01) and supplements in the combination of calcium, folic acid and iron (OR,0.02,CI, 0.02-0.01) had lower levels of lead compared to women who did not consume these products on a regular basis. A promising hope in Botswana is that currently the Government provides supplements in the form of calcium, iron and vitamin C to pregnant women as soon as they register for prenatal care. Dietary deficiencies of calcium, iron, and zinc enhance the

effects of lead on cognitive and behavioral development.[19] This good development requires strengthening to prevent lead exposure in pregnant women. It is however unfortunate as indicated in the previous chapter, that pregnant women do not consume these supplements because of several reasons which include among others the strong smell of the supplements, the taste of the supplements and the lack of awareness on the importance of consuming such supplements. These are discussed further in chapter 7. It is imperative that awareness campaigns are initiated to ensure that pregnant women utilize the supplements provided in order to prevent lead exposure.

6.6.3 Trimester or stage of pregnancy as a predictor of blood lead levels

Trimester of pregnancy is another important predictor of blood lead levels in this study. In this research there was a corresponding increase in blood lead levels by trimester. The increase may suggest implications maternal of bone lead due to the increased need for calcium in the last half of pregnancy. Prior research has shown a significant increase in maternal blood lead during periods corresponding to 20-36 weeks.[20,21]. An increase of PbB concentrations in the last half of pregnancy is reported to coincide with an increased foetal need for calcium as well as an increased maternal provision of calcium. The resultant effect is that if the needed supply of calcium is supplied from the expectant woman's bone, then women with high loads of bone lead may transfer more lead to the bloodstream with calcium.[20,21]

6.6.4 Water source as a predictor of lead level:

Women who got their drinking water from an outdoor tap were 4 times as likely to be at risk of blood lead levels >2µg/dL than women who got their water from an indoor water tap (OR, 4.3, CI, 1.6-12.03). In chapter 5 water lead levels were 19 times higher than the recommended World Health Organisation standard of 0.01ppm. About 60% of the water was from outdoor water taps. We apportioned the high lead level in water to plumbing equipment,[22-24] and water temperature which increases leachability of lead from lead

soldered materials, particularly during day.[25] Lead in water has been implicated in increased maternal blood lead levels[26,27]

6.7 LIMITATIONS

The sample size of 63 women presented challenges in presenting this model. Future research is necessary to compare these results. Many women were lost to follow up. However the results are useful in knowing trends in lead exposure during pregnancy and after delivery.

6.8 CONCLUSION

Research has shown that behaviours and practices of women such as pica, intake of alcohol and tobacco smoke as well socioeconomic status may contribute to increased blood lead.[28,29]. This study has identified behaviours, practices and environmental factors of pregnant women that can be used to predict blood lead levels during pregnancy and after delivery. The data can therefore can be used to develop lead screening strategies to prevent exposure to elevated blood lead levels.

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Chapter 7

Developing a Screening Tool For Assessing Lead Exposure Levels during pregnancy and after Delivery

7.1 INTRODUCTION

7.1.1 Building a case for lead exposure prevention programs during pregnancy and after delivery

A review of literature in chapters 1 and 2 of this thesis highlighted the true extent of the difficulty to measure lead poisoning, particularly in developing countries due to limited data. The problem of limited data on lead poisoning, particularly in the adult population is recognised in the developed world as well despite such countries having blood lead epidemiology and surveillance programs in place to monitor reported elevated blood lead levels.[1] Lead poisoning can present with nonspecific signs and symptoms such as abdominal pain, constipation, irritability, difficulty concentrating and anaemia. It is crucial that health professionals are aware of these symptoms and diagnosis in order to assess and document early health effects. Research has evidently established that chronic exposure to levels of lead too low to trigger symptoms, can increase the risk for hypertension[2] and accelerated future cognitive decline in adults.[3] Chapter 2 also highlighted potential challenges for clinicians to misdiagnose lead toxicity in their patients due to its vague symptoms particularly in developing countries where clinicians may have never attended to a lead poisoning individual because lead screening may have never been done.[4] Chronic low dose exposure may manifest with non-specific gastrointestinal disturbances, subtle neurologic and subclinical cognitive deficits.[5, 6] Delays in the diagnosis of lead poisoning as a result of the lack of awareness of the symptoms of lead poisoning and subsequent misdiagnosis has resulted with adverse consequencies.[7] The greatest hope in lead poisoning incidents is that the removal of the lead source has proved to be sufficient to relieve the symptoms and reduce the lead load, particularly in low lead cases.[8-11] The results of this work have shown a dose response relationship in terms of diet and lead exposure. Women who consumed more iron and

calcium supplements had lower blood lead levels compared to women who consumed none. A key recommendation that consistently emerged from all the chapters of this thesis emphasized the need for health professionals to be aware of lead and its detrimental effects on maternal and child health in order for them to be proactive in early detection and prevention of lead exposure and subsequent lead poisoning.

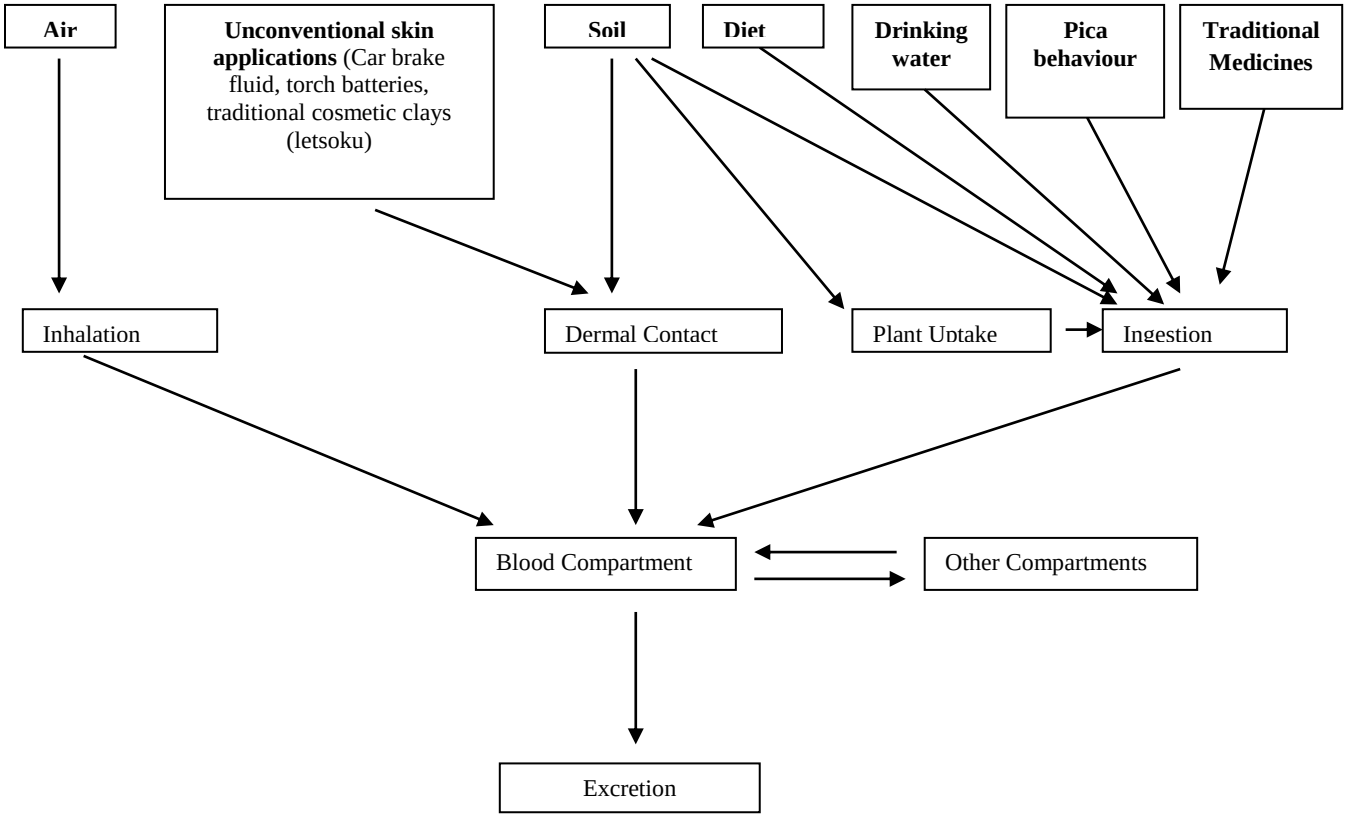


Figure 7.1 Conceptual model of lead exposure during pregnancy and after delivery

The overall aim of this thesis was therefore to develop a cost effective clinical assessment-screening tool for lead exposure levels during pregnancy and after delivery. The previous chapter (Chapter 6) has identified the best fit model for lead exposure in pregnant women aged 18 to 42 in the Central District of Botswana. The model identified multiple risk factors, trimester of pregnancy, consumption of calcium and iron supplements and citrus fruits, pica behaviour and source of water supply as independent.

risk factors for lead exposure during pregnancy and after delivery. The multiple risk behaviours included pica behaviour, the uses of unconventional skin treatment solutions, the alcohol consumption, tobacco use and traditional medication use.

The objective of this chapter is therefore to present a conceptual model (figure 7.1) of lead exposure during pregnancy in Botswana and key interventions developed as a result of the model.

Previous models have focused on predicting child blood lead levels for residential exposure scenario and for adult blood lead levels for industrial exposure scenarios.[12] This model is a modification of the Conceptual Model of Lead exposure and bio kinetics in the California Model.[12] The model recognises pica behaviours and practices such as the application of brake fluid as an important exposure pathways for lead exposure.

Three key deliverables have been developed and validated to address exposure issues identified by the model and they include a) a clinical assessment tool for use by health workers to lead exposure levels during pregnancy and after delivery; b) a policy brief to be used as an awareness tool for lead exposure targeted at policy makers in Botswana and; c) an awareness leaflet for pregnant and lactating women on lead exposure. It is worth noting that to develop these documents involved a process of validation by key authorities in Botswana. The validation processes are described as well as a brief introduction to each document which is attached as appendices to this thesis.

7.2 THE CLINICAL ASSESSMENT TOOL GUIDELINE

7.2.1 Document development

This is a mini handbook developed to provide information on lead, its sources, health effects and primary prevention strategies to educate, assess risks and confounders for lead exposure, provide counselling and care during pregnancy and follow-up after delivery (See Appendix11). Currently alcohol consumption and tobacco use are the only lead related risks (confounders) assessed during pregnancy and included in the obstetric record. Two workshops were organized for health workers at the beginning of the project

and at the end of the project (See appendix 7&8). The first workshop was held in July 2009 prior to recruitment of study participants to raise the level of awareness on lead and its impact on human health and the environment, exposure sources for the general public and pregnant women. The workshop was also intended to introduce the study and its protocols among health workers and the expected inputs from each facility. The workshop targeted senior staff from Sekgoma Memorial Hospital in Serowe and Palapye Primary Hospital in Palapye. Participants included matrons, senior nursing sisters from maternal and child health departments, labour wards, laboratory, theatre and outpatient departments. The Second workshop was held in October 2012 to disseminate the results of the study and to pre-test and validate the clinical assessment tool, the policy brief and the leaflet for pregnant women. This workshop was attended by staff from all the participating health facilities from Lerala, Maunatlala, Sekgoma Memorial and Palapye Primary hospitals. Observations were put together in a workshop report and shared with the participants for feedback. The following sections summarize the observations made at the two workshops

7.2.2 Observations from the first workshop:

a) Health workers reported that they were not aware of lead and its impact on human health and pregnancy.
b) The health workers confirmed that the only risk factors for pregnancy reported in the obstetric record were alcohol and smoking. They also noted that even then these were not associated with lead exposure.
c) Health workers confirmed that most women ingest soil during pregnancy, however they have associated these with iron deficiency and were not aware that soil ingestion could be a source for lead exposure
d) Health workers confirmed knowledge of use of substances such as brake fluid and other used car oils, torch batteries by not just pregnant women but the general public for treatment of ringworm, psoriasis including open wounds.

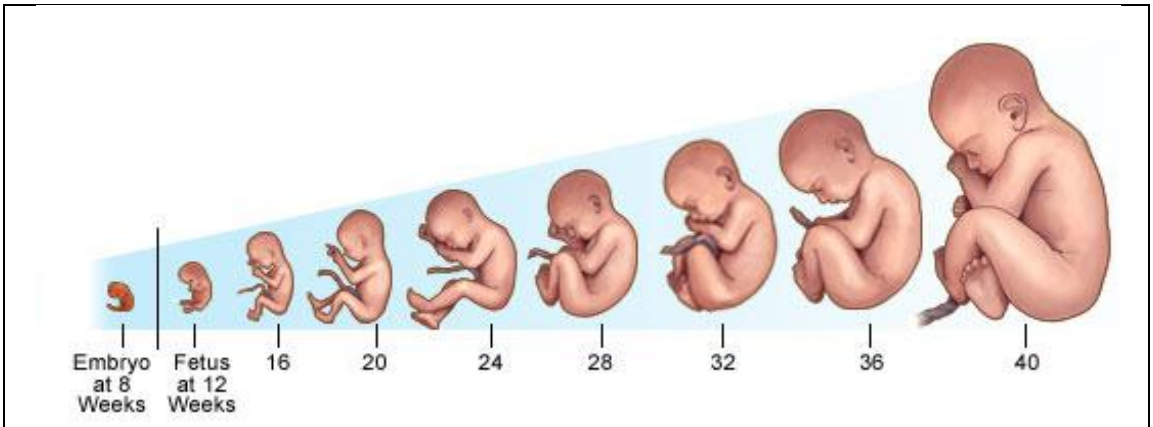
They further revealed that this was not an issue of socio economic status; the products are widely used by population groups across all the social strata.

e) Health workers endorsed their full support for the study and recommended the following:

a. That all health workers should be sensitized on lead and its impacts through regular workshops and training
b. That the development of guidelines for screening and assessing lead exposure levels will be necessary to guide health workers in the primary prevention of lead exposure during and after pregnancy.
c. That the results of the study should be disseminated to policy makers, health workers and the general public to prevent further exposure. They further recommended the development of a policy brief for Government to start thinking lead and its prevention in a broader way
d. There was acknowledgement that some cases of lead poisoning could have been misdiagnosed due to the lack of awareness by health care workers

7.2.3 Observations from the Second workshop:

a) Health workers were given a presentation on the results of the study, which covered the behaviours and practices of pregnant women, the results of environmental lead levels and the results of the blood lead levels and factors associated with blood lead levels. Key issues discussed included pregnant women engaging in multiple risk behaviours such as the ingestion of non-food items by pregnant women, the application of non-conventional skin application items that have not been reported anywhere in the literature such as brake fluid, torch batteries and light brown shoe polish. Some of the health workers acknowledged that they have in fact used some of the products such as shoe polish and brake fluid without the knowledge that they could be exposed to lead.



1.5µg/dl*
<1.00-12.901.5µg/dl**

1.8µg/dl*
<1.00-11.8µg/dl**

2.0µg/dl*
<1.00-12.90µg/dl**

2.3µg/dl* **
<1.00-10.30µg/dl**

Irreversible Neurodevelopmental effects
Transplacental transfer
Decreased growth, decreased hearing,
Decreased IQ

Reproductive effects observed in females associated with low-level lead exposure

Low birth weight
Spontaneous abortions
Still birth
Delays in sexual maturation
Preterm birth
Delayed puberty with BLL as low as 3µg/dL[1]

*Geometric mean of blood lead levels of pregnant women in Botswana at each trimester

** Range
*** Geometric mean (post delivery)

Figure 7.2: Blood lead levels of Pregnant women at each stage of pregnancy, Serowe/Palapye

b) Health workers were made aware of the fact that despite the pregnant women supplied with calcium, iron and vitamin C supplements during pregnancy they did not utilize the supplements. Some of the reasons for the non-consumption of the supplements were that the women did not like their smell or did not like the taste of the supplements. Others women reported the pills were making them sick.
c) Health workers were familiarized with the ATSDR diagram as in the clinical assessment tool (Appendix 8) showing blood lead levels associated with adverse health effects for children and adults.
d) A further visual tool (Figure 7.2) was developed and shared with the health workers, which could be turned into a poster that can be used by health workers as a reference point for blood lead levels at each stage of pregnancy.
e) A step by step visual summary model guideline (Figure 7.3) for lead exposure assessing was also discussed shared with health workers according health workers an opportunity to understand it and its feasibility. Health workers further proposed that this model guideline could be made into a poster to ensure a quick assessment at the workplace. This model is contained in the screening tool booklet with further explanations.
f) Health workers were familiarised with the screening tool and had an opportunity to have an input into it as well as the policy brief and the awareness leaflet for pregnant and lactating women.
g) Health care workers were given an opportunity to give feedback on the draft clinical assessment tool, the policy brief and the awareness booklet for pregnant women. The following feedback was given by the health workers:
    a. That the clinical assessment document was a good tool, however, they strongly recommended that the risk assessment questionnaires in the tool should be incorporated in the obstetric record as a matter of urgency so that every health workers and the pregnant women can continuously

monitor the behaviour and environmental factors likely to expose pregnant women to lead.

b. That lead should be included in the curriculum of nursing students and particularly midwives to ensure that every health worker in Botswana is aware of lead, its exposure sources, effects and prevention.

c. Health worker acknowledged their awareness on pregnant women not consuming the supplements given to them during pregnancy and were aware of the reasons raised by study participants that they do not like the smell and taste of the supplements. They suggested that the supplements should be coated to reduce smell and improve taste

d. Health workers confirmed other potential household uses of lead such as mending cast iron pots and metal dishes, likely to expose family members to lead.

e. Education of all health workers on potential lead exposure sources was recommended by the health workers.

