Heavy Metals and Parasitic Geohelminths Exposure among Geophagous Pregnant Women in Nakuru Municipality

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DECLARATION AND RECOMMENDATION

Declaration

This research thesis is my original work and has not been presented wholly or in part for any award in any institution of learning.

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DEDICATION

This work is dedicated to my family members, Parents Rose Odongo and Leonard Odongo, Wife Ruth Owino and my lovely daughters Dishan Anne Owino, Rachael Amondi Owino and Naomi Rose Owino for their inspiration and unwavering support.

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ABSTRACT

Geophagia is defined as deliberate consumption of earths' materials e.g. soil, clay and soft stones. The practice is widespread among pregnant women and there are conflicting views as to whether it is beneficial to health or not. Geophagic materials may be a source of micronutrients though the materials may bind the micronutrients thus reducing or hindering their bioavailability in the body. Geophagia is closely associated with geohelminthic infections among pregnant women and heavy metal poisoning which constitute significant public health problem in many developing countries like Kenya. The main objective of this study was to determine whether pregnant women practicing geophagia in Nakuru Municipality are exposed to heavy metals and parasitic geohelminths. The research design was descriptive cross sectional study whereas data was collected using structured questionnaire, laboratory analysis and observations. A total of 431 pregnant women in different trimesters of pregnancy were interviewed and 38 geophagic materials analysed. The study sites comprised of level 2 and 3 Nakuru municipal health facilities. Demographic survey was conducted in the month of January to April 2014. The geophagic materials were subjected to standard digestion procedures and analyzed for Zinc, Lead and Iron by atomic absorption spectroscopy (AAS). Analysis results showed that geophagic materials contained elevated levels of Fe at mean concentration value of 80.10ppm, Pb 3.28ppm and Zn1.81ppm for a 1.00 g sample. An average of 20grams of the geophagic material was consumed per day. The pregnant women were exposed to 65.52ppmPb per day .This exceeded the WHO lead exposure limits of 25ppm/day for pregnant women. The materials were also subjected to microscopic examination for *Ascaris lumbricoides, Trichuris trichiura, Taenia Spp, Necator americanus* and *Ancylostoma duodenale*. Analysis showed that the geophagic materials contained no observable eggs, larvae or adult species of the geohelminths. Both point and period prevalence rates of geophagia were determined to be 35 and 58 per 100 pregnant mothers respectively. In conclusion, there was relatively high point prevalence rate of geophagia, the women were exposed to heavy metals-Iron, Zinc and Lead but there was no exposure to geohelminths. There is need to integrate public health education on geophagia, lead screening and testing with antenatal support care systems. This will enhance maternal and child health thus reducing infant and maternal morbidity and mortality rates.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS AND ACRONYMS

• AAS	Atomic Absorption Spectrophotometry
• BLL	Blood Lead Level
• DNA	Deoxyribonucleic Acid
• ECDE	Early Childhood Education
• FAO	Food and Agriculture Organization
• FPE	Free Primary Education
• GOK	Government of Kenya
• KIPPRA	Kenya Institute for Public Policy Research and Analysis
• KNBS	The Kenya National Bureau of Statistics
• KDHS	Kenya Demographic Health Survey
• MDGs	Millennium Development Goals
• MNCH	Maternal, Newborn and Child health
• MCN	Municipal Council of Nakuru
• NVP	Nausea and Vomiting of Pregnancy
• RDA	Recommended Daily Allowance
• STHs	Soil-transmitted helminths
• UK	United Kingdom
• UN	United Nations
• UNCHS	United Nations Centre for Human Settlements
• VLDL	Very Low Density Lipoproteins
• VLBW	Very low birth weight
• WHO	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Pica is an eating disorder typically defined as the persistent eating of non-nutritive substances for a period of at least one month at an age in which the behaviour is considered mentally inappropriate (Gupta and Gupta, 2005).Pica presents itself in various forms and some of the most commonly described types involve eating earth which is termed as geophagia, ice (pagophagia) and starch (amylophagia). However, pica has also been associated with the ingestion of stones, ashes, hair, paint chips and paper(Patrick, 2007).