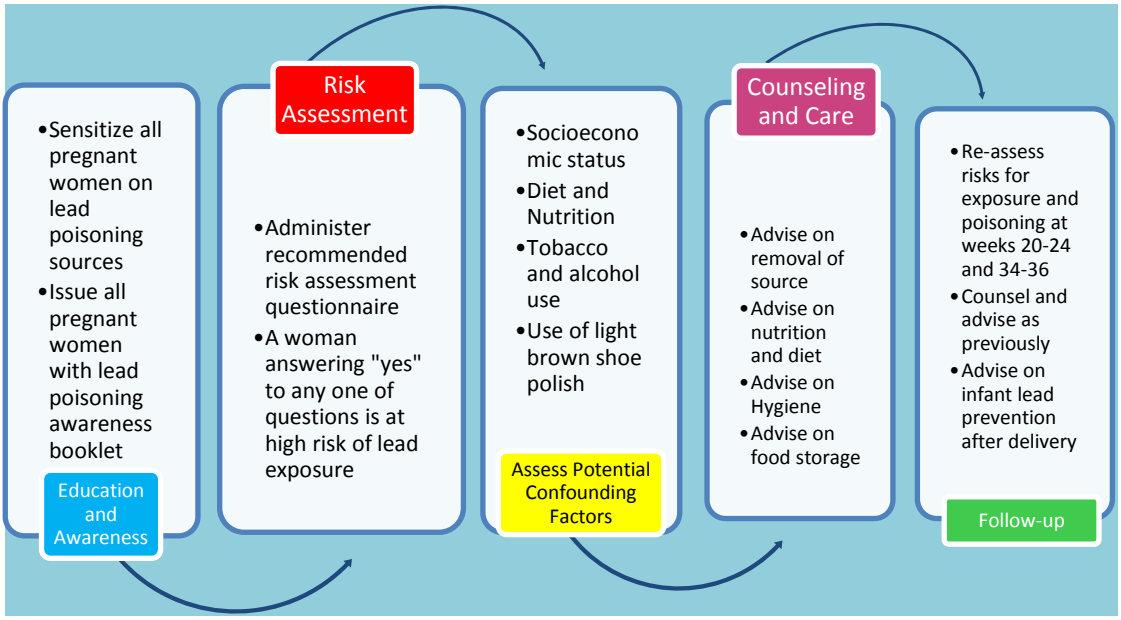


Figure 7.3: Summary model guideline for lead exposure assessment during pregnancy

7.3 POLICY BRIEF PRETESTING AND VALIDATION

The draft policy brief was presented to the Ministry of Health in October 2012 in a meeting to disseminate the results of the study (See Appendix 10). Key departments/divisions of the Ministry that attended the briefing were Maternal and Child Health, Food and Nutrition and Health Promotion and Education. Participants felt that other Government Ministries such Trade and Consumer Affairs and Environment should be engaged to ensure that they start controlling lead containing materials. The Ministry of Health officials strongly felt that the water authorities should test lead in water and start regulating the use of lead containing material in plumbing pipes and other gadgets. Key recommendations of the policy brief should include lead education in the curriculum of health workers, development of lead surveillance programs, regulation of lead containing plumbing materials and regular testing of drinking water for lead. Finally the Ministry of Health representatives felt that the Botswana Bureau of Standards should be engaged to institute standards that will regulate lead containing materials in Botswana. It was also recommended that even though this study was conducted in the Serowe Palapye District, the results should apply nationally since these practices are observed in all parts of the country. They however recommended a national study to be conducted.

7.4 FOCUS GROUP DISCUSSION – AWARENESS BOOKLET

A group of women who participated in the study were invited to take part in the pretesting of the awareness booklet. The women endorsed the exposure sources listed in the leaflet. They recommended regular education of the general population on lead exposure sources and prevention. They also recommend a campaign to discourage people to use brake fluid oil, torch batteries and other potentially lead containing substances for treatment of skin conditions.

7.5 STRENGTH OF THE RESEARCH AND THE DELIVERABLES

This research has identified the following:

a) Key lead related behaviours among pregnant women in Botswana

b) It has generated baseline data on lead levels in pregnant women, which can guide future national studies on lead

c) Key predictors of lead exposure levels have been identified

   a. Pica behaviour is well elaborated in Chapter 3 of this thesis

   b. Lead exposure levels increased by trimester, an important finding that implies the release of lead from bone due to poor diet on the part of pregnant women. This was particularly highlighted from the fact that women from poorer smaller villages had significantly higher lead levels compared to women from the major villages. An interesting finding of this research is that women from Palapye who were expected to have higher lead levels due to living in the vicinity of a mining area, had lower lead levels and this can be apportioned to better living conditions, and better eating habits;

   c. Multiple risk behaviours which include the use of brake fluid oils, the use of torch batteries, traditional medicines and cosmetic clays are another predictor variable for lead exposure in Botswana.

   d. Water source and in particular outdoor tap water tap from boreholes is yet another predictor variable for lead exposure. This is well elaborated in Chapter 4, which has revealed that water in the Serowe Palapye area (across all villages) is in excess of the World Health Organisation drinking water quality standards

7.6 MAJOR RECOMMENDATIONS:

These recommendations are informed by the findings of this research as well as the processes that have been discussed above:

1) Surveillance on Lead levels in water - Botswana policy issue:

   Botswana should initiate the regular testing of water to prevent adverse effects from lead exposure. The regulation of lead containing plumbing materials should be considered as a matter of urgency

2) It is recommended that the predictor variables of this work be included in the Botswana Government obstetric record
3) Education on lead awareness not only to pregnant women, but other vulnerable groups should be initiated as a matter of urgency
4) There is an urgency to implement a national lead surveillance programme in Botswana. It may be useful to make this a regional effort to curb costs as the same problems in Botswana could be experienced in the region

7.7 STUDY LIMITATIONS

This study was intended to cover a major city in Botswana at the initial stages. However due to funding limitations the study focussed in one area, but covered four location of different geographical settings. One which is semi urban (Palapye) the other a typical major village in Botswana and two rural villages. On this basis the author believes the results of this study can be applied to other parts of the country in the absence of a national study.

7.8 CONCLUSIONS

The interventions and the processes discussed in this chapter highlight the importance of this research and have generated interest in the area of lead. An important lesson learnt is that future research should engage the public to gain further insights into research. There is an evident wealth of information in the public that can be tapped through focus group discussions and workshops. For example, the revelation that even health workers engage in some of the habits and behaviours identified in this research would have not been disclosed had the researchers not engaged the health workers. It is also worth noting that health workers in the study area now appreciate the value of research as a tool to improve public health. The researcher also noted an outcry by health workers, and study participants that more often the public scientists carry out research but do not share the results with the public. They expressed their happiness on the extent of the involvement they had in this research from the initial stages to the project completion.

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Chapter 8:

GENERAL DISCUSSION AND CONCLUSIONS

8.1: OVERVIEW

The main impetus of this thesis was to develop a clinical screening tool to assess lead exposure during pregnancy and after delivery in Botswana. To arrive at the tool, the author investigated lead exposure among pregnant women from the behavioral, toxicological and environmental perspectives addressed by the different chapters as follows:

Chapter 1 focused on the general introduction to the investigation covering issues of lead sources as well as characterizing the uses of lead and possible exposures in Botswana. The toxicity of lead was discussed in general with highlights on vulnerable groups such as women and children. Special but strong mention is made to the limited research, policies and interventions to address lead in the developing countries. Finally the chapter spells out the rationale for the study and the knowledge it will add to Botswana. There is an acknowledgement in Chapter 1 that newer sources of lead poisoning are emerging. These sources are not well studied and could be detrimental to human health in the context of developing countries. A more holistic approach for assessing lead exposure sources that is not just limited to the traditional lead exposure sources such as paint and occupational sources but explores the cultural and economic setup of the different countries and groupings is suggested.

Chapter 2 presents an in-depth systematic literature review of published scientific reports on uncommon sources of lead poisoning in the general public. The chapter notes one study that has comprehensively reviewed uncommon sources of lead poisoning and therefore attempts to establish the extend of lead poisoning from the non-traditional sources. The main objective of this chapter is to identify population groups at the most risk, commonly reported lead poisoning sources and where these incidents occur. The findings of this chapter proved useful in two ways. First, they highlighted pregnant

women as a vulnerable group to exposure to atypical sources of lead poisoning in the context of the developing world. A good example is that geophagia or intentional ingestion of soil, is a known practice in most developing nations and yet it is not receiving attention in terms of toxic materials exposure. Secondly, the majority of the cases of lead poisoning from exposure to atypical sources occur in the developing world where there are no standards for regulating lead in household products and additionally these cases are only picked in pregnant women when they relocate to the developed countries where there is routine testing of lead exposure for children and pregnant women. Chapter 2 further highlighted the need to assess behavior and practices of different population groups that could potentially expose them to lead such as pica, some cultural practices, as well as socioeconomic factors contributing to lead exposure.

Chapter 3 identifies the prevalence of risk behaviours and practices of pregnant women in Botswana that could potentially expose them to lead during the first trimester of pregnancy. This chapter brings out new knowledge in terms of the behaviours of pregnant women such as the application of brake fluid, torch batteries and shoe polish dermally. The author has not come across any study that has studied the prevalence and predictors of risk behavior for pregnant women in relation to lead exposure. The findings of this chapter have an impact on future policy guidelines for Botswana.

To add to the complex story of potential exposure sources for lead during pregnancy in Botswana, Chapter 4 investigated lead concentrations in soil, water and cosmetic clays and these are compared with international maximum permissible levels. Concentrations of lead in water exceeded the WHO permissible levels and this was identified as a potential source of lead exposure and presents a key policy issue for lead exposure prevention.

Having assessed the behaviours and practices of pregnant women and environmental sources of lead in Botswana, Chapter 5 assesses the baseline concentrations of lead at

each stage of pregnancy. This is not just the first study to measure lead levels over duration of pregnancy in Botswana, but also one of the few studies to achieve this goal regionally. The results indicate a significant increase in blood lead levels at each stage of pregnancy and certainly of clinical importance. Further, this chapter characterizes the women with higher lead levels in terms of their socioeconomic and geographical location. Poorer women who live in small villages were more affected by lead.

Chapter 6 concludes the story by proposing a model for assessing lead exposure levels during pregnancy and after delivery. The model predicts blood lead levels ≥2µg/dL in order to develop a clinical assessment tool. Predictor behaviours are pica, multiple risk behaviours, diet, nutrition and socioeconomic factors. The stage of pregnancy was also identified as a risk for lead exposure. This finding is an indicator for lead release from bone and is a crucial finding around which interventions for lead exposure should be developed.

Chapter 7 represents a unique process that led to the development of the clinical screening tool for assessing lead exposure levels, a policy brief and an awareness booklet. It is a representation of the process followed to test the implementation of the protocol. This work therefore not only pieces together a complex story of lead exposure among pregnant women in Botswana, but also achieved the following:

a) Set the levels in the mother-baby pair
b) Established the main predictors of lead exposure in Botswana including behavior and practices that are not reported in the current literature such as the use of brake fluid, shoe polish and letsoku and torch batteries.
c) Implementation of the proposal resulting with three key documents which include; the clinical assessment tool for guiding clinicians and public health professionals, a policy brief for decision makers in Botswana and an awareness booklet which will not only benefit pregnant women but the general population as well.

8.2 STRENGTHS AND LIMITATIONS

A notable strength of this work is that it is the first in Botswana to assess lead exposure levels at each stage of pregnancy and after delivery. It is the first to investigate the behaviours and practices of pregnant women that could potentially expose them to lead in Botswana. It is the first to test drinking water as a potential source of lead exposure in Botswana and most importantly, it is the first to deliver a pragmatic lead exposure screening and assessment tool for health professionals and a policy brief to facilitate information dissemination on the problems posed by lead to public health for policy makers. The study developed an empirically based conceptual framework for predicting lead exposure in an inclusive manner taking into account multiple levels of sources and exposure.

A further strength of this study was that it has combined the qualitative and quantitative methods to provide an overall picture of the behaviours, practices of pregnant women and lead concentrations in blood and environmental medium. The quantitative data offered a valuable picture of what and how much of lead from the different sources, while the qualitative data explained where the lead levels would be more prevalent and why it would affect a certain group of pregnant women more than the other/s. Clearly the two methods were complimentary to each other

The weakness of this study design is that it focused on major and rural villages and therefore misses the component of areas that are fully urbanized in Botswana. The study could also not provide information on the knowledge and attitudes of women on lead and its exposure sources. It therefore makes assumptions that women were not knowledgeable on lead and its sources.

As a result of the loss to follow up, the number of women who completed the study (first trimester until after delivery) was small. The limited resources also contributed to a small sample size of environmental samples.

Despite the limitations, the study design offered sufficient information to enable the findings to be applied to many districts in Botswana if not nationally. It is acknowledged that these findings may not entirely be applied to the cities in Botswana because of the socio economic reasoning. The services and the infrastructure in the cities are entirely different. For example the cities are not services with borehole water while major and rural areas are serviced with such.

8.3 GENERAL RECOMMENDATIONS

The implications of the findings of this work are discussed in detail in the different chapters and therefore to avoid repetitions, the reader is referred to the summaries and conclusions made at each chapter.

8.3.1 Public Awareness on Lead Hazards

There is a need to initiate public awareness programs that will not only target pregnant women, but the general public. The rational for this is that some of the practices and behaviours of pregnant women may affect other family members. As reflected in the literature some of the lead poisoning sources, particularly at household level may have an impact on the rest of the family (refer to chapter 2). Typical examples are folk remedies and utensils used at the household level that may contain lead. Furthermore, this study has shown that despite an extensive and growing global body of knowledge of the health and social hazards of lead, there is limited awareness in the general public in Botswana. This is evidenced by the practices and habits of pregnant women reported in Chapter 3 of this work. Particular attention should be paid to poorer communities. The booklet developed from this work should be translated into Setswana to accommodate members of the public who could not read English.

8.3.2 Health Worker Training:

Health workers are agents of change and therefore should be equipped with knowledge to facilitate change. Evidently, the feedback from health workers during the study

workshops (refer to Chapter 7) showed little awareness on lead and its impacts on public health or the sources and mechanisms of exposure to lead. This was reflected by their responses and the interest they showed in the study. Every health worker in Botswana should be familiarized with the contents of the clinical assessment tool for lead exposure regardless of whether they are based in rural or major villages or the cities and towns in Botswana. The rationale for this is that naturally Batswana have three homes, the lands/fields, the home village and the workplace, which could be a village or a city. Additionally, health workers who work in Government facilities may be transferred to the rural/small or major villages or towns or cities. Consistency of information is therefore important.

8.3.3 Policy Options for Botswana

To address the gaps in this study, it is recommended that the Government of Botswana initiate a national lead surveillance programme to identify the key sources of lead, the mechanism of exposure and related risk factors for lead exposure. It is further recommended that the obstetric record booklet be reviewed to incorporate potential risk factors for lead exposure. Finally Botswana Government is encouraged to follow the international world and start regulating lead containing materials for plumbing as well as imported lead containing household products. These are well elaborated in the policy brief (Appendix 8). The good news is Botswana is already doing some of the required primary prevention strategies for lead exposure such as supplying pregnant and vulnerable groups with food supplements (without knowing that it is a lead prevention measure), the setback is that there is no follow-up to establish is pregnant women use the supplements (refer to Chapter 5 and 6). There is therefore a need for Botswana to carry out research that will establish why pregnant women do not take supplements as prescribed. Informal discussions with respondents revealed that they do not take them because of unacceptable odour. This is a policy issue needing investigation. For example it would save government money perhaps to consider discussing with manufacturers that

the supplements be coated to reduce the strong odour. This will go a long way in protecting public health and in particular maternal and child health

8.3.4 Development of a Criterion for Lead testing during Pregnancy

Finally, there is currently no lead testing or standards for any population grouping in Botswana. This study reveals the pregnant woman as a source of lead exposure for babies who are not yet born. It is perhaps time for Botswana to consider developing a criterion for lead testing during pregnancy. Throughout this thesis it has become evident that prenatal lead exposure to lead is a course for concern. The stage of pregnancy as a predictor for lead exposure is a matter that should be taken seriously. Even though the lead levels are low in this study, literature (as cited in all the chapters of this thesis) show that waiting for levels that are higher may course irreversible damage to the developing brain of the child. No country with an intention to protect and to preserve public health can wait to see the symptoms to check lead exposure any longer. Chapter 2 of this thesis has shown that chelation therapy is not the solution, but education and awareness, the removal of the sources of lead poisoning, good diet and nutrition are better solutions to lead management.

8.4 DIRECTIONS FOR THE FUTURE

8.4.1 The results of this thesis have been shared in a national workshop (Appendix 9) as well as to the Ministry of Health program officers, and local health workers in the study areas (Appendix 8). It is the intention of the author of this thesis to follow up on the recommendations of this work and use this work to foster more collaborative work with scientists in the region to elevate lead exposure as a problem likely to affect the current and future generation in the developing world as reflected in chapter 2 of this thesis.

8.4.2 There is need for more research on lead poisoning and lead exposure sources in Botswana. This is given the fact that lead containing materials are not regulated in Botswana and given the fact that household members purchase lead solder for different

purposes including mending cooking and eating utensils. These and many other concerns require further investigation.

8.4.3 The utility of the clinical assessment tool developed in this research should be tested and evaluated. This can only be done if awareness on the tool is created and thus the tool is utilized in health facilities. The need to publicise the tool is therefore identified.

Appendix 1: Ministry of Health Ethics Committee Approval letter

Telephone: (267) 3632000
FAX (267) 353100
TELEGRAMS: RABONGAKA
TELEX: 2818 CARE BD

MINISTRY OF HEALTH
PRIVATE BAG 0038
GABORONE

REPUBLIC OF BOTSWANA

REFERENCE No: PPME: 13/18/1 Vol V11 (649) 11 October, 2012

Principal Investigator: Bontle Mbongwe

Department/ Organization: University of Botswana

Protocol Title: **DEVELOPING A CLINICAL ASSESMENT TOOL FOR SCREENING LEAD EXPOSURE LEVELS DURING PREGNANCY AND AFTER DELIVERY**

Review Type: Health Research and Development Committee

Review Date: 05 October, 2012
Approval Date: 11 October, 2012
Expiration Date: 10 October, 2013

This certifies that the continuing review request for the protocol above was reviewed and approved for a period of 1 year.

____ The research poses minimal risk to participants

___ The study has not been activated

___ _ Enrollment is still ongoing

__ X __ Study is still open for data analysis and report writing

____ includes only collection of data from voice, video, digital, or image recordings made for research purposes

____research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior)

____Research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies.

Continuing Review
In order to continue work on this study (including data analysis) beyond the expiration date, the Health Research and Development Committee (HRDC) must reapprove the protocol after conducting a substantive, meaningful, continuing review. This means that you must submit a Continuing Report form as a request for continuing review. To best avoid a lapse, you should

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Appendix 2: University of Pretoria Ethics Committee Approval Letter

The Research Ethics Committee, Faculty Health Sciences, University of Pretoria complies with ICH-GCP guidelines and has US Federal wide Assurance.

* FWA 00002567, Approved dd 22 May 2002 and Expires 13 Jan 2012.
* IRB 0000 2235 IORG0001762 Approved dd Jan 2006 and Expires 13 Aug 2011.

100 1908 - 2008

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Health Sciences Research Ethics Committee
Fakulteit Gesondheidswetenskappe Navorsingsetiekkomitee

DATE: 26/06/2009

PROTOCOL NO.	**110/2009**
PROTOCOL TITLE	Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery.
INVESTIGATOR	**Principal Investigator:** Ms B Mbongwe
SUBINVESTIGATOR	Not Applicable
SUPERVISOR	Prof K Voyi kvoyi@med.up.ac.za
DEPARTMENT	**Dept:** School of Health Systems and Public Health **E-Mail:** bm190460@gmail.com
STUDY DEGREE	PhD (Environmental Health)
SPONSOR	None
MEETING DATE	24/06/2009

This **Protocol** and **Informed Consent** have been considered by the Faculty of Health Sciences Research Ethics Committee, University of Pretoria on 24/06/2009 and found to be acceptable

* *Members attended & Feedback at the meeting .*

Prof A Nienaber	(female) BA (Hons) (Wits); LLB; LLM (UP); PhD; Dip l.Datametrics (UNISA)
Prof V.O.L. Karusseit	MBChB; MFGP (SA); MMed (Chir); FCS (SA)
Dr N K Likibi	MB.BCh; Med.Adviser (Gauteng Dept.of Health)
Dr T S Marcus	(female) BSc (LSE), PhD (University of Lodz, Poland)
*Snr Sr J. Phatoli	(female) BCur (Eet.A) BTec (Oncology Nursing Science)
*Dr L Schoeman	(female) B.Pharm, BA Hons (PSy), PhD
*Dr R Sommers	(female) MBChB; MMed (Int); MPharMed;
Mr Y Sikweyiya	MPH; SARETI Fellowship in Research Ethics; SARETI ERCTP; BSC (Health Promotion) Postgraduate Dip in Health Promotion
*Prof TJP Swart	BChD, MSc (Odont), MChD (Oral Path), PGCHE
*Dr A P van Der Walt	BChD, DGA (Pret) Director: Clinical Services of the Steve Biko Academic Hospital
*Prof C W van Staden	MBChB; MMed (Psych); MD; FCPsych; FTCL; UPLM; Dept of Psychiatry

DR R SOMMERS; MBChB; MMed (Int); MPharMed.
Deputy Chairperson of the Faculty of Health Sciences Research Ethics Committee, University of Pretoria

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Appendix 3: Client Consent Form

UNIVERSITY OF PRETORIA
&
UNIVERSITY OF BOTSWANA

UNIVERSITY OF BOTSWANA

PhD Research Topic:
Clinical Assessment Tool for Screening Lead Exposure Levels during Pregnancy and After Delivery

Client Consent Form Information Sheet

For collection of blood, Environmental Samples and access to information after delivery.

PRINCIPAL INVESTIGATOR CONTACT DETAILS:

Bontle Mbongwe, University of Pretoria, **Contact telephone Numbers**: 3905809 (Home); 355 5238 (work)

Mobile Number: 718 01975 or 72301975

E-mail address: mbongwe@mopipi.ub.bw OR bm190460@gmail.com

THE PURPOSE OF THIS CONSENT FORM:
This consent form is meant to provide you with information and to invite you to participate in a research project intended to develop clinical assessment tool for screening lead exposure levels during pregnancy until two months after delivery

INTRODUCTION TO THE STUDY:
We invite you to participate in a study intended to assess lead exposure levels among pregnant women until they deliver. If you are within the ages of 15 and 49 you qualify for the study.

Lead is absorbed into the body following inhalation, ingestion and skin absorption. Once a person is exposed, lead is distributed throughout the body. Several studies have shown that lead levels increase in pregnancy rising overall by 20-30%. This therefore suggests your fetuses could potentially be exposed to significant amounts of lead during pregnancy. Short-term effects of lead include headache, fatigue, nausea, abdominal cramps and joint pains. Long-term effects include forgetfulness, irritability, tiredness, impotence and depression morbidity and mortality from exposure in *utero*. Other potential consequences for pregnant women include high blood pressure, still-births, pre-term births, etc. The potential effects of low-level lead exposure on reproduction in humans are a cause for concern.

In developed countries screening mechanisms have been put in place to safeguard the health of women, children and their babies. Such mechanisms include blood-lead test analysis. The tests are however, extremely

expensive and developing countries such as Botswana faced with competing health priorities can not afford to send every pregnant woman for blood lead tests.
This study therefore seeks to collect information that can be used to develop screening tool that can be used by health workers to identify lead exposure levels in pregnant women. The tool will enable the health workers to detect whether the blood lead test is necessary or not.

The specific objectives of the study are:

a) To determine blood-lead levels in pregnant women aged 18-49 years in city of Gaborone and Serowe/Palapye villages.
b) To estimate lead levels and related health outcomes during pregnancy and two months after delivery.
c) To assess pregnancy related behaviours and practices that have an influence on the severity of lead poisoning among women of reproductive age.
d) To identify environmental lead sources soil, water and paint and blood using stable isotopes of lead.

NUMBER OF PARTICIPANTS:
Approximately 500 women will participate in the study and data collection is expected to last 15 months (June 2009-September 2010).

WHAT WILL HAPPEN DURING THE STUDY?
Interested participants will be recruited from Government and private clinics with or without maternity. Once you have signed this form, you will be issued with a risk assessment questionnaire, which will ask you questions about yourself, personal behaviours, cultural practices, tobacco use, diet, type of energy used at home, etc. A trained and experienced phlebotomist will then collect blood samples from you three times during the your entire pregnancy. A final blood sample will be collected after you deliver your baby. During the study, a registered nurse will be engaged to make clinical observations throughout your pregnancy. This may include following you at your home.

You will be issued a unique identifying number at the time you sign the consent form. You will be requested to donate approximately a tablespoon of blood (15 ml) in two containers of 7mls each. The blood sample will be taken to the laboratories in South Africa for testing. We will only collect blood samples from through your permission. If you are not feeling well at the time of blood collection please inform the phlebotomist in order to decide whether to take a sample or not. The blood collection will be repeated during your 2nd and 3rd trimester and once after delivery.

For us to know where you could be getting you blood lead levels from, we will also collect soil, water and paint samples at your home or in the surrounding grounds only once during your pregnancy. A second sample may only be collected if you change locations during pregnancy. These samples will also be sent to the laboratories in South Africa for testing. If you eat soil or non-food items during pregnancy, we will also take such a sample for analysis.

<u>An appointment will be made with you for a home visit prior to the collection of the environmental samples (soils, water, etc.). No activity will be undertaken at your home without prior arrangements.</u>

WHAT ARE THE RISKS INVOLVED WITH BEING ENROLLED IN THIS STUDY:

Your safety in blood collection will be given the highest priority possible. This will be achieved through the employment of a qualified phlebotomists and a registered nurse who will be recruited and trained specifically for this purpose.

Drawing of blood is normally done as part of routine medical tests and presents a slight risk of discomfort. It may result with a bruise at the puncture site. You are assured of protection by the employment of experienced personnel to perform the procedure under sterile conditions.

WITHDRAWAL FROM THE STUDY:
You may refuse to take part in this study or, once in the study, you may decide to discontinue participation at any time.

The data collected from you before you discontinue participation will be used by the study sponsor. Data, which has already been collected, will be maintained with the research records.

DATA COLLECTION AND CONFIDENTIALITY:
Maintaining confidentiality is important to this study. Any personal information concerning you will be identified by a number (coded). Your name will not appear in any publications or reports produced from this study.

You have the right to know about the data being collected on you for the study and about the purpose of this data.

WHOM SHOULD YOU CALL WITH QUESTIONS ABOUT THIS STUDY?
You have the right to ask the Principal Investigator, Bontle Mbongwe any questions concerning this study at any time. Her contact details are at the very beginning of this document. You may also contact the Ministry of Health at this address:

Head of Health Research Unit
Ministry of Health
Private Bag 0038
Botswana
Tel: (+267) 3914467 Fax: (+267) 3914697

POTENTIAL BENEFITS OF PARTICIPATION
By taking part in this study, you will know your blood-lead levels and whether some interventions are necessary to reduce the levels either at home or workplace. Should your blood lead-level exceed the Centers for Disease Control action level of 10µg/dL, you will (should you so wish) be informed as well as receive information and advice on possible interventions for reducing exposure to lead. You are advised to indicate at the end of this consent form if you will be interested in knowing your blood-lead level. You may also be referred to a medical practitioner for further assistance should the levels exceed the recommended action level.

Other benefits include acquisition of knowledge on lead and how you can avoid possible or further exposure. The results of this project may also help researchers acquire more money to expand this study to other study groups such as infants and school children in Botswana as well as motivating the Government to make it mandatory for all pregnant and lactating women to have blood-lead level screening.

YOUR RESPONSIBILITY:
You are responsible for providing accurate information about yourself during pregnancy and after delivery. This will help us to determine whether blood samples should or should not be collected from you. By giving this consent, you are also giving us permission to consult you antenatal and postnatal cards. After delivery,

your baby will be examined by a qualified midwife for any abnormalities which could be associated with high lead levels.

CLIENT STATEMENT OF CONSENT:

I voluntarily consent to participate in this study. I understand the nature and the purpose of the study.

The information I have been given has mentioned both possible risks and benefits to consider before participating in this study.

I have been given time and an opportunity to read the information carefully, to discuss it with others and to decide whether to take part in this study.

I understand that I am free not to participate in the study or to withdraw at any time.

I confirm that I have informed the investigator and/or the project team to the best of my knowledge of my health status prior to the study.

I understand that I will keep a copy of the signed and dated consent form for my own records. By signing and dating this consent form, I have not waived any of the legal rights that I would have if I were not a participant in the study.

_____ _____

Head of Household Signature Date Printed Name

_____ _____

Your Name/ (Print Name/s) Signature

_____

Your date of birth

Would you like to know your blood-lead level ☐ Yes ☐ No

Contact Details:

Postal Address _____ Plot number _____

_____ Area/Kgotla _____

_____ Tel: _____

_____ Cell: _____

For Official Use Only:

Client ID Ref #.....

Appendix 4: Risk Assessment Questionnaires for Trimester 1, 2 & 3

UNIVERSITY OF PRETORIA

School of Health Systems and Public Health

For Official Use:	
Client Ref ID Code #	
Date of first interview	
Date of first blood Test	
Date of water collection	
Water sample ref ID	
Date of soil collection	
Soil sample ref ID	
Pica material collected	
Pica sample Ref ID	
Soil field rapid test conducted	
Field soil ref ID	
Field Water rapid test done	
Field water ref ID	
Dust field rapid test done	
Field dust ref ID	
Hematocrit test done	
Hematocrit test ID	

PhD Research Topic:

Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery

Risk Assessment Questionnaire (First Trimester)

About this questionnaire:

This questionnaire is part of the research targeting women aged 18 to 49 years, who are pregnant and have consented to take part in this study. Women who are eligible to respond to these questions must have signed a consent form and have a full understanding of the requirements of the research.

A trained research assistant will ask the client questions and complete the questionnaire on her behalf.

The client/respondent is therefore requested to spend 30 to 45 minutes to complete the questionnaire. After responding to the questionnaire, a blood sample will be collected as soon as possible.

Date Interview Completed: ..... DD MM YY

Interviewer Contact details:

First and last Names: .....

Mobile Phone: ..... + 2 6 7

Email address: .....

SECTION A: CLIENT INFORMATION

All questions must be attempted.

1. **Client ID REF. CODE #** (As in Consent Form)..... .....

2. **Study Area Code #**.....

3. **Health Facility Code:** .....

4. **Current place of residence:** village/town/..... .....

5. **Length of stay at the present address**:
   - ☐ Days (specify).....
   - ☐ Weeks (specify).....
   - ☐ Months (specify).....
   - ☐ Years (specify).....

6. **Where did you live before you came to stay here? (Please fill as appropriate, you may tick more than one response)?**

Area	Name	Length of stay
Urban area in Botswana		
Rural Area in Botswana		
Other		

7. **Date of birth**: .....

DD		MM		YY	

8. **Marital status** (please tick as appropriate):
   - ☐ Single
   - ☐ Married
   - ☐ Divorced
   - ☐ Other (Please specify).....