Geophagia as form of picawas a common act among pregnant women during the 19th century in the Southern United States, primarily among the slaves. The etiology of geophagia remains unclear. Evidence suggests that there may be several major contributing factors to geophagia, including nutritional, sensory, physiologic, neuropsychiatric, cultural, or psychosocial factors(Sayetta, 1986).More often, the diagnosis is made because of its complications, which include anaemia, lead poisoning, parasitic infestation, intestinal obstruction, or other metabolic conditions(Patrick, 2007). Geophagia can have serious medical implications which may include metabolic abnormalities such as heavy metal poisoning, electrolyte disturbances, vitamin deficiencies, iron and zinc deficiencies. It can also lead to soil-borne parasitic infection, dental injury, and achlorhydria. Furthermore, it has been associated with gastric and intestinal obstruction from bezoars, foreign bodies, feces or parasites. Other abdominal complications such as perforation and peritonitis have been reported as well (Patrick, 2007).

Some hypotheses suggest that geophagia may be beneficial in that it can provide the much needed micronutrients among people with deficiencies and protection from toxins and pathogens (Young *et al*, 2007). It is proposed that geophagic substances protect either by adsorbing pathogens and toxins within the gut or lumen or by coating the surfaces of the intestinal endothelium thereby rendering it less permeable to toxins and pathogens. Additionally, this hypothesis implies that geophagic materials would be ingested during periods of rapid growth i.e. the times of greatest need for protection from toxins and microbes e.g. during childhood and pregnancy are the periods when pica is likely to occur (Flaxman and Sherman, 2000; Fessler, 2002).

In Africa, the habit is widespread and is passed from one generation to another because of cultural beliefs (Giessler *et al*, 1997). In Kenya, previous studies on geophagia among school children and pregnant women in Western Kenya have been described by Giessler*et al*. (1997). They found out that over 70% of the sampled school going children in Nyanza province consume soil at an average rate of approximately 30mg daily. The eaten soils were mainly from termite nests, weathered stones and walls of huts. Another study conducted by Moturi (2009) in Mauche division Nakuru County showed that geophagia among children in this region of Kenya was a risk factor for diarrhoea. Evidence from studies has recorded high prevalence rates of geophagia during pregnancy to be a common phenomenon. A study by Giessler *et al* (1998) involving 275 pregnant women at the coast of Kenya recorded 56% of the women eating earth soil regularly and another study done by Ngozi (2008) in Nairobi reported that 89.9% of the respondents ingested soft stones (odowa) regularly during pregnancy. The varying daily intake quantities among geophagous pregnant women and the possible heavy metals present in these materials like lead might result to heavy metal poisoning. Nevertheless, geophagia as a risk factor for diarrhoea might be due to the geohelminths exposure. It is evident that the periodic consumption of geophagic materials might adversely affect the health of the mother and infant during pregnancy.

1.2 Statement of the problem

Several health risks are associated with the geophagous behaviour like geohelminths infections, iron deficiency anaemia, impaired nutritional status of the mother, lead poisoning and poor birth outcomes among others, all of which can result to both infant and maternal morbidity and mortality. In addition,geohelminth infections in pregnancy have been associated with increased iron deficiency, maternal anaemia, and impaired nutritional status, as well as decreased infant birth weight, intra-uterine growth retardation, and other adverse birth outcomes (Villar*et al* 1989;WHO, 2002). Investigations have also shown that heavy metals, including lead, cross the barrier of the placenta and are transported to the foetus. As concentrations of lead in the blood of infant increases, chronic effects like mental retardation, learning deficits, or other neurological and behavioral problems are observed later in life (Lindgren andViksna, 1997).The practice among pregnant women who might be anaemic and malnourished with increased nutritional requirements and lowered immunity might result to increased maternal and infant mortality rates. Five hundred and seventy maternal deaths per 100,000 births were reported in 2008-2009 KDHS in Nakuru and 60% of infant deaths in Kenya occur during the first month of life (KNBS, 2008-2009). This survey indicated high maternal and infant mortality rate in Nakuru where there exists no empirical study on geophagia among pregnant women. The only recorded study that has been carried in the region was on geophagia as a risk factor for diarrhoea among children by Moturi (2009) in Mauche division. This therefore sparks a quest for knowledge of the prevalence of geophagia and the potentially available heavy metals contents and parasitic geohelminths contamination of the geophagic materials.