9. **Level of education:**
   - ☐ Primary
   - ☐ Secondary
   - ☐ Tertiary
   - ☐ non-formal
   - ☐ Other (please specify).....

10. **Religion:**
    - ☐ Christian
    - ☐ Islam
    - ☐ Hinduism

- ☐ Buddhism
- ☐ Other (Please specify).....

11. **Number of Pregnancies including this one:**
    - ☐ None
    - ☐ 1
    - ☐ 2
    - ☐ 3
    - ☐ More than 3

12. **Ages of Children:**

Child	Age
1st child	
Last child	
N/A	

13. **Length of breastfeeding:**

Child Number	Months/years	Comments
1st		
Last		
N/A		

14. **Do you plan to breastfeed this child?**
    - ☐ Yes
    - ☐ No

15. **Your last menstrual period:**.....

SECTION B: EMPLOYMENT AND YOUR OCCUPATION:

16. **Are you employed:**
    - ☐ Yes
    - ☐ No

17. **Monthly income (in Pula):**
    - ☐ Less than 1500
    - ☐ 1500-2500
    - ☐ 2501-3500
    - ☐ 3501-4500
    - ☐ 4501-5500
    - ☐ 5501-6500
    - ☐ 6501-7500
    - ☐ 7501-8500
    - ☐ 8501-9500
    - ☐ More than 9500

18. **Occupation (Please tick as appropriate)- US Bureau of Labour Statistics Criterion):**

Occupation category	Job title	Yes	No	Years/months worked
Management				
Professional & related				
Service				
Sales & related				
Office & administration support				
Farming, fishing and forestry				
Construction, trades& related				
Installations ad repairs				
Production				
Transportation & material moving				
Armed forces				
Other				

19. **Do you ever work with:**

Item	Yes	No	Years/months worked
Pigments			
Painted surfaces (house)			
Painted surfaces (bridge, other structure			
Spray painting			
Solder material (new)			
Solder (old plumbing repair)			
Welding material			
Cleaning chemicals			
Cosmetics			
Television and radio repairs			
Car batteries			
Automobile radiators			
Pottery/ceramic glazes			
Scrap metal			
Bullets (lead shots)			
Lead glass			
Other (specify)			

20. **Is your spouse/partner employed**
- ☐ Yes
- ☐ No

21. **Spouse/partner income:**
- ☐ Less than 1500
- ☐ 1500-2500

- ☐ 2501-3500
- ☐ 3501-4500
- ☐ 4501-5500
- ☐ 5501-6500
- ☐ 6501-7500
- ☐ 7501-8500
- ☐ 8501-9500
- ☐ More than 9500

22. **Does your spouse/partner or other members of your family that you live with ever work with:**

Item	Yes	No	Don't know
Pigments			
Painted surfaces (house)			
Painted surfaces (bridge, other structure			
Spray painting			
Solder material (new)			
Solder (old plumbing repair)			
Welding material			
Cleaning chemicals			
Cosmetics			
Television and radio repairs			
Car batteries			
Automobile radiators			
Pottery/ceramic glazes			
Scrap metal			
Bullets (lead shots)			
Lead glass			
Other (specify)			

SECTION C: PERSONAL HABITS:

23. **Do you wash your hands before eating/drinking?**
- ☐ Never
- ☐ Occasionally
- ☐ Usually
- ☐ Always

24. **Do you use any of the following tobacco products (Please tick as appropriate)?**

Tobacco product	Yes	No
Cigarettes		
Rolled tobacco		
Snuff		
Chewing tobacco		

25. **Do you wash your hands before using tobacco products?**
    - ☐ Never
    - ☐ Occasionally
    - ☐ Usually
    - ☐ Always

26. **Does anyone living with you smoke cigarettes?**
    - ☐ Yes
    - ☐ No

27. **Does anyone living with you smoke rolled tobacco?**
    - ☐ Yes
    - ☐ No

28. **Maternal Alcohol use during pregnancy:**

Alcohol use	Yes	No
Not drinking at all		
Binge drinking		
One drink per day		
Two drinks per day		
Three or more drinks per day		

29. **Did you drink alcohol before falling pregnant?**
    - ☐ Yes
    - ☐ No

30. **Have you used any recreational drugs:**
    - ☐ Yes
    - ☐ No

31. **At any time during your lifetime, did you eat any of the following non-food items (please tick as appropriate)?**

Item	Always	Usually	Occasionally	Never
Soil				
Clay (seloko)				
Crushed pottery (nkgwana e e sidilweng)				
Termite mounts (Seolo)				
Crushed bone meal				
Paint chips				
Painted furniture				
Matchsticks				
Pencil				
Other (Specify).....				

32. **If the answer is yes to any of the above, please indicate in the table below when you usually eat these items:**

Item	I started during this pregnancy	In all my previous pregnancies	Occasionally even when I am not pregnant
Soil			
Clay (seloko)			
Crushed pottery (nkgwana e e sidilweng)			
Termite mounts (Seolo)			
Crushed bone meal			
Paint chips			
Painted furniture			
Matchsticks			
Pencil			
Other (Specify).....			

33. **Does anyone in your family have a history of eating soil, clay or anthill mounts (Please tick as appropriate?**

Relative	Yes	No
Mother		
Aunt		
Father		
Uncle		
Sister		
Brother		
Other		

34. **Have you renovated your home /place of residence recently (please tick appropriate answer:**

Renovation	Yes	No
Less than a month ago		
1-3 months ago		
3-6 months ago		
Over 6 months ago		

35. **At any time during your lifetime did you use any of the following products to treat skin diseases/ringworm? (please tick as appropriate)**

Item	Yes (Specify ailment)	No
Dry cell Batteries powder		
Used Brake fluid oil		
Other (Please specify).....		

36. **Have you ever used skin lightening creams?**
- ☐ Yes
- ☐ No

37. **How often do you dye your hair?**
- ☐ Never
- ☐ Once a month
- ☐ Once every 3 months
- ☐ Other (please specify).....

SECTION D: DIET & HEALTH:

38. **Have you recently experienced any of the following (Please tick all those that apply):**
- ☐ Extreme tiredness
- ☐ Irritability or nervousness
- ☐ Metallic taste in your mouth
- ☐ Stomach aches or abdominal cramps
- ☐ Weak wrists or ankles
- ☐ Trouble sleeping
- ☐ Difficulty concentrations
- ☐ Muscle or joint pain
- ☐ Weight loss
- ☐ Headache
- ☐ Anaemia
- ☐ Constipation
- ☐ Nausea
- ☐ High blood pressure
- ☐ Low blood pressure
- ☐ Ringing of the ears
- ☐ Heart disease
- ☐ Type 1 diabetes mellitus (DM)
- ☐ Type 1 diabetes mellitus (DM)
- ☐ Other (please specify).....

39. **Are you on anti-depressants**
- ☐ Yes
- ☐ No

40. **Are you on hypertension medication?**
- ☐ Yes
- ☐ No

41. **Periodontal care:**

Condition	Yes	No	Don't know	Don't Remember
Do your gums ever bleed?				
Are your teeth loose?				
Have your gums receded, or do your teeth look longer?				
Have you seen a dentist in the last two years?				
How often do you floss?				
Have you had any adult teeth extracted due to gum disease?				

Have any of your family members had gum disease?				

42. Have you had spontaneous abortion/miscarriage?

☐ Yes
☐ No

43. If yes, to above question, how many?

☐ One
☐ Two
☐ More than two

44. At what months were the abortions/miscourages?

Trimester	Yes	No
1st		
2nd		
3rd		

45. Do you normally have a good appetite?

☐ Yes
☐ No

46. How often do you eat the following (please tick as appropriate)?

Food item	Response			
Green leafy vegetables,	Everyday	Often (at least twice a week)	Seldom (Once a month)	Other (please specify)
Citrus fruits(oranges, etc)				
Legumes				
Whole grains				
Peas				
Peanuts				
Breakfast cereals				
Red meat				
Fish				
Poultry				
Eggs				
Dried fruits				
Milk				
Ice cream				
Yogurt				
Canned fish(salmon)				
Canned foods in general				

47. Are you using any supplements during this trimester?

Supplement	Yes	No
Iron		
Calcium		

Folate (folic acid)		
Zinc		
Vitamin D		
Other (specify)		

48. **Did you use supplements prior to pregnancy?**
- ☐ Yes
- ☐ No

49. **If yes please indicate which supplements you have used prior to this pregnancy:**

Supplement	Yes	No
Iron		
Calcium		
Folate (Folic acid)		
Zinc		
Vitamin D		
Other (specify)		

50. **Do you use over the counter drugs currently?**
- ☐ Yes (specify).....
- ☐ No

51. **Do you use traditional herbs during this pregnancy?**
- ☐ Yes
- ☐ No

52. **If yes on the above question, mention the condition you are using them for?.....**

53. **Do you use any pottery dishes for cooking or storing food?**
- ☐ Yes
- ☐ No

54. **Do you ferment mabele or phaleche on a clay pot?**
- ☐ Yes
- ☐ No

55. **Do you ever fast at any stage of pregnancy?**
- ☐ Yes
- ☐ No

SECTION E: HOUSING:

56. **Your home is:**
- ☐ Owned
- ☐ Rented
- ☐ Other (please specify).....

57. **How do you describe the home:**

- ☐ House (cement and brick)
- ☐ House (mud and brick)
- ☐ Informal house (shack)
- ☐ Other (please specify).....

58. **How many people live in this house?** .....

59. **Is your home painted, pigmented (Please tick as appropriate)?**

Type of paint, pigment	Yes	No
Oil paint		
Water-based paint		
Both water and oil paint		
Pigmented (Lokgapho)		

60. **Is the paint peeling from inside walls, doors or window sills of your home?**
- ☐ Yes
- ☐ No

61. **How old is the home (approximately)?**

.....Years, ...Months

62. Is your near a busy road (approximately 500 M)
- ☐ Yes
- ☐ No

63. **Is your home near a rail road or a railway station?**
- ☐ Yes
- ☐ No

64. **What fuel is used most for cooking in your home?**
- ☐ Electricity
- ☐ Paraffin
- ☐ Gas
- ☐ Wood
- ☐ Coal
- ☐ Car batteries
- ☐ Other (please specify).....

65. **Have you ever used treated wood or gum poles for heating or cooking?**
- ☐ Yes
- ☐ No

66. **Do you use cold or hot tap water for cooking?**
- ☐ Yes
- ☐ No

67. **Where do you get your water most of the time?**

- ☐ Indoor tap
- ☐ Outdoor tap
- ☐ Rainwater tank
- ☐ Borehole
- ☐ River/stream
- ☐ Other (please specify).....

68. What type of plumbing (water pipes) does your home have?

- ☐ Plastic
- ☐ Metal

Other (please specify).....

69. Do you damp dust or use feather duster when cleaning?

- ☐ Damp dust
- ☐ Feather dust
- ☐ Both

70. Do you dampen the ground when sweeping outside to reduce dust?

- ☐ Yes
- ☐ No

71. Do family members take off their shoes when entering the house?

- ☐ All the times
- ☐ Sometimes
- ☐ Never

72. How many cars are owned by people living in your home? .....

73. Does anyone do regular car repair work at your home?

- ☐ Yes
- ☐ No

74. Do your neighbors do car repair work at home?

- ☐ Yes
- ☐ No

75. Does anyone regularly do spray painting at your home?

- ☐ Yes
- ☐ No

76. Does anyone in your hose do paint art?

- ☐ Yes
- ☐ No

77. Does anyone in the household do Tv/radio repairs

- ☐ Yes

☐ No

78. **Is your home near a waste dump site?**
☐ Yes
☐ No

SECTION F: SOCIAL ASPECTS

79. **How many people live in this house?**
☐ 1-3
☐ 4-6
☐ 7-9
☐ More than 9

80. **With whom do you live (you may circle more than one answer)?**
☐ My partner/husband
☐ Both parents
☐ Mother only
☐ Father only
☐ Other (please specify).....

81. **What is the highest education qualification of your husband/partner/father/mother?**
.....

82. **What type of job does your husband/partner/father /mother have?**
.....

83. **Please describe the hobbies of people living in the house**
☐ Home remodelling
☐ Car/boat repair
☐ Radio/TV repair
☐ Oil painting
☐ Making stained glass
☐ Repairing old painted wooden or metal toys
☐ Glazing/making pottery
☐ Jewellery making
☐ Re-loading/target shooting
☐ Using pastel art pencils
☐ Furniture re-finishing
☐ Welding
☐ Other (please specify).....

84. **Does your partner/husband/father/mother bring work clothes home for laundry?**
☐ Yes
☐ No

END of Questionnaire, thank you for your time

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School of Health Systems and Public Health

For Official Use:

Client Ref ID Code #	
Date of 2nd interview	
Date of 2nd blood Test	
Ref ID for blood test	
Any follow up samples	
Hematocrit sample taken	
Ref ID for Hematocrit test	

PhD Research Topic:

Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery

Risk Assessment Questionnaire (2nd Trimester)

This questionnaire is for follow up purposes when collecting blood samples during the second trimester.

The questionnaire is administered at the time of the second blood sample collection for lead analysis.

Date Interview Completed: ..... DD MM YY

Interviewer Contact:

First and last Names Name: .....

Mobile Phone: ..... + 2 6 7

Email address: .....

SECTION A: CLIENT INFORMATION:

1. **Client ID REF. CODE #** (As in Consent Form)..... .....

2. **Study Area Code #**.....

3. **Health Facility Code:** .....

4. **Current place of residence:** village/town/..... .....

5. **Is this the same place you lived at the last time you were interviewed?**
   - ☐ Yes
   - ☐ No

6. **Have your contact details changed since the first trimester:**
   - ☐ Yes
   - ☐ No

7. **If yes please provide the following:**

Physical address	Telephone contacts	Postal address

8. **Do you have a craving for any of the following non-food items at this stage (please tick as appropriate)?**

Item	Always	Usually	Occasionally	Never
Soil				
Clay (seloko)				
Crushed pottery (nkgwana e e sidilweng)				
Termite mounts (Seolo)				
Crushed bone meal				
Paint chips				
Painted furniture				
Matchsticks				
Pencil				
Other (Specify).....				

9. **Have you renovated your home /place of residence recently (please tick appropriate answer):**

Renovation	Yes	No
Less than a month ago		
1-3 months ago		
3-6 months ago		
Over 6 months ago		

SECTION B: DIET & HEALTH:

10. **How do you feel this trimester? (Please tick all those that apply):**
    - ☐ Extreme tiredness
    - ☐ Irritability or nervousness

- ☐ Metallic taste in your mouth
- ☐ Stomach aches or abdominal cramps
- ☐ Weak wrists or ankles
- ☐ Trouble sleeping
- ☐ Difficulty concentrations
- ☐ Muscle or joint pain
- ☐ Weight loss
- ☐ Headache
- ☐ Anaemia
- ☐ Constipation
- ☐ Nausea
- ☐ High blood pressure
- ☐ Low blood pressure
- ☐ Ringing of the ears
- ☐ Heart disease
- ☐ Type 1 diabetes mellitus (DM)
- ☐ Type 1 diabetes mellitus (DM)
- ☐ Other (please specify).....

11. Are you on anti-depressants?

- ☐ Yes
- ☐ No

12. Are on blood pressure medication?

- ☐ Yes
- ☐ No

13. How often do you eat the following this trimester (please tick as appropriate)?

Food item	Response			
Green leafy vegetables,	Everyday	Often (at least twice a week)	Seldom (Once a month)	Other (please specify)
Citrus fruits(oranges, etc)				
Legumes				
Whole grains				
Peas				
Peanuts				
Breakfast cereals				
Red meat				
Fish				
Poultry				
Eggs				
Dried fruits				
Milk				
Ice cream				
Yogurt				
Canned fish(salmon)				

14. **Are you using any supplements during this trimester (please tick all that apply)?**

Supplement	Yes	No
Iron		
Calcium		
Folate (folic acid)		
Zinc		
Vitamin D		

15. **Do you use any over the counter drugs during this trimester?**
    - ☐ Yes (specify).....
    - ☐ No

16. **What do you use them for?** .....

17. **Do you use traditional herbs during this trimester?**
    - ☐ Yes
    - ☐ No

18. **What do you use the herbs for?** .....

19. **Have you fasted during this or the previous trimester?**
    - ☐ Yes
    - ☐ No

20. **Are there any changes in your overall health this trimester?**

.....
.....
.....
.....
.....
.....