1.3 Objectives

1.3.1 Broad objective

To assess whether pregnant women practicing geophagia in Nakuru Municipality are exposed to heavy metals and parasitic Geohelminths.

1.3.2 Specific objectives

1. To find out the prevalence of geophagia in pregnant women attending antenatal clinics in Nakuru Municipality.
2. To determine the concentration of lead, zinc and ironin the geophagic materials consumed by the pregnant women.
3. To determine the leadexposure of pregnant women who practice geophagia and compare to the World Health Organization (WHO) limits.
4. To determine geohelminths (*Ascaris lumbricoides, Trichuris trichiura, Taenia Spp* and hookworm- *Necator americanus* and *Ancylostomaduodenale)* exposure of pregnant women who practice geophagia.

1.4 Research questions

1. What is the prevalence of geophagia among pregnant women attending antenatal clinics in Nakuru Municipality?
2. What is the concentration of lead, zinc and iron in the geophagic materials consumed by the pregnant women?
3. What is the lead exposure to the pregnant women who practice geophagia and how is the exposure compared to the World Health Organization (WHO) limits.
4. Is there exposure to geohelminths (*Ascaris lumbricoides, Trichuris trichiura, Taenia Spp* and hookworm- *Necator americanus* and *Ancylostomaduodenale)* among the pregnant women who practice geophagia?

1.5 Justification of the study

Geophagia is a practice that has been observed among pregnant women of different cultural and socio-economic backgrounds not only in Kenya but also in other parts of Africa. Nakuru municipalityis cosmopolitan, with its population originating from all the ethnic groups around the country with different cultural practices thus ideal for the study. Two of the 2015 Millennium Development Goals (MDG) are to reduce the under-five child mortality rate by two-thirds (MDG 4) and improving maternal health (MDG 5).Under Vision 2030, Kenya expects to meet its Millennium Development Goals (MDGs) by the deadline of 2015. Health is captured under the social pillar in the Kenya Vision 2030 in which some of the flagship projects include community based information systems and developing and offering integrated comprehensive healthcare services. Some of the barriers in achieving the maternal, newborn and child health (MNCH) care interventions include health sector policy and household behaviours like geophagia. Lead, zinc and iron are heavy metals which can be bound to earth soils and rocks ingested by the pregnant women. Zinc and iron are micronutrients required during pregnancy but whose bioavailability may be interfered with by geophagia and their interaction with lead in the body.

Lead exposure is of importance since its intoxication can lead to hypertension, renal failure and life-long cognitive impairments. Women who practice geophagia may be particularly at risk of infection with *Ascaris lumbricoides*, *Trichuris trichiura*, *Taenia Spp* and hookworms - *Necator americanus* and *Ancylostoma duodenale* by ingesting eggs from contaminated soil. Thus there is need to assess and determine the iron, zinc and lead concentrations of these geophagic materials and also the possible geohelminths contamination that may result to adverse health outcomes to the mother and the foetus. The findings will generate information that can be used in addressing the various factors associated with mortality rate including nutritional status, intoxication, breastfeeding, maternal and child health status, environmental health factors, and socioeconomic factors and developing appropriate interventions. The availability of geophagia prevalence data will improve the levels of awareness among the communities, health practitioners and other policy makers to develop comprehensive reproductive and primary health care programmes that can adequately address the practice and its health implications.

1.6 Scope of the Study

This study was part of a larger study involving identification of socio-economic, nutritional and cultural factors that may influence geophagia among pregnant women. In this study, pregnant women in different stages of pregnancy (1st, 2nd and 3rd trimester of pregnancy) were sampled from public health clinics within Nakuru Municipality. Prevalence rate was determined among different age groups, trimester of pregnancy, family income and the various education levels of the pregnant women. The sources and the types of the geophagic materials were determined and the assessed materials included those that were in possession by the women. Laboratory analysis of geophagic materials was undertaken for metals-Lead, Zinc and Iron and parasitic geohelminths -*Ascaris lumbricoides, Trichuris trichiura, Taenia Spp,* andhookworm- *Necator americanus* and *Ancylostoma duodenale.* The daily exposure levels for the heavy metals were calculated based on the amounts of the consumed materials.

1.7 Limitations and assumptions

The following were the limitations and assumptions of the study:

- Determining the correct quantities of the geophagic materials being consumed posed a challenge because of recall bias and difficulty in estimation of portions by various respondents. This was controlled by providing packaged samples of various weights of the soil presented to the respondents.
- Some of the respondents were not in possession of the geophagic materials being consumed at the time of the interview, only geophagic materials in possession by the respondents were sampled and analysed.
- The bioavailability of iron, zinc and lead was not ascertained in the study neither was the assessment of clinical signs and symptoms of the heavy metals poisoning and the parasitic geohelminths infections done.

1.8Definition of Terms and operationalization of variables

Pica	is an eating disorder which entails persistent eating of non-nutritive substances for a period of at least one month at an age in which the behaviour is considered mentally inappropriate.
Geophagia	is defined as deliberate consumption of earths' materials i.e. earth eating.
Pregnancy	is the period from conception to birth.
Earth eating	in this study involves consumption of soil, clay and other soft stones.
Geohelminths	(soil-transmitted helminths) are intestinal nematodes, part of the development of which takes place outside the body – in the soil.
Encephalopathy	means disorder or disease of the brain.
Heavy metals	are metals that have a high atomic number, atomic weight and gravity greater than 5.0; they include some metalloids, transition metals, lanthanides and actinides.
Smectite	is clay minerals containing hydrous aluminium, sometimes with variable amounts of iron, magnesium, alkali metals and other alkaline earth metals.
Peritonitis	is an inflammation of the peritoneum, the thin tissue that lines the inner wall of the abdomen and covers most of the abdominal organs.
Gastroenteritis	is a medical condition characterized by inflammation of the gastrointestinal tract resulting in some combination of diarrhea, vomiting, abdominal pain and cramps.
Psychiatric disease	is a psychological anomaly, usually reflected in behaviour i.e. generally associated with disability, and which is not considered part of normal development.

Autism is a disorder of neural development characterized by impaired social interaction and verbal and non-verbal communication. It affects information processing in the brain by altering how nerve cells and their synapses connect.

Stupor is the lack of critical cognitive function and level of consciousness wherein a sufferer is almost entirely unresponsive and only responds to base stimuli such as pain.

Hypophosphatemia is an electrolyte disturbance in which there is an abnormally low level of phosphate in the blood.

Arthralgia (joint pain) is a symptom of injury, infection, illnesses (in particular arthritis) or allergic reaction to medication.

Postpartum period is the period beginning immediately after the birth of a child by a mother extending for about six weeks.

Eosinophilia is a condition in which the eosinophil count in the peripheral blood exceeds 0.45×10^9/L (450/μl).

Achlorhydria or hypochlorhydria refers to states where the production of gastric acid in the stomach is absent or low, respectively.

Bezoar is a mass found trapped in the gastrointestinal system (usually the stomach), though it can occur in other locations.

Pseudobezoar is an indigestible object introduced intentionally into the digestive system.

Recommended Dietary Allowance (RDA) is the average daily dietary intake level that is sufficient to meet the nutrient requirement of nearly all (97 to 98 percent) healthy individuals in a particular life-stage and gender group.

Tolerable Upper Intake Level (UL) is the highest level of continuing daily nutrient intake that is likely to pose no risk of adverse health effects in almost all individuals in the life-stage group for which it has been designed.

Level 2 health care facilities include the clinics and dispensaries.

Level 3 health care facilities include the health centres, maternity and Nursing homes.