SECTION C: FOLLOW-UP DETAILS:

21. Your expected date of delivery:.....

22. Do you plan to move from the current location before the end of the next trimester?:
    - ☐ Yes
    - ☐ No

23. If yes please give details of where you can be found:.....
.....
.....

END of Questionnaire, thank you for your time

UNIVERSITY OF PRETORIA

School of Health Systems and Public Health

For Official Use:	
Client Ref ID Code #	
Date of 3rd interview	
Date of 3rd blood Test	
Hematocrit test	
Any follow up samples	

PhD Research Topic:

Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery

Risk Assessment Questionnaire (3rd Trimester)

This questionnaire is for follow up purposes when collecting blood samples during the third trimester.

The questionnaire will only be responded to strictly by clients who took part in the study during the first and second trimesters.

Date Interview Completed: ..... DD MM YY

Interviewer Contact:

First and last Names Name: .....

Mobile Phone: ..... + 2 6 7

Email address: .....

SECTION A: CLIENT INFORMATION

24. **Client ID REF. CODE #** (As in Consent Form)..... .....

25. **Study Area Code #**.....

26. **Where do you stay currently** .....

27. **Is this the same place you lived at the last time during the 1st and 2nd trimesters?**
    - ☐ Yes
    - ☐ No

28. **Have your contact Details changed since the first trimester:**
    - ☐ Yes
    - ☐ No

29. **If yes pleas provide the following in the table below:**

Physical address	Telephone contacts	Postal address

30. **Do you have a craving for any of the following (please tick as appropriate)?**

Item	Always	Usually	Occasionally	Never
Soil				
Clay (seloko)				
Crushed pottery (nkgwana e e sidilweng)				
Termite mounts (Seolo)				
Crushed bone meal				
Paint chips				
Painted furniture				
Matchsticks				
Pencil				
Other (Specify).....				

31. **Have you renovated your home /place of residence recently (please tick appropriate answer):**

Renovation	Yes	No
Less than a month ago		
1-3 months ago		
3-6 months ago		
Over 6 months ago		

SECTION B: HEALTH AND DIET:

32. **How do you feel this trimester? (Please tick all those that apply):**
    - ☐ Extreme tiredness
    - ☐ Irritability or nervousness
    - ☐ Metallic taste in your mouth
    - ☐ Stomach aches or abdominal cramps
    - ☐ Weak wrists or ankles

- ☐ Trouble sleeping
- ☐ Difficulty concentrations
- ☐ Muscle or joint pain
- ☐ Weight loss
- ☐ Headache
- ☐ Anaemia
- ☐ Constipation
- ☐ Nausea
- ☐ High blood pressure
- ☐ Low blood pressure
- ☐ Ringing of the ears
- ☐ Heart disease
- ☐ Type 1 diabetes mellitus (DM)
- ☐ Type 1 diabetes mellitus (DM)
- ☐ Other (please specify).....

33. Are you on anti-depressants?

- ☐ Yes
- ☐ No

34. Are on blood pressure medication?

- ☐ Yes
- ☐ No

35. Are you using any supplements during this trimester (Please tick all those that apply?

Supplement	Yes	No
Iron		
Calcium		
Folate (folic acid)		
Zinc		
Vitamin D		

36. Do you use home remedies for illness or to improve health?

- ☐ Yes (specify).....
- ☐ No

37. Do you use traditional herbs during this trimester?

- ☐ Yes
- ☐ No

38. Have you fasted this trimester?

- ☐ Yes
- ☐ No

39. Are there any changes in your overall health this trimester?

.....

.....

.....

.....

.....
.....

SECTION C: FOLLOW-UP DETAILS:

40. **In which facility do you intend to deliver your baby:**

Facility Name	Village/town	Expected date of delivery

41. Do you plan to move from the current location before the end of the next trimester?:
☐ Yes
☐ No

If yes please give details of where you can be found:.....
.....
.....

END of Questionnaire, thank you for your time

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Appendix 5: Proof of Statistical Support

SOUTH AFRICAN MEDICAL RESEARCH COUNCIL

BIOSTATISTICS UNIT

Private Bag X385, Pretoria, South Africa,
No. 1 Soutpansberg Road, Pretoria
Tel: 012 339 8519, Fax: 012 339 8582
URL://www.mrc.ac.za/

Date: 28/05/2009

LETTER OF STATISTICAL SUPPORT

This letter is to confirm that the student, Bontle Mbongwe studying at the University of Pretoria discussed the Project with the title "Developing a Clinical Assessment Tool for Screening Lead Exposure Levels during Pregnancy and After Delivery" with me.

I hereby confirm that I am aware of the project and also undertake to assist with the statistical analysis of the data generated from the project.

Sample size issues have been addressed and data analysis will involve modelling, e.g. logistic regression.

Prof. PJ Becker

Appendix 6: Proof of Validation of Questionnaire by Scholars

Daily News does not publish on Saturdays, Sundays and public holidays. Please email your comments to DailyNews@gov.bw

From 6 July 2006, a graphic version of current edition is available at the Daily News Online web site.

Return to main news index
Next: Magistrate extends Briton remand warrant

Lead threatens human life
17 April, 2009

GABORONE - Scholars in the fields of public and environmental health have stated that any amount of lead in a human being is dangerous as opposed to the past when it was deemed beneficial.

Lead, a known toxicant, affects nearly every system in the body and relates to both adults and children. "Unborn and young ones suffer metabolic and developmental damage from exposure levels of lead previously thought safe," said Ms Bontle Mbongwe, PhD scholar with the University of Pretoria.

She said babies both lactating and those still in their mothers' wombs face a rage of the lead if it is present in their mother's bodies. Children born under such circumstances stand a good chance of being perpetrators of social ills.

Such children, Ms Mbongwe said, can exhibit aggression, delinquency and abuse.

Others are born hyperactive combined with anti social behaviours. The presence of toxic lead in the human body has long-term effects.

The low amounts will result in decreased performance of the functions of the nervous system. The victims will exhibit weaknesses in fingers, wrists and ankles. Ms Mbongwe said lead is a naturally occurring element, which is found almost everywhere in the environment. It can be found in many of the household equipment such as pottery and it can enter the human bodies through ingestion and inhalation.

Her findings reveal that, "there is a linear association between blood lead concentration and high blood pressure in adults." However, it is worth noting that lead is not the only cause of high blood pressure in adults.

The persistent toxicant element is said to have bad and far-reaching consequences

on humankind.

In reproduction, lead is "associated with sterility, spontaneous abortion, stillbirths and neonatal morbidity and mortality from exposure to utero," reveals the research. Pregnant and lactating mothers face the chances of spontaneous abortion and hypertension. Other worse results may be reduced gestational age, reduced birth weight and adversely delayed cognitive development. Pregnant and lactating mothers usually acquire lead through their habits and other factors such as equipment and environmental issues.

Pica behaviour has been identified as the pathway for pregnant women to get lead. These include intentional ingestion of non-food items.

Most of these women ingest soil, pottery parts, paint chips and others.

Ms Mbongwe highlighted that children and pregnant women absorb 70 per cent of ingested lead whilst the non pregnant absorb only up to 20 per cent. Though they absorb 70 per cent of ingested lead, only small amounts of it are excreted through faeces, sweat, hair and nails.

Ms Mbongwe is currently working on the effects of lead in pregnant and lactating mothers in Botswana.BOPA

Return to main news index
Next: Magistrate extends Briton remand warrant

Appendix 7: Proof of Training Health Workers at Conception of Project

Developing a Clinical Assessment Tool for Screening Lead Exposure Levels During Pregnancy and After Delivery

Training Workshop for Participating Health Facilities

02 July, 2009, Cresta Botsalo Hotel, Palapye

1. In attendance:

Name	Facility	Section	Contact Telephones
G. Mogorosi	Palapye Primary Hospital	Laboratory	4920333/74012113
K. Dongwana	Palapye Primary Hospital	Mataernal & Child Health	4920333/71382827
B. Mmutle	Palapye Primary Hospital	Maternity Ward	4920333/72756002
T. Gower	Palapye Primary Hospital	General Ward	4920333/74616802
J. setshego	Palapye Primary Hospital	Maternal & Child Health	4920333/72296726
I. Bontsheng	Serowe Memorial Hospital	Labour Ward	4611000/72362793
K. Serefentse	Serowe Memorial Hospital	Maternal & Child Health	4611000/71489181
Clemence Simango	Serowe Memorial Hospital	Laboratory	4611000/71404289
K. Rajemane	Palapye Primary Hospital	Theatre	4920333/72166060
Z. Busumane-Khiwa	Palapye Primary Hospital	Out-Patient Ward	4920333/72235090
L. Morotsi	Palapye Primary Hospital	Out-Patient Ward	4920333/71431238
G. Ntau	Research Assistant	Midfife	4632081/72374289
Tshego Badubi	Research Assistant		72927633

2. Introductions and Workshop Objectives:

Participants introduced themselves. The Principal investigator gave the following as the objectives of the workshop:

a) To raise the level of awareness of the health workers in the participating health care facilities on lead and its impacts on human health.
b) To familiarizes participating facility health professionals with critical study protocols and recruitment processes required for the study
c) To agree on research logistics and identify contact persons for each facility
d) To agree on the work program

Appendix 8: Proof of Pretesting and Validation (Clinical Assessment Tool, Policy Brief, awareness leaflet)

UNIVERSITY OF BOTSWANA

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FACULTY OF HEALTH SCIENCES
Private Bag 0022
Gaborone, Botswana

Telephone: (+267) 355 000 (*Switchboard*)
(+267) 355 2917 (Direct)
E-mail: medical@mopipi.ub.bw
Fax: (+267) 397 4538
Telegraph: University Gaborone
Telex: (+267) 2429 BD

Date: October 2012

Validation of Screening tool & Policy brief

Briefing and pretesting Meeting – Ministry of Health

Name	Division	Contacts	Signature
A. MAKWA	Nutrition & Food Control Division NFCD	3632160	A. Makwa
R. Pitsinyane-Modise	NFCD	3632136	R. P. M.
J. Sibuja	NFCD	3632163	Sibuja
Yvonne T. Chinyanga	NFCD	3632186	Chinyanga
DR BORNAPATG NKOMO	Disease Control Division DCD – DPH	3632108	
Mphagamodimo Mongati	NFCD	3632134	
TSHIAMO R. KEAKABETSE	Sexual Reproductive Health SRH	3632170/63	
MPODI KEBAFILWE	NFCD	3632159	Mpodi
Rinett Phaedhlatlhe	NFCD/MOH	3632263	
Michael BASHEKE	NFCD	3632162	
HH. T. JARIMO	MOH-NFCD	3632124	

P. Madabe	NFCD	36327158	

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Telegraph: University Gaborone
Telex: (+267) 2429 BD

Date: 9 October 2012

Leaflet Pretesting Meeting – Women, Serowe

Name	Village	Contacts	Signature
Ania Basekeng	Serowe	71279570	A. Basekeng
Gelly Gaamangwe	Serowe	74552812	G. Gaamangwe
Bonolo Modikeng	Serowe	74080378	B. Modikeng
Godiramang S. Letlhaile	Serowe	75513081	
TSHIAMOKHUMONG	SEROWE	71126021	
SAKEBITSE NTAU	SEROWE	72374289	S Ntau

Comments

Appendix 9: Proof of Journal article submission and conference Presentation:

Submission of Manuscript (Review Paper) to Journal of OEM - Email Confirmation

oemeditorial@bmjgroup.com via manuscriptcentral.com 2/20/12

to me, mbongwe

20-Feb-2012

Dear Ms. Mbongwe:

Your manuscript entitled "Uncommon sources of lead poisoning: an emerging public health threat with life-long implications – A review of literature" has been successfully submitted online and is presently being given full consideration for publication in Occupational and Environmental Medicine.

Your manuscript ID is oemed-2012-100738.

Please mention the above manuscript ID in all future correspondence or when calling the office for questions. If there are any changes in your street address or e-mail address, please log in to ScholarOne Manuscripts at http://mc.manuscriptcentral.com/oem and edit your user information as appropriate.

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Thank you for submitting your manuscript to Occupational and Environmental Medicine.

Respectfully,

Editor Occupational and Environmental Medicine

Presentation of Paper (Chapter 3) at National Conference, Gaborone, Botswana

Republic of Botswana

MINISTRY OF INFRASTRUCTURE SCIENCE AND TECHNOLOGY

Inaugural RSTI Policy Launch, S&T Conference and Exhibition Programme

14-15 August 2012

GICC, Grand Palm Hotel, Gaborone

Day 1: RSTI POLICY LAUNCH AND OFFICIAL OPENING OF THE CONFERENCE		
MC: Mr Christopher Nyanga		
Chairperson: **Mr. Alan Boshwaen, Botswana Innovation Hub**		
Rapporteurs:		
7:30	Registration and tea	
	Arrival of the Minister of Infrastructure Science and Technology	
09:00	Prayer	Volunteer
9:05 - 9:15	Introduction of guests	Ms. Lorato Plaatjie, *MIST DPS Corporate Services*
9:15 - 9:30	Welcome Remarks	Mr Dikagiso B. Mokotedi, *MIST PS*
9:30 - 9:45	Highlights of the RSTI Policy and Implementation Plan	Ms. Lesego M. Motoma, *Director Department of Research Science and Technology*
9:45 - 10:30	Keynote Address: STI for Botswana's economic development: a personal perspective	Prof. Nelson Torto, *Head of the Department of Chemistry, Rhodes University, RSA*
10:30 - 10:40	Entertainment	Ms. Keabonye T. Bareng, Poet
10:40 - 11:10	Launch of the RSTI Policy and the official opening of the	Hon. Johnie K. Swartz, *Minister of*

	RSTI Conference and Exhibition	*Infrastructure Science and Technology*
11:10 - 11:20	Entertainment	Kgabosereto Traditional Troupe
11:20 - 11:35	Vote of Thanks	Mr Godfrey Mosimaneotsile, *Botswana Technology Centre*
11:35 - 11:45	Entertainment	Kgabosereto Traditional Troupe
11:45 - 12:00	Group Photo	MIST PR and Journalists
12:00 - 12:30	Tour of the exhibition stalls	Minister and his entourage
LUNCH		

SESSION 1: PLENARY		
MC:		
Chairperson: Dr. Edson T. Selaolo		
Rapporteurs:		
14:00 – 14:15	Objectives of the S&T conference and exhibition	Mr. Tebelelo Tsheko, *Deputy Director DRST*
14:15 - 14:35	**Presentation**: Views on the implementation of the RSTI policy	Kalmari, *A. Aika (Pty) Ltd*
14:35 - 14:45	Discussion	
14:45 – 15:05	**Presentation**: Harnessing Botswana's Natural Capital for Economic Development	Totolo, O. *University of Botswana*
15:05 – 15:15	Discussion	
TEA		
SESSION 2a: WATER RESOURCES		
Chairperson: Prof. Wellington Masamba, Okavango Research Institute		
Rapporteurs:		
15:30 – 15:50	**Presentation**: The fate of inorganic contaminants in treated sewage water used for irrigation	Paphane, B.D and Mogopodi, D *Botswana College of Agriculture*
15:50 – 16:00	Discussion	
16:00 – 16:10	**Presentation**: Towards Improved Water Management Strategies for Botswana	Parida, B. P. Kenabatho, P. K. and Moalafhi, D. B., *University of Botswana*
16:20 – 16:30	Discussion	
16:30 – 16:50	**Presentation**: Biotechnology is an innovative technology that can mitigate climate change	George, D.G.M., *Department of Agricultural Research*
16:50 – 17:00	Discussion	
17:00	Wrapping up and closure of Day 1	Chairperson