1st Trimester of Pregnancy - pregnancy period between 1st to 12th weeks

2nd Trimester of Pregnancy- pregnancy period between 12th to 24th weeks

3rd Trimester of Pregnancy- pregnancy period between 24th to 40th weeks.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

The term pica comes from the Latin word meaning magpie, presumably named after the bird's peculiar eating behaviours; the magpie shows an indiscriminate preference for foods and non-foods. Pica of dirt and clay was known to the Greeks and the Romans and was recorded in a 13th century Latin work. (Aneli and Lagercrantz, 1958).

Geophagia, 'the habit of eating earth including clay and other types of soil' (Halsted, 1968) , is a form of pica that has been observed in many parts of the world (Abrahams and Parsons, 1996), but is especially widespread in sub-Saharan Africa. Soil or clay is mostly consumed by pregnant or breast-feeding women and also by children (Luoba, *et al.*, 2004); little data is available on the percentage of women consuming clay or on the amount consumed. Several studies, however, suggest that in African regions where geophagia occurs, between 46% and 73% of pregnant or breast-feeding women consume soil regularly. The amounts differ considerably, with average values from 1- 100 g/day (and more) being reported (Luoba, *et al*., 2004).The practice of geophagia is deeply embedded in cultural traditions, and in many cultural contexts earth eating is seen as normal (Luoba, *et al*., 2004).

2.2 Prevalence of geophagia

Globally, the available literature shows that the prevalence rate of geophagia varies from place to place and has been reported to range from 0 to 68% depending on the characteristics of the population studied (Smulian, *et al*, 1995).A low prevalence rate (8.8%) of geophagia was documented by al-Kanhal and Bani (1995) in a study involving 321 pregnant Saudi Arabian women. Walker *et al* (1997) recorded 2.2% and 1.6% prevalence rates respectively among the Indian and Caucasian pregnant women. Other studies carried out in Western societies reported high prevalence rates in their subjects. Lacey (1990), for example, recorded 38% prevalence in a study involving 128 pregnant women in Greenville, USA. In Jamaica, in 1992, in a study on the dietary habits of rural women during pregnancy, 20% reported geophagia in the studied population (Melville and Frances, 1992).

In Africa, geophagic earth is either obtained from local sources such as termite mounds, house walls and from natural exposures or purchased in local markets where it has often been traded over long distances (Vermeer and Ferrell, 1985). Geophagia is widespread among pregnant women in five African countries, Malawi, Zambia, Zimbabwe, Swaziland and South Africa. In the rural areas an estimated prevalence rate of 90% was recorded (Hunter, 1993). In Malawi it is reported to be surprising for a pregnant woman not to practice geophagia. The taste of soils is claimed to diminish the nausea, discomfort and vomiting in "morning sickness" (Hunter, 1993). Mothers and other women in the household play a primary role in the transfer of geophagia from one generation to the next and in adulthood geophagia is exclusively associated with women (Vermeer and Frate, 1979). Because of the absorptive capacity of some clay, geophagia has been practiced as a relief of diarrhoea and stomach discomfort (Barteson and Lebroy, 1978; Morgan, 1984). Deficiencies of specific nutrients, such as iron and zinc have also been linked to geophagia (John and Duquette, 1991).

Studies have also established that geophagia is common among the Tanzanians and Kenyans in the Eastern part of Africa (Young *et al*., 2007). A particular study by Louba *et al*. (2004) among 827 pregnant women in western Kenya during and after pregnancy showed that a significant number of these women (65%) reported earth eating before pregnancy. The prevalence remained high during pregnancy, and then declined to 34.5% and 29.6% at 3 and 6 months post-partum, respectively. Another study on geophagia prevalence in pregnancy done by Giessler*et al* (1999), investigated geophagia in pregnant women attending antenatal clinic at Kilifi District Hospital in Coast province. The study involved 275 pregnant women and 56% reported eating soil regularly. In a later study involving 52 pregnant women, 73% reported practicing geophagia on regular basis.

Several different types of clay soil are ingested by geophagic persons around the world and vary in colour from whitish, creamy, greyish, yellowish, to reddish (Woywodt and March 2002;Stokes,2006). The preferred type of earth eaten by Kenyan women according to Louba *et al*. (2004) was soft stone, known locally as *odowa* and earth from termite mounds.

2.3 Possible beneficial human health effects from geophagia exposure to Iron and Zinc

Various hypotheses on geophagia have been advanced and there are conflicting views as to whether soil eating is beneficial to health or not. Several studies point to positive effects: geophagic material is a source of mineral nutrients – especially of iron (Abrahams, *et al* 2006); helps against gestational nausea (Ferrell and Vermeer, 1985) and detoxifies foods, for example, by adsorption of various plant secondary compounds (John and Duquette, 1991). The consumption of clay increases food efficiency (Habold, *et al*., 2009) which might be important in poor countries. Furthermore, smectite and other clays have long been used in pharmaceutical preparations and to treat acute gastroenteritis (Sz ajewska, *et al* 2006).

2.3.1 Zinc

It is critical that a pregnant woman satisfy her body's need for zinc. Low zinc intake has been associated with an increased risk of low birth weight, and low zinc intake earlier in pregnancy is associated with pre-term delivery (Bhowmik, *et al* 2010). Because of zinc's role in generating cells, it is essential for the developing foetus where cells are rapidly dividing. It is also worth noting that adequate zinc in the pregnant mother's diet reduces the risk of premature birth and improves neonatal survival (Bhowmik,*et al* 2010).

Foetus needs zinc for proper growth thus pregnant women are vulnerable to zinc deficiency (Shah and Sachdev, 2001). A study conducted by Salimi *et al* (2004) in Iran indicated 49% prevalence of zinc deficiency in pregnant women. The prevalence of zinc deficiency in age group of 20-30 years mother was higher than that of less than 20 years and the mothers more than 30 years had lower zinc deficiency than mothers in age group of 20-30 years. This was may be due to higher requirement of zinc for younger age because of their growth age (Salimi *et al*, 2004).Studies have shown that the foetus grown with zinc deficiency end up with abnormalities in central nervous systems, congenital abnormalities, abnormal tasting sense and prolonged pregnancy among women (Jameson, 1982;Prasad, 1998).While using medicinal supplementary zinc materials by pregnant mothers, increased newborn birth weight, prevented adverse pregnancy outcomes and decreased the mortality rates (Osendarp,*et al*, 2001).

Zinc deficiency affects reproduction adversely in females since all the hormones and a wide range of enzymes involved in reproduction are sensitive to zinc as a microelement in the body. In particular, zinc is essential for the synthesis and secretion of luteinizing hormones and follicle-stimulating hormone, gonadal differentiation, and fertilization. Zinc is involved in the formation of prostaglandins required for maintenance of pregnancy and also important at parturition to initiate the uterine contractions for expulsion of the foetus. It is also required for many physiological functions including normal immune function and neurosensory functions (Nriagu, 2007).

2.3.2 Iron

Iron is an essential micronutrient, majority of which is bound in haemoglobin found in erythrocytes where it is used in transportation and processing of oxygen within the body. Most of the remainder is stored in the compound ferritin. Over two thirds of the iron is deposited in the liver and the bulk of the remainder in the bone marrow and reticulo-endothelial cells (WHO/FAO, 2004). Smaller trace amounts fulfill key roles within the body with functions such as immune defense, neural function, DNA synthesis (Beard, 2007), cellular energy production, liver function, apoptosis, elastin production and collagen production (Ilich and Kerstetter, 2000).

Among pregnant women, iron deficiency can occur even when pre-pregnancy iron levels were adequate since iron requirements increase as the pregnancy proceeds. Third trimester iron requirements of 5-7.5mg/day cannot be met even from high bioavailability diets (from which under 5mg may be absorbed and must be met from the body's iron stores or supplementation (Bothwell, 2000). Iron and lead occupy similar niches within the human body and so compete for likely binding sites particularly during absorption. Low iron levels by themselves produce cognitive decline especially among young children, exacerbating lead's impact of mental retardation (Murrray-Kolb and Beard, 2007).

It is believed that clay inhibits the absorption of iron from the gut into the blood stream (Mogongoa, *et al*, 2011). A case study was reported at the University Hospital Basel, Petersgraben-Switzerland in the year 1993 and 2005. The reported African woman who consumed soil for more than 10 years indicated the association of geophagia with iron deficiency anaemia (Von Garnier *et al*,2008). The discussed patient by Von Garnier *et al*. (2008) failed to respond to oral iron therapy since she was still consuming stones. She was subsequently treated with intravenous iron replacement which corrected the anemia. Geophagia is associated with iron deficiency in humans but whether people consume stones because of iron deficiency or iron deficiency is the result of geophagia has not yet been established (Whitney and Rolfes, 1993; Mogongoa, *et al*, 2011). Therefore even though the consumed geophagic materials by the pregnant women may contain iron, the bioavailability may not be guaranteed.

2.4 Possible adverse human health effects from geophagia exposure of Lead, Zinc and Geohelminths

Other studies report negative effects of geophagia, for example an association of geophagia with iron and other mineral nutrient deficiencies (Hood, *et al*, 2002), anaemia (Kuwai, *et al* 2009) and geohelminths infections (Saathoff, *et al*, 2002). Moreover, geophagic materials can contain toxic heavy metals; especially lead (Dean, *et al*, 2004). The heavy metals lead, Zinc, mercury, cadmium and many others are ubiquitous and persistent environmental pollutants that primarily affect the kidneys and the brain. Exposure to these metals during pregnancy and early childhood can impact children's renal systems and brain development (Dean, *et al*, 2004).

Geophagia has been associated with lead poisoning, hyperkalemia, phosphorous intoxication, dental injury and other undesirable effects including low bone mineralization (Glickman, *et al*, 1981). Moreover geophagia may result to parasitic geohelminths exposure. In other studies, well-preserved helminths ova have been recovered in soil samples from archaeological excavations (Bouchet, 1997). However other parasitological studies conducted in Lusaka-Zambia showed that the types of soil ingested by geophagous pregnant women did not contain helminth ova. This could have been attributed to the fact that some geophagous people roast the soil before consumption which could render it harmless and of no risk for helminthiasis. This is because geohelminths ova of *Ascaris lumbricoides* and *Trichuris trichiura* require moisture to survive and embryonate (Shinondo and Grace, 2008).

2.4.1 Lead

The principle toxic effects of lead occur in the liver, kidney, and central nervous system. Lead mimics calcium and thereby alters the normal functioning of these biologic systems (Williams, *et al* 2000). In the liver, lead interferes with heme synthesis leading to anaemia and the inhibition of erythrocyte pyrimindine-5-nucleotidase, which normally breaks down pyrimidine nucleotides.

In the kidneys, lead primarily targets the proximal tubule of the nephrons where it causes suppressed resorption of glucose, phosphate and amino acids. This suppression can lead to glycosuria, aminoaciduria, and a hyperphospaturia with hypophosphatemia (Middendorf and Williams, 2000). The most serious and irreversible effects of lead exposure occur in the central nervous system where lead can distort enzymes and structural proteins.

Additionally, many of lead's damaging effects can be attributed to its ability to compete with or mimic calcium. Even at very low concentrations, lead can compete with calcium for binding sites throughout the body. In the central nervous system, lead can affect neuronal signaling by competing with cerebellar phosphokinase C (Markov and Goldstein, 1988). Lead can also inhibit calcium's passage through the cell membrane. When lead is absorbed by the mitochondria, it distorts the cristae, inhibits cellular respiration and other calcium reactions, including energy coupling (Holtzman, *et al* 1984).Research continues to indicate that there is no safe threshold blood lead level (BLL) for lead in infants and young children(Middendorf and Williams, 2000). Although the results of acute lead exposure may be reversible with chelating treatment, chronic lead exposure may cause irreversible dysfunction and morphologic changes, resulting in eventual renal failure and death (Middendorf and Williams, 2000).