SESSION 2b: ICT:		
Chairperson: **Dr. Audrey Masizana, University of Botswana**		
Rapporteurs:		
15:30 – 15:50	**Presentation**: Implementing the M3 & E Model	Roodt, L. and Lubbe, S., *Chervil (Pty) Ltd*
15:50 – 16:00	Discussion	
16:00 – 16:10	**Presentation**: Alternative Livestock and Crops Diagnostic Technology System: a Case Project at Botswana College of Agriculture	Mabalane, D. and Hulela, K, *Botswana College of Agriculture*
16:20 – 16:30	Discussion	
16:30 – 16:50	**Presentation**: E-Government: My Stake as "Monana wa Motswana"	Morakanyane, R., *University of Botswana*
16:50 – 17:00	Discussion	
17:00 – 17:20	**Presentation**: E-Crime: Obligating A New Paradigm Towards A Cyber Secure Botswana Nation	Sekgwathe, V., *Directorate on Corruption and Economic Crime*
17:20 – 17:30	Discussion	
17:30 – 17:50	**Presentation**: Mobbo: Re-imagining and Monetizing Online Social Networking	Setuke, M, *Entrepreneur and software developer*
17:50 – 18:00	Discussion	
18:00	Wrapping up and closure of Day 1	Chairperson
SESSION 2c: SCIENCE, ENGINEERING AND TECHNOLOGY		
Chairperson: Prof. Otlogetswe Totolo, University of Botswana		
Rapporteurs:		
15:30 – 15:50	**Presentation**: A Quantum Description of Space-time and Gravitation	Marongwe, S., *McConnell College*
15:50 – 16:00	Discussion	
16:00 – 16:10	**Presentation:** Impacts of Palm Wine Tapping on the Populations of Hyphaene petersiana in Shorobe, Northern Botswana	Sethebe, B., *University of Botswana*
16:20 – 16:30	Discussion	
16:30 – 16:50	**Presentation**: E-Waste Recycling: A Review of the Infrastructure and Technology Alternatives available for Botswana	Sethebe, K. M. and Molelekwa, T., *Rural Industries Innovation Centre*, Barbus,V., *Silogistic (Pty) Ltd*
16:50 – 17:00	Discussion	
17:00 – 17:20	**Presentation**: Interaction of Large Magnetic Fields and the Quantum Vacuum	Marongwe, S., *McConnell College*
17:20 – 17:30	Discussion	
17:30	Wrapping up and closure of Day 1	Chairperson

Day 2: SESSION 3 PLENARY		
MC:		
Chairperson: Mr. Malekantwa Mmapatsi, Private technology policy practitioner		
Rapporteurs:		
8:00 – 8:05	Prayer	
8:05 – 8:10	Recap	
8:10 – 8:30	**Presentation**: The role of the private sector in RSTI development: A case study of Dobi Foods	Motlhabane, R., *Dobi Foods*
8:30 – 8:40	Discussion	
8:40 – 9:00	**Presentation:** Promoting Science Technology and Innovation based businesses through the Botswana Innovation Hub	Tacheba, B., *Botswana innovation Hub*
9:00 – 9:10	Discussion	
9:10 – 9:30	**Presentation:** Sustainable Economic Development through Public Sector Innovation: The Case of Developing Economies	Agolla, J. E., *Botswana College of Distance and Open Learning* and Kolawole, I. O. *Limkokwing University of Creative Technology, Botswana*
9:30 – 9:40	Discussion	
TEA		
SESSION 4a: SUSTAINABILITY		
Chairperson: **Dr. Haniso Motlhabane, Botswana International University of Science and Technology**		
Rapporteurs:		
10:00 – 10:20	**Presentation**: Fodder potential of leaves and pods of planted Leucaena diversifolia and L. leucocephala species in semi-arid Botswana	Walker, K. P., *National Food Technology Research Centre*
10:20 – 10:30	Discussion	
10:30 – 10:50	**Presentation:** Social use of riverine resources within the Chobe Enclave: Botswana	Phuthologo, B., and Mmopelwa, G. *Okavango Research Institute* and Mtaolo, F. W, *University of Dar es Salaam Tanzania*
10:50 – 11:00	Discussion	
11:00 – 11:20	**Presentation:** Inter-linkages between ecosystems services and management of natural resources: an Analytic Hierarchy Process Modeling for Stakeholders' Preference in Botswana	Lepetu, J., *Botswana College of Agriculture*
11:20 – 11:30	Discussion	
11:30 – 11:50	**Presentation**: Review of Botswana's Industrial Property Act of 1996	Maedza, B., *Soils Research and Testing Centre* and Motlhaping, T., *Botswana Technology Centre*
11:50 – 12:00	Discussion	

12:00 – 12:20	**Presentation:** Food technologies for entrepreneurship development; the NFTRC'S approach	Kebakile, M.,*National Food Technology Research Centre*
12:20 – 12:30	Discussion	
LUNCH		
SESSION 4b: HEALTH:		
Chairperson: **Dr. Marape Marape, Botswana Baylor Children's Clinical Centre of Excellence**		
Rapporteurs:		
10:00 – 10:20	**Presentation:** Characterization of *Lactobacillus fermentum* Kh09, a bacterioncin producing strain isolated from *madila*	Matsheka, M. and Wale, R. K., *University of Botswana*
10:20 – 10:30	Discussion	
10:30 – 10:50	**Presentation:** Natural product G-protein coupled receptor (GPCR) agonists: A new class of potential anti-parasitic and insecticidal drug candidates	Dube M., et al, *University of Botswana*
10:50 – 11:00	Discussion	
11:00 – 11:20	**Presentation:** Evaluation of aflatoxins in animal feed	Mogopodi, D., Paphane, B. and Motube, G., *Botswana College of Agriculture*
11:20 – 11:30	Discussion	
11:30 – 11:50	**Presentation**: Influence of the processing factors on pesticide residues in fruits and vegetables and its application in consumer risk assessment	Keikotlhaile B. M. et al, *National Food Technology Research Centre*
11:50 – 12:00	Discussion	
12:00 – 12:20	**Presentation**: Diet and cardiovascular disease risk factors in Botswana	Kwape, L., *National Food Technology Research Centre*
12:20 – 12:30	Discussion	
12:30 – 12:50	**Presentation**: Prevalence and Predictors of Risk Behaviours for Lead Exposure During Pregnancy in the Central District, Botswana.	Mbongwe, B., Voyi K. and Rollin, H., *University of Botswana and University of Pretoria*
12:50 – 13:00	Discussion	
LUNCH		

Appendix 10: Short Curriculum Vitae, Bontle Mbongwe

Education:

1. **Education**:

   I hold an MSc**.** Degree in Biology with a specialization in Chemical and Environmental Toxicology obtained from the University of Ottawa, Canada in 2000. (**Thesis title:** Fate and Persistence of DDT and its Metabolites in the Okavango Delta, Botswana).

2. **Professional Experience:**

I am currently a Lecturer of toxicology and environmental health in the Department of Environmental Health, Faculty of Health Sciences, University of Botswana. I have previously worked for the Ministry of Health in different capacities (1985-2004) from junior to senior health officer. Before I left the Ministry of Health to join the University of Botswana in 2004, I was Head of the Environmental Health Unit responsible for policy development in areas of chemical safety, public health and tobacco control. I moved to the University of Botswana to start the Environmental Health program in the Faculty of Science, which is now a department in the Faculty of Health Sciences. My key areas of research are on heavy metals and persistent organic pollutants as can be seen from the publications below. I have collaborated with the South African Medical Research Council on lead research. I started my doctoral degree in the School of Health Systems and Public Health, University of Pretoria in 2009.

3. **Selected Journal Articles of toxicological and environmental importance**

1. **Mbongwe B**, Barnes B, Tshabang J, Zhai M, Rajoram S, Mpuchane S, et al. 2010. Exposure to Lead Among Children in the City of Gaborone. Journal of Environmental Health Research, Issue 10(1), pp 17-26

2. Mmualefe, L. C., Torto, N., Huntsman-Mapila, P., & **Mbongwe, B**. 2009. Headspace solid phase microextraction in the determination of pesticides in water samples from the Okavango Delta with gas chromatography-electron capture detection and time-of-flight mass spectrometry **Microchemical Journal** Volume 91, Issue 2, March 2009, Pages 239-244

3. Mmualefe, L. C., Torto, N., Huntsman-Mapila, P., & **Mbongwe, B**. , 2008 , Supercritical fluid extraction of pesticides in sediment from the Okavango Delta, Botswana, and determination by gas chromatography with electron capture detection (GC-ECD) and mass spectrometry (GC - MS). Water SA, 34(3), 405 - 410

4. **Mbongwe B.,** Mmereki B.T., Magashual A. 2007. Healthcare waste management: Current practices in selected healthcare facilities, Botswana. Waste Management, 28 (1), pp. 226-233

5. **Mbongwe, B.,** Legrand, M., Blais, J.M., Kimpe, L.E., Ridal, J.J. & Lean, D.R.S., 2003. "Dichlorodiphenyltrichloroethane in the Aquatic Ecosystem of the Okavango Delta", Botswana. *Journal of Environmental Toxicology and Chemistry* Vol. 22, No.1. pp 7-19.

4. Selected Conference Presentations of toxicological, behavioral and environmental importance

1. **Mbongwe B**., Voyi K., Röllin H. 2012. Prevalence and Predictors of Risk Behaviours for Lead Exposure During Pregnancy in the Central District, Botswana. Inaugural RSTI Policy Launch, S&T National Conference and Exhibition, Gaborone International Conference and Exhibition Center, 14-15 August 2012, Gaborone, Botswana.
2. **Mbongwe B**.; Barnes B.; Mpuchane S.; Mathee.; Tshabang A.;2006. Elevated blood-lead levels among children in Gaborone – Conference paper: 9th World Congress on Environmental Health. Dublin, Ireland, 18-23 June, 2006
3. **Mbongwe B.** 2004**.** Lead Contaminated Soils and Children's Health – Are Botswana's Children at Risk? A paper presented at the 18th Environmental Health Conference and Exhibition, Boipuso Hall, Gaborone, Botswana
4. **Mbongwe B**. 2003. Chemicals and Their Impact on the Environment, in: National Workshop on the Standard on Classification, Packaging and Labeling of Chemicals, Tati-River Lodge, Francistown, Botswana. Ministry of Health.

Thesis

Mbongwe B. 2000. Fate and Persistence of DDT and its Metabolites in the Okavango Delta, Botswana. Thesis submitted to the School of Graduate Studies and Research, University of Ottawa in fulfillment of the Requirements for the M.Sc. Degree in the Ottawa-Carleton Institute of Biology.

Appendix 11: Lead Screening and Assessment Guideline for Health Workers, Policy Brief for Decision Makers and an Awareness leaflet on Lead Exposure for Pregnant and Lactating Women

CLINICAL ASSESSMENT TOOL FOR SCREENING LEAD EXPOSURE DURING PREGNANCY AND AFTER DELIVERY

Guidelines For Health Professionals 2012

This guideline provides information on lead, its sources, health effects and primary prevention strategies to educate, assess risks and confounders for lead exposure, provide counseling and care during pregnancy and follow-up after delivery.

The guideline is informed by current research and has been adapted to complement the information in the Botswana Obstetrics Record to be able to assess lead exposure risks along with other pregnancy risks.

Table of Contents

Part I: Introduction

Lead is a poison that affects many systems and functions in the human body including the neurologic, hematologic, gastrointestinal, cardiovascular and renal systems. It has a wide variety of uses in industries and at the household level.

The general uses of lead include:

- Batteries Production
- Ammunition Production
- Metal products (sheet lead, solder, brass and bronze products)
- Ceramic glazes
- Paint additive
- Medical equipment (radiation shields for protection against X-rays, ultra sound machines, surgical equipment)
- Scientific equipment (circuit boards for computers and other electronics)
- Military equipment (jet turbine engines)
- Fuel

Lead may also be found in household items such as mini plastic blinds, ceramic tiles, pottery plates, crystal glass and even in sweets and children's toys. Other practices which involve the uses of lead or lead containing products in the context of Botswana include backyard repair shops and battery repairs, commonly observed in lower income families.

Car lubricants from backyard repair shops may contain lead naphthenate, an additive which is also used in wood preservative; insecticides; paint and varnish drier. Gear oil is one of the lubricants also known to contain high levels of lead. Lead is oftne used to mend Cast Iron pots and metal dishes in rural areas. This may expose family members and pregnant women.

How is the general public exposed to lead?

Lead exposure occurs when lead dust or fumes are inhaled, or when lead is ingested through contaminated hands, food, water, cigarettes or clothing. When lead enters the body, the respiratory and digestive systems, it is released to the blood and distributed throughout the body.

More than 90% of the total body burden of lead is accumulated in the bones, where it is stored and released later in life during times of stress. Lead in bones may be released into the blood, re-exposing organ systems long after the original exposure.

Part II: Health effects of lead

Lead can affect anybody, but children under five years of age are at greater risk because they tend to put their hands or other objects into their mouths; they absorb more ingested lead than adults; and their brains are still at a developing stage so they are more sensitive to the effects of lead.

Exposure to low doses of lead in children may persistently and irreversibly affect their neurological development. The US Centers for Disease Control and Prevention (CDC) defines an elevated concentration of leadinthebloodas 10µg/dL. However, there is evidence that some health effects can occur below this level and no level of lead in blood has been found to be safe (Diagram 1).

Diagram 1: Blood lead levels associated with adverse health effects in children and adults

Lead Concentration in Blood (ug/dL)		
150	Death	Encephalopathy
		Nephropathy
100	Encephalopathy	
	Nephropathy	Frank Anaemia
	Frank Anaemia	
	Colic	Male Reproductive Effects
50		Haemoglobin Synthesis and Female Reproductive Effects ↓
40	↓ Haemoglobin Synthesis	Nerve Conduction Velocity ↓
30		
	↓ Vitamin D Metabolism	Elevated Blood Pressure
20		Erythrocyte Protoporphyrin (Men) ↑
	↓ Nerve Conduction Velocity	Erythrocyte Protoporphyrin (women) ↑
	↑ Erythrocyte Protoporphyrin	
	↓ Vitamin D Metabolism (?)	
10		
	Developmental Toxicity	
	↓ IQ, ↓ Hearing, ↓ Growth	
	Transplacental Transfer	

Please Note: the sign ↓ = decrease and ↑ = an increase.

Source: Adapted from ATSDR, 1992

Lead exposure has been associated with multiple health effects ranging from death to impaired cognitive behaviour. The following are some of the examples of the adverse effects of lead:

- Damage to brain and nervous system
- Developmental effects
- Gastrointestinal effects
- Behaviour and learning problems in children
- Anaemia
- Slow growth
- Damages to kidney and immune system
- Reproductive health problems

Signs and symptoms of lead poisoning

Lead poisoning can be hard to detect — because even people who seem healthy can have high levels of lead in blood. Signs and symptoms usually don't appear until dangerous amounts have accumulated. The following are some of the known lead poisoning symptoms:

- headaches
- muscle and joint weakness or pain
- excessive tiredness or lethargy
- behavioural problems or irritability
- difficulty concentrating
- loss of appetite
- metallic taste in the mouth
- abdominal pain, nausea or vomiting
- constipation

Part III: Why are pregnant women of major importance in lead poisoning and prevention?

Even though children are particularly susceptible to lead poisoning, pregnant women are now recognized as a vulnerable group to lead exposure and lead poisoning because they often behave in similar ways as children such as ingesting non-food items.

For example many pregnant women have been reported to have cravings for soils, chalk, and other non-food items. Additionally, the body's demand for calcium increases during pregnancy to support fetal bone development, which might release lead that was stored in bone.

Pregnancy and lactation can therefore accelerate the release of lead that was stored in bone during childhood to circulate in the blood stream. Once lead is in the blood stream, it passes through the placenta into the baby and into the baby's developing bones and other organs.

The following are some of the adverse effects of lead exposure for the mother and child:

- increased risk of hypertension in pregnant women
- increased risk of miscarriage
- decreased IQ scores in babies born to lead poisoned mothers
- impaired neurobehavioral development in children born to mothers exposed to lead
- deficits in academic and cognitive skills in children and adolescents later in life

Part IV: Basis for developing lead exposure screening and prevention guideline during pregnancy and after delivery

Evidence building:

In light of recent research which highlight the negative effects of prenatal lead exposure even at very low levels on maternal and infant health and the consequent life-long impacts on population health, a research was carried out in the Central Administrative District of Botswana to assess potential environmental sources of lead exposure during pregnancy, assess the behaviours and practices of women likely to influence lead exposure and finally assess blood lead levels at each stage of pregnancy and after delivery.

The Central Administrative District was chosen due to the existence a coal mine and a coal fired Power Station in the district. The study therefore compared results from an area in the vicinity of the mine (Palapye), a major village further away from the mining area and Power Station (Serowe) and two small villages with minimal industrial activity and traffic volume (Maunatlala and Lerala).

The purpose of the study was:

a) To assess blood lead exposure levels during pregnancy
b) To assess environmental lead levels in soils and water
c) To assess behaviors of pregnant women that could potentially expose them to lead
d) To use the information obtained from the study to develop lead exposure screening and prevention guideline for health workers, develop an awareness leaflet for pregnant women and a policy brief to disseminate the research result directly to decision makers in Botswana.

The following is a summary of the results:

- **Environmental Sources of lead exposure:** Soil lead concentrations were lower than the set international soil lead levels, however lead concentrations in drinking water by far exceeded permissible World Health Organization (WHO) drinking water-quality standards and therefore present a potential exposure source for pregnant women. Mean lead concentrations in water in Palapye, Serowe and small villages were 0.32 ppm, 0.25 ppm and 0.12 ppm respectively in excess of the WHO drinking water quality permissible lead concentration of 0.01ppm.

- **Behaviours and practices of pregnant women:** The study found that 83% out of a total of 142 pregnant women ingested non-food items such as soil (55%), pencil (10%), match sticks (13%), paint (4%), chalk and bone meal both accounting for 2% of the women. Pregnant women also engaged in unfamiliar practices such as the application of brake fluid (20%), torch batteries (8%) for “treatment” of psoriasis, ringworm and wounds. Light-brown shoe polish and traditional cosmetic clays were used by (18%) of women each for beautification purposes (vanishing and improving skin complexion). A substantial number of pregnant women in the study area engaged in alcohol consumption (31%), tobacco use (8%) and traditional medicines use (11%). Multiple risk behaviors (two or more risk behaviors) were practiced by 62% of women. Overall, age, employment and parity were significant predictors of whether a woman would engage in a risky behavior or not during the first trimester of pregnancy. The following is a summary of the implications for these behaviours based on current research elsewhere:

- **Eating soil (known as geophagia):** Severe lead poisoning from the ingestion of soil has been reported by many studies resulting with detrimental health effects for maternal and child health.

- **Eating other non food substances:** eating paint chips from furniture and walls, matchsticks, crushed bone meal, chalk and chewing pencil may cause. lead poisoning. Some paints have lead therefore eating paint chips and chewing pencil (which is painted) can expose pregnant women to lead.

- **Applying brake fluid, torch battery contents on skin:** Brake fluid and other car oils contain lead and other heavy metals and studies have found high blood lead levels in people who apply brake fluid to their skin. Some torch batteries contain not only lead but other harmful chemicals to the health of the baby and the mother such as mercury, cadmium and arsenic.

- **Application of letsoku (red, yellow and brown clay) to skin:** Some pregnant women use letsoku for beautifying themselves by applying it on their skin. Other women have reported using letsoku to treat stomachaches. These clays have been tested and contain lead and other heavy metals which may be absorbed through the skin and the gastrointestinal tract and therefore expose women to lead.

- **Drinking alcohol and smoking:** Alcohol consumption during pregnancy may increase the absorption of lead and tobacco smoke contains lead. Maternal drinking and smoking during pregnancy and prenatal exposure to low doses of lead have been associated with reduced gestational age and weight at birth. Alcohol consumption and tobacco use are therefore potential confounders for lead exposure. Some homemade alcohol brews may be processed in lead based containers such as PVC material and therefore lead may leach into the brew and expose the women who consume such brews.

- **Traditional and other remedies:** Some women use traditional and other remedies from other countries. These may contain lead as they are extracted from different soils or processed in containers which may be contaminated by lead. Studies globally have shown that traditional medications cause severe lead poisoning in pregnancy.

- **Light-brown shoe polish:** Shoe polish contains high concentrations of solvents and the solvents contained in shoe polish, just like lead, cause adverse effects on the central nervous system which may result with brain damage. Other effects of solvents from shoe polish similar to those caused by lead found in animal studies include anemia and embryo-toxic effects such as significant reduction in fetus weight. The solvent concentrations in shoe polish may therefore be potentially confounding factors for lead exposure.

- **Blood lead levels:** Concentrations of lead in the blood of pregnant women in the Central District were lower than the US Centers for disease Control and Prevention (CDC) action level of 10µg/dL (mean blood lead levels 2.34µg/dL, range 0.5-12.90µg/dL). Out of 137 women who donated blood 6% had blood lead levels greater or equalto5µg/dL.Asignificantincrease in blood lead levels was observed between the first and third trimester of pregnancy. Mean blood lead levels (±SEM) for the first, second and third trimesters were 1.96(±0.14)µg/dL, 2.49(±0.17) µg/dL, 2.66±0.19) µg/dL respectively.The highest concentrations of lead in blood were observed in women from Lerala and Maunatlala, the smallest rural villages located further away from any pollution sources when compared to major villages being Serowe and Palapye. It was concluded that the increase in blood lead levels in small villages

was more a function of the socioeconomic status of women in Lerala and Maunatlala villages who were poorer, had more children, ingested soil and had poorer dietary habits compared to women from major villages. Additionally, these factors had an influence on blood lead levels which significantly increased at each stage of pregnancy, therefore reflecting past lead exposure from bone stores in women of lower socio economic status, with poorer dietary intake of iron and calcium rich foods. It is also important to note that even thought these women were prescribed iron and calcium supplements at Government clinics, they did not utilize them as instructed, reflecting poor awareness on the importance of a good dietary intake of such supplements during pregnancy.

Low blood lead levels in pregnant women, should we be concerned?

The results of the study just presented showed very low blood lead levels. Should we be concerned? The answer is yes we should. While the US CDC has set10µg/dL as an action level for lead poisoning, recent research suggests that there is no safe level of lead and that the current action level should be reduced to 2µg/dL. Prenatal lead exposure has been linked to adverse neurodevelopment effects with meanbloodleadlevelsaslowas1-2µg/dL.

Furthermore, not only does research support the existence of adverse effects at levelslowerthan10µ/dL,butthattherateof decline in intelligence quotient (IQ) scores for example, might be greater at levels below10µg/dLthanitisatlevelsabove10µg/dL. It is further important to note that even though cognitive outcomes have historically been the the focus of most studies, higher lead exposures have been linked to psychosocial disorders such as attention deficit hyperactivity disorder (ADHD) and aggression or even delinquency. In such high dose lead levels, chelation therapy has been used and a major concern raised by researchers is that chelation will not prevent or reverse neurodevelopmental deficits. (Please refer to Annexure 1 for further reading)

The evidence just presented by these studies emphasizes primary prevention of exposure as the best hope for mitigating the impacts of lead exposure. It is on this basis therefore that these lead exposure screening and prevention guidelines for health workers are prepared. It is further recognized that, the guidelines on their own will not make a difference.

It is therefore necessary to continue research and surveillance of lead exposure sources as new lead exposure sources keep emerging. It is also necessary to continuously inform the health workers to fully appreciate their roles as agents of change in lead prevention, and finally, it is critical that pregnant women, along with the general public be made aware of lead exposure sources, how to prevent exposures and maintain a healthy personal and environmental health.

Part V: Screening and prevention guidelines for lead exposure dur - ing pregnancy and after delivery:

The diagnosis of lead poisoning is challenging due to its vague symptoms. Only in high dose lead poisoning, symptoms such as severe abdominal pain, irritability, decreased consciousness, motor, and sensory deficits can enough diagnostic suspicion of lead toxicity be raised.

Chronic low dose exposure may manifest with non-specific gastrointestinal distur-

bances, subtle neurologic and subclinical cognitive deficits. In the majority of lead poisoning cases, the simple removal of the lead sources has proved sufficient coupled with a good iron, calcium and vitamin C-rich diet and good environmental lead prevention strategies.

Primary prevention of lead poisoning

It is better to prevent lead poisoning from happening in the first place than to treat lead poisoning after it has occurred. These screening guidelines (refer to diagram 2) are aimed at preventing lead exposure from occurring and thus decrease the number of pregnant women who may suffer from lead poisoning through:

- Increased education and awareness on lead poisoning and how it can be prevented
- Identification of lead exposure risks and confounders;
- Counselling and care of women who may be exposed to lead;
- Follow up of pregnant women through the entire pregnancy and after delivery to eliminate potential lead exposure sources.

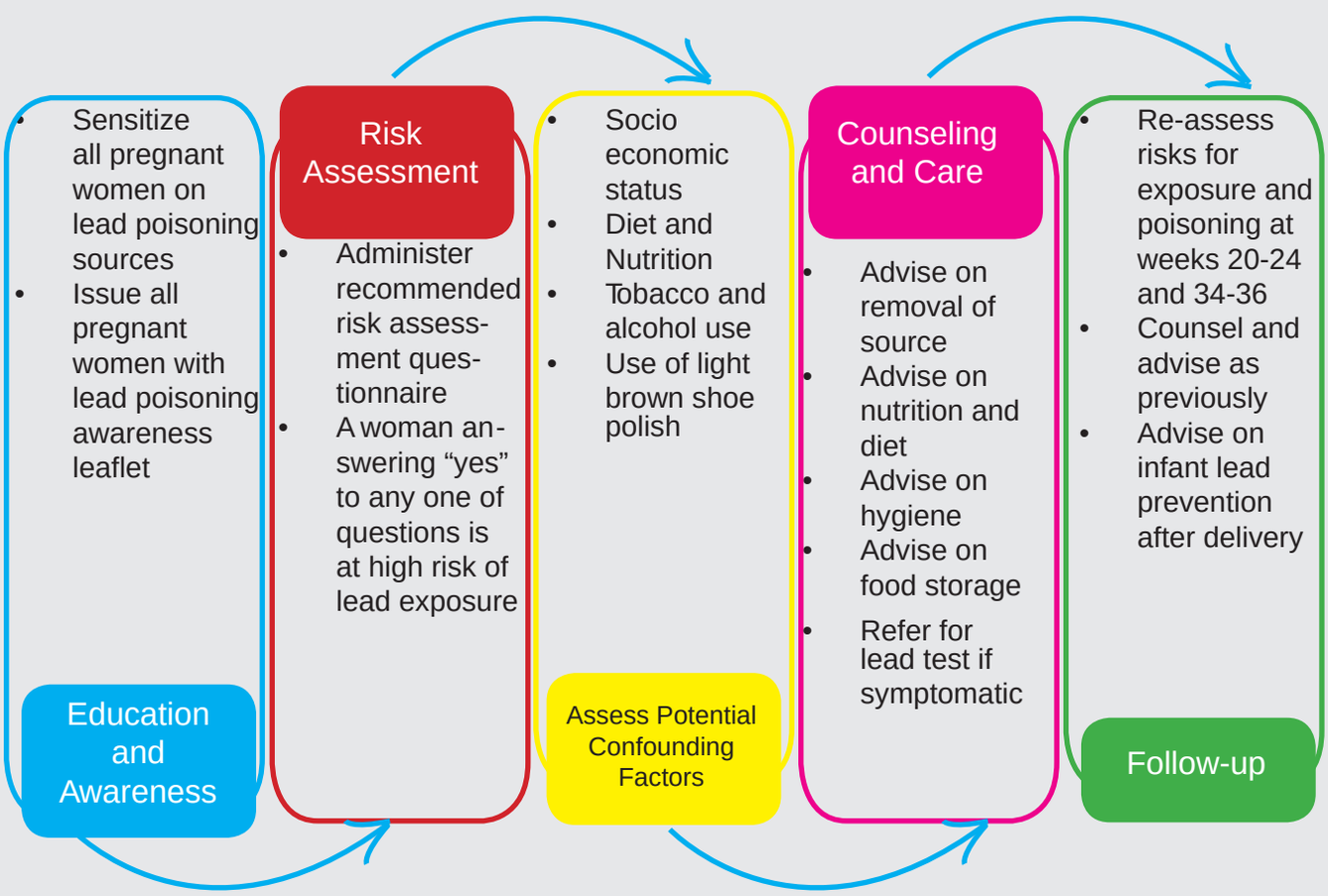

Diagram 2: The primary prevention of lead poisoning approach to mitigate lead exposure during and after pregnancy

Education and awareness:

- All Pregnant women should be issued with the lead awareness leaflet when they register for prenatal clinic at the initial visit during the first trimester of pregnancy. Key educational messages should focus on:

- Avoiding eating non-food items such as soil, matches, pencil, bone-meal, chalk, paint chips, and so forth;
- Avoiding to use unregulated traditional and other medicines from other countries which may contain lead;
- Avoiding applying brake-fluid, and torch battery contents, letsoku or any other products likely to expose them to lead;
- Not to purchase any herbal products that they are not sure of as they may contain lead, but to consult the health professionals for advice and treatment;
- Avoiding to use hot water directly from the tap for cooking and drinking;
- Reading the labels of all products to check if they contain lead;
- Practicing good hygiene and hand washing such as damp dusting instead of feather dusting;
- Being aware of environmental factors such as water, fuel used for cooking and lead emitting practices such as backyard mechanics, home renovation, and waste management sites that may expose them to lead.
- Education and awareness of supplements prescribed at clinics should be reinforced, for women to take as prescribed

Risk assessment

All pregnant women should be asked the following questions upon their first prenatal registration. The reported practices should be incorporated in their obstetric record along with other pregnancy risks for follow up purposes. Answering yes to any of the questions is an indication that the woman is at risk of lead exposure:

1. Do you sometimes have a craving to eat soil, matches, pencil, paint, bone meal, chalk or anything that is non-food?
2. Do you use letsoku for vanishing or for any other purposes?
3. Do you sometimes use brake fluid (new or old) or torch battery contents for treatment of psoriasis, ringworm or wounds?
4. Do you use traditional medicine produced locally or remedies from other countries sold in informal or formal markets? (see Box 1)
5. Is your job lead-related? (see Box 2)
6. Do you engage in hobbies or activities likely to expose you to lead? (see Box 3)
7. Is your water from a public standpipe?

Assessment of potential confounding factors:

a) Social status: poorer, unemployed women are at a higher risk of lead exposure due to poor diets, and lead contaminated environments such as backyard car repair workshops, living closer to waste management facilities which would have contaminated soils, and living in dusty environments.

b)Alcohol and tobacco use: see Part IV

c)Use of light brown shoe polish- see Part IV

Counselling and Care

Any woman who has answered yes to any of the risk assessment questions is at risk of lead exposure and possible poisoning and should receive counselling and guidance on how to avoid exposure sources.

The following is a guide to facilitate proper counseling and care of pregnant women:

Source/behavior or Practice	Investigate	Action
Pica behaviour	• Establish the item ingested • Establish where it is obtained from • Establish history (how long it has been practiced)	• Provide counseling and advise woman immediately to stop the behaviour • Record the behavior on the Obstetric Record(MH022/ rev.97) under “other risks” for follow up • Test for low iron in blood • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead. (see Box 4)
Cosmetics and traditional or other self prescribed remedies	• Establish the source of the remedy • Establish the reason for the use of reported remedy or cosmetic • Investigate the condition being treated with the remedy	• Provide appropriate counseling, treatment and care for the condition reported • Record the behavior on the Obstetric Record(MH022/ rev.97) under “other risks” for follow up • Advise on cosmetics and remedies (traditional and non-traditional) that may contain lead (see Box 1) • Test for low iron • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).

Use of brake-fluid, torch batteries and so forth.	• Establish item used • Establish condition being treated • Establish preparation of item before use and mixtures used	• Provide appropriate treatment • Advise the woman to stop the usage of the product immediately • Advise on the health impacts of the practice • Record the behavior on the Obstetric Record(MH022/ rev.97) under “other risks” for follow up • Test for low iron • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).
Alcohol consumption and tobacco use	• Establish the type of alcohol used (formal or traditional brews) • Establish type of tobacco used (snuff or smoking, cigarettes or roll-your-own) • Establish history of behavior and family members involved in the habit likely to affect the health of the pregnant woman (e.g. cigarette smoking)	• Advise the woman to stop the usage of the product • Offer advise to other family members likely to affect the pregnant woman. This might require a home visit • Advise on the health impacts of the practice • Record the behavior on the Obstetric Record(MH022/ rev.97) under “other risks” for follow up • Test for low iron • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).

Use of light-brown shoe polish	• Establish purpose of use • Establish history of use	• Offer advice on immediate stoppage of product • Advise on health effects of solvents in shoe polish and effects on pregnancy • Test for low iron • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).
Hygiene and home environment	• Establish if home is paved or has lawn • Establish indoor and outdoor cleaning practices (if cleaning routine follows damp dusting or feather dusting, etc) • Establish Handwashing practices	• If home surroundings are not paved or have a lawn advise dampening the ground before sweeping • Advise damp dusting in the house as opposed to feather dusting • Advise on regular hand washing before preparation of meals and eating • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).