Permanent deleterious effects of chronic lead exposure have been observed in children with BLLs, well below 10 μg/dL, the current "level of concern" (Needleman, 2004). Often, the first visible symptoms of lead toxicity are exhibited as mild behavioral alterations or flu-like symptoms which can easily go undiagnosed. At increasing doses, clinical symptoms become more obvious with abdominal pain, arthralgia, clumsiness and headache presenting as the most common early signs of encephalopathy. Untreated, the condition may progress to include loss of consciousness, stupor and convulsions. Many children who recover from clinical encephalopathy retain serious life-long cognitive, attention and behavioral impairments. Lead can also cause other serious long-term effects, ranging from hypertension and renal failure to adverse effects on reproduction (Needleman, *et al* 1990).

Investigations have shown that heavy metals including lead cross the barrier of the placenta and are transported to the foetus (Viksna and Lindgren, 1997). Lead that is absorbed into the body can be stored in a person's bones for years. When a woman becomes pregnant, the lead that she may currently be exposed to and the lead stored in her bones gets into the blood stream and can be passed to the baby. Several physiological factors modulate the movement of lead from maternal bone to the growing foetus. Both the total lead exposure and the rate of lead exposure influence the concentration and location of lead in the maternal compartment. This in turn affects the bioavailability and mobilization of lead into the placenta and foetus. The maternal body lead burden and available concentration is influenced by maternal age, as mineral metabolism is a key factor (Ashley, *et al* 2012).

2.4.2 Zinc

Even though Zinc is an essential requirement for a healthy body, excess zinc can be harmful and cause zinc toxicity. Excessive absorption of zinc can suppress copper and iron absorption. The free zinc ion in solution is highly toxic to plants, invertebrates, vertebrate like fish and even humans. Excess amounts of zinc and when accumulated in the body organs, tissues and cells results to both acute and chronic health effects. Ingestion of high levels of zinc has resulted in lethargy, lightheadedness, staggering, difficulty in writing clearly, anxiety, depression and somnolence (Nriagu, 2007). Under normal circumstances, the major route of zinc excretion is via the pancreas. Prolonged consumption of supplements may lead to an accumulation of zinc and impairment of the pancreatic function, resulting in increased release of amylase, lipase and alkaline phosphatase into the blood stream (Nriagu, 2007).

2.4.3 Geohelminths

These are intestinal nematodes or parasites in which at least one developmental stage (ova) requires period of development or incubation in the soil prior to being infective. Infection occurs through contact with parasite eggs or larvae in faecally contaminated soil. The soil-transmitted helminths (STHs) of major concern to humans are *Ascaris lumbricoides*, *Trichuris trichiura*, Hookworms-*Necator americanus* and *Ancylostoma duodenale* (WHO, 2012).

Geophagous behaviour among pregnant women may result to parasitic geohelminths infections since they might ingest the parasites eggs during consumption. A study among school children in Western Kenya showed that geophagia does not directly contribute substantially to the infections with soil-transmitted helminths at least in the dry season (Giessler, *et al* 1997).However another cohort study conducted in Western Kenya on the role of geophagia and other risk factors for helminthiasis in pregnant and lactating women showed that geophagia significantly increased the risk of infection with *Ascaris* after antihelminth treatment (Wong, *et al* 1988).

Soil-transmitted helminths (STHs) are among the most common of all chronic human infections occurring predominantly in areas of poverty and inadequate hygiene and sanitation in the developing world. Unlike many other tropical diseases, infection with STHs does not typically result in clinical disease, and the majority of infected individuals exhibit no signs or symptoms. This is because pathology is strongly related to the number of worms present (the intensity of infection).It should however be noted that most often individuals harbour only a few worms (WHO, 2012).Immunological effects of geohelminths can differ by species and may affect both a pregnant woman and her foetus (Malhotra, *et al*, 1997; Quinnell, 2004). Hookworm disease is caused by *Ancylostoma duodenale* and *Necator americanus*. Mature hookworms can cause intestinal bleeding and protein loss proportional to worm burden; however the severity of the effect is dependent on the host's underlying nutritional status (Diemert, *et al*, 2008). Hookworm infections can cause or exacerbate iron deficiency and anaemia. Blood loss can be a feature of *Trichuris trichiura* infection which can occur along with hookworm infections and thus may accelerate the onset of iron-deficiency anaemia. *