Environmental factors (water source, fuel source)	• Reestablish the type of water source • Establish type of plumbing • Establish heating and cooking source • Establish renova-tion status	• Advise woman to run water from standpipe or tap for at least one minute first thing in the morning or if the water has been standing in the tap for a few hours. • Advise woman not to use hot water for cooking, drinking and mixing formulas directly from the tap. Lead leaches more from hot water if plumbing if lead based • If heating source is wood, advise woman not to use treated wood as it may contain lead • Advise women to avoid staying in the house during renovations to avoid dust from paint and other materials that may contain lead • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).

Lead related occupations and hobbies	• If the pregnant woman is employed, establish the if the job is not lead related • Establish if the woman has lead related hobbies	• See Box 2&3 for lead related jobs and hobbies • If the job is lead related, offer advice on hygiene such as regular hand-washing, not taking work clothes home, informing the employer of her pregnancy and to avoid lead exposure. • Test for low iron • Offer advice on diet and nutrition – Iron, calcium and vitamin C rich diet reduces absorption of lead (see Box 4).

Follow up

1)All women should be followed up during subsequent visits at weeks 20-24, 34-36 and six weeks after delivery to establish if the behavior, practices and environmental factors identified above are still continuing or have been stopped. If the practices have not been stopped appropriate advice and counseling should be continued.

2)Education after delivery:

a. All steps must be taken to advise women after delivery to prevent lead poisoning of the infant:

b. Where the baby is not breastfed and infant formula used, women must be advised to boil tap water and not to use hot water directly from the tap. All tap water should be run for at least one minute if it has been standing for a while:

c. The baby should be fed with foods that are rich in iron to lower their lead risk:

d. Mothers must be advised to purchase lead-free infant toys and hands must be washed often.

Part VI: Lead exposure sources _examples

- **Letsoku - A traditional clay cosmetic for vanishing and skin conditioning**
- **kohl surma - a black powder used as an eye cosmetic and sometimes an umbilical stump remedy**
- **Azarcon - bright orange powder often used to treat gastrointestinal upset stom - ach**
- **BaliGoli:Around,fatbean dissolved in “gripe water” for treatment of stomach ache**
- **Greta: Yellow-Orange pow - der used to treat digestive problems**

Box 1: Examples of cosmetics and remedies found to contain lead

- Use of paints containing lead
- Home rennovation
- Recycling and metal scrap yards or working in waste dispoasl sites
- Glass recycling, stained glass and glass manufactur - ing
- Manufacturing or installation of plumbing components
- Pottery making
- Battery manufacturing and repair
- Production and use of chem - ical preparations
- Firing range work
- Car repair shops

Box 2:Examples of lead related occupations

- Scraping, sanding and burn - ing of paint containing lead on woodwork, walls and other household structures
- Handling electronics with lead solder
- Glass blowing with leaded solder
- Making pottery and ceramic utensils with lead glazes and paints
- Scrap metal collection and processing
- Painting
- Mending three legged cast iron pots and metal dishes with lead solder

Box 3: Examples of hobbies, activities that may cause lead exposure

Part VII. Diet and nutrition guide

Lead is more easily absorbed on an empty stomach. In order to reduce lead absorption, pregnant women should be advised to eat regular meals and eat more frequently. Dietary deficiencies in iron, calcium, and vitamin C may make pregnant women more vulnerable to lead exposure. Diets rich in iron discourage absorption of lead. Calcium is known to compete with lead and can inhibit its absorption. Vitamin C is important to facilitate increased excretion of lead by the kidneys. Where women are prescribed iron, calcium and vitamin C supplements as is the current Government policy, this must be accompanied by proper education and counselling to promote compliance on regular intake of such supplements alongside good eating habits.

Box 4: Dietary Sources of Iron, Calcium and Vitamin C

Sources of iron	**Meat:** lean beef, veal, ham, pork, chicken, lamb **Fish:** clams, mussels, oysters, tuna, cod, sardines **Eggs** **Liver** **Cereal:** iron fortified cereals, wheat germ **Fruits:** dried fruits (apricots, raisins, prunes, dates) **Vegetables:** spinach, collard greens, lentils, peas, beans, peanut butter
Sources of calcium	**Fish:** sardines, anchovies, shrimp, trout, cod, mackerel, tuna, salmon, crab, lobster Milk, ice cream, yoghurt, cheese **Vegetables:** cabbage, collard, broccoli, spinach **Fruits:** oranges, pineapples, raisins, fortified orange juice
Sources of vitamin C	**Fruits:** grapefruit, oranges, cantaloupe, strawberries, juices, wild berries, moretlwa, morula, mmopudu, mogorogowana **Vegetables:** broccoli, green peppers, greens

Annexure 1: Additional Reading

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UNIVERSITY OF BOTSWANA

POLICY BRIEF NO: 1

UB Department of Environmental Health

Research dissemination results for decision-makers

Environmental Lead Exposure During Pregnancy and After Delivery

Introduction

Lead is a persistent heavy metal that is toxic to humans and the environment. Due to such persistence lead is detected in water and soils even in the most remote parts of the world. The negative effects of lead are known globally and as a result countries around the world have developed lead exposure prevention policies and legislation to protect public and environmental health.

Health Effects of Lead

Lead exposure has been associated with multiple health effects ranging from death to impaired cognitive behaviour. Lead can affect anybody, but children are at a greater risk because they tend to put their hands or other objects in their mouths, additionally because their organs are not fully developed, the effects of lead on them are more devastating.

Even though children are particularly susceptible to lead poisoning, pregnant women are now recognized as a vulnerable group to lead exposure and lead poisoning because they often behave in similar ways as children such as ingesting non-food items.

Many pregnant women have been reported to have cravings for soils, chalk, and other non-food items.[1] More than 90% of lead is accumulated in bones where it is stored and released later in life during times of stress such as pregnancy.[2] Pregnant women therefore have additional lead from bone during pregnancy, which is released with calcium to support the unborn baby's bone development.

Once lead is in the blood stream, it passes through the placenta into the baby's developing bones and other organs and may cause increased spontaneous abortions, and low birth weight,[3] decreased intelligence quotient (IQ) in babies,[4] deficits in academic and cognitive skills in children[5] and hypertension[6] and anaemia in pregnant women.[1]

Sources of Lead Exposure Pathways for Pregnant Women

There is an increased recognition that lead contaminated soils are an exposure source to humans. Soil can enter the human body through inhalation, eating soil and through skin lesions.[1,7,8] Another important pathway for lead exposure is water. Water lead levels can vary from dwelling to dwelling due to the variations in plumbing configurations as well as social factors.[9] Water is also relatively efficiently absorbed by the body compared to other sources. Recent research further estimated that water, both in its direct form and indirectly through adsorption contributes on average to at least 10% of lead in food.[10]

International Guidelines for Lead Exposure

The developed world has long recognised lead as a toxin and has put in place guidelines for monitoring lead exposure particularly in children and pregnant women. The US Centers for Disease Control has for example set blood lead levels at 10µg/dL or higher as an action level to prevent lead poisoning.[11] Current research suggests that there is no safe level of lead and that the current action level should be reduced to 2µg/dL.[5]

Exposure of infants during pregnancy has been linked to adverse neurodevelopment effects with mean blood lead levels as low as 1-2µg/dL. [5] It is further important to note that even though cognitive outcomes have historically been the focus of most studies, higher lead exposures have been linked to psychosocial disorders such as attention deficit hyperactivity disorder (ADHD) and aggression or even delinquency. The World Health Organisation (WHO) has also set a water lead levels standard of 0.01 ppm[12] to prevent lead exposure and potential lead poisoning.

Lead Studies in Botswana

The following studies have been carried out in Botswana:

In 2012 a study was carried out in pregnant women from four villages in the Central District of Botswana (current study). Blood samples were collected during the first, second and third trimesters of pregnancy from 137 women. The mean blood lead levels were 2.34 µg/dL.

The highest mean blood levels were in women from Lerala village in all trimesters of pregnancy compared to other villages (3.33 µg/dL, 3.78 µg/dL and 3.84 µg/dL during the first, second and third trimesters respectively). The highest blood lead level was 13 µg/dL(detected from a woman from Lerala during the third trimester).

Poorer women living in small rural villages had significantly higher blood lead levels. In the same study water lead levels were tested and showed that the levels were 19 times higher than the permissible concentrations set by WHO.

The habits of pregnant women have also been studied from the Central District to establish women potentially exposed to lead. Out of a group of 142 pregnant women, more than 80% ate non-food items and out of these more than 50% ate soil (diolo). More than 30% of the women also applied lead containing substances such as brake fluid and torch batteries to treat conditions such as ringworm and psoriasis.[13]

In 2010 a study was carried out among children in the city of Gaborone. Out of a total of 220 children aged 1-6 years, 31% had blood lead levels equal to or greater than 10 µg/dL and of these children 5% had blood lead levels equal to or above 20 µg/dL.[14]

Conclusion

Prenatal exposure to lead is increasingly becoming an issue of concern due to several reasons. Among these is concern that substantial foetal lead exposure can occur from mobilization of maternal skeletal lead stores, which can in turn persist for many years after external lead exposure has declined. Another concern is that the foetal nervous system is extremely sensitive to neurotoxins.

Few studies have been conducted in Botswana on lead exposure and poisoning. However the studies reported above indicate that more pregnant women and children could be exposed to lead. The need for primary prevention of lead exposure in these vulnerable groups can therefore not be over emphasized. This is in light of emerging evidence that lower lead levels can cause adverse health effects on women and children than previously thought.

Policy Recommendations/ Options

Surveillance of Lead Levels in Water

Botswana currently has set water standards that are in line with the WHO water quality standards; however, lead is not currently tested in water. There is need for water to be tested regularly to prevent adverse health effects caused by lead in population health.

Regulation on Lead Containing Plumbing Materials

There is an urgent need for Botswana to consider regulating materials containing lead for plumbing purposes. The high levels of lead in the Central District could be attributed to lead solder which is not regulated in Botswana. It is also important that other water parameters such as pH need to be monitored in order to reduce lead leaching accelerated by water that is highly acidic.

Inclusion of Lead Related Risk Behaviour Screening Questions in The Obstetric Record

It is recommended that the Botswana Government should include behaviors and practices such as pica, the use of brake fluid and other harmful practices in the obstetric record as women register for the first time in order to identify lead related risk behaviours and provide proper counselling, care and follow up in subsequent trimesters.

Education and Awareness

Education, awareness, counselling and care of pregnant women who engage in soil pica and other non-food items should be intensified and these behaviours incorporated in the current obstetric record when pregnant women register for the first time at prenatal clinics. This should be preceded by intensive training of health workers on lead exposure and its adverse health effects. It is further recommended that lead exposure and poisoning training be incorporated in the curriculum of midwives.

Research and Surveillance

A national lead surveillance programme should be implemented in Botswana to identify the key sources, mechanisms of exposure and ingestion of other risk factors for lead exposure during pregnancy and lactation. The survey should incorporate environmental sources of lead exposure as well as behaviours that could potentially expose different population groups. For example brake fluid use, and torch battery use seem to be accepted by communities as treatment options for skin problems. Communities in rural and low income areas could also still be mending cooking pots and utensils with lead solder. These and many other practices need further investigation.

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DID YOU KNOW THAT LEAD IS A POISON?
IF YOU ARE PREGNANT OR LACTATING, READ THIS LEAFLET TO KEEP YOU AND YOUR BABY SAFE

WHAT IS LEAD?

It is a persistent heavy metal that is harmful to humans & the environment. Lead may also occur naturally in rocks and soil. It is used also to join water pipes and other metallic products. Lead is also found in many household and industrial products such as torch and car batteries and is used in car lubricants such as brake fluid and gearbox oil. Decorated plates (pottery) may also contain lead. In Botswana some people also use it to mend leaking cast iron cooking pots (the three legged pot) and metal dishes. Some people also use it to join the rods used for pot stands (matshego) in villages.

It may also be found in dinkgwana (clay-based pots) used to store water in villages.

WHAT IS LEAD POISONING?

Lead poisoning is a medical condition caused by increased levels of lead in the body. Lead in the body can cause permanent damage to the brain and other organs. Children are most at risk for the damage caused by lead poisoning. But, a pregnant woman who has lead in her body may expose her baby by passing the lead to the expected baby. Symptoms include abdominal pain, confusion, headache, anaemia, irritability and it may even cause seizures, coma and death when the levels are very high.

WHY SHOULD I BE WORRIED ABOUT LEAD?

Lead exposure can cause:

- High blood pressure in a pregnant woman
- Babies born too soon or too small
- Miscarriage and stillbirth
- Lower IQ in children
- Learning and behavior problems in children
- Slow growth in children
- Poor hearing in children

HOW CAN I BE EXPOSED TO LEAD?

We breathe lead in the air and dust. People who eat soil and ant-hills are also exposed to lead. We may also be exposed to lead from water pipes where lead solder (material used to join pipes) has been used. In Botswana pregnant women also use brake fluid and other car oils and torch batteries to 'treat' skin problems such as psoriasis and ringworm.

Lead and other heavy metals in these products may be absorbed through the skin when you use them and circulate in your blood making you sick.

If a pregnant woman has been exposed to lead as a child, her body may store the lead in her bones and teeth. If the pregnant woman's diet does not contain enough calcium, the body may substitute lead in her bones for the calcium that the baby needs.

HOW CAN MY UNBORN BABY BE EXPOSED TO LEAD?

- A pregnant woman can breathe in or swallow lead. This passes from her to the baby.
- The lead can enter the mother's bloodstream.
- Lead in the mother's womb passes through the placenta and can get into the baby's bones, brain, and other organs.
- If a pregnant woman was exposed to lead in the past, before becoming pregnant, this can also cause problems for the unborn baby. This lead can be stored in her bones for many years and then be released during pregnancy

HOW CAN I PREVENT LEAD EXPOSURE?

Lead poisoning can be devastating, but it is preventable. If you follow these messages you and your baby will be safe.

DOs

1. Eat foods rich in calcium, iron, and vitamin C: These will protect you and your unborn baby.
- Calcium is in milk, yoghourt, cheese, and green leafy vegetables like spinach.
- Iron is in lean red meat, beans, cereals, and green leafy vegetables like spinach.

- Vitamin C is in oranges, green and red peppers, broccoli, tomatoes, moretlwa, morula, mmupudu, mogorogorwane and juices.
- Be careful when eating sweets, spices, and other foods that have been brought into the Botswana from other countries, especially if they appear to be non-commercial products.

2. Store food properly. Some food containers may contain lead. It is important to store and serve your food properly.

- Avoid using or storing food in imported lead-glazed ceramic pottery or any pottery produced locally if you are not sure it may contain lead.
- Avoid using brass containers or utensils to cook, serve, or store food.
- Avoid using leaded crystal to serve or store drinks.
- Do not use dishes that are chipped or cracked.

3. Use only cold water directly from the tap for cooking and drinking: Run water for 30 to 60 seconds the first thing in the morning or during any part of the day especially if you haven't used your water for a few hours. Hot water will make lead in pipes dissolve in water.

4. Encourage members of your family working in lead related jobs to shower at work: If a member of your family works in an industry with high lead exposure, he or she can bring lead dust home on his or her clothes, hair, shoes and skin, passing the dust to others in the family. Their clothes should also be washed separately.

5. Read the labels on anything that you buy: check if the product contains lead.

DON'Ts

- Do not eating soil or chew pencil, matches, peeling paint chips from furniture or walls and chalk. If you have cravings for any of these, contact your health care provider so that they may help you.

- Do not apply brake fluid or any other car oil to your skin; it contains lead and other chemicals that can harm you and your child. If you have a skin disease please consult your health care provider, they will give you treatment for that condition. Also do not use used car oil to condition your floors because you will carry lead in your shoes and crawling babies will be exposed from their hands.

- Do not use torch batteries for treatment of ringworm. Torch batteries contain lead , mercury, arsenic and other chemicals that may affect you and your unborn baby.

- Do not apply letsoku on your skin or drink it if you have stomach ache. Some letsoku that is sold on the market (dimausu) contain lead that can be absorbed through your skin and your gastrointestinal tract.

- Do not apply shoe polish on your skin. It has the same effects as lead and may cause brain damage and anaemia. You may also give birth to a small baby.

- Do not use traditional medicine mixtures, especially those sold out in dimausu (informal markets). Consult your health professional if you have any condition to treat.

- Do not smoke cigarettes or drink alcohol during pregnancy. Snuff tobacco is also not safe.

If you have any questions, consult your nearest local clinic. They will provide you with more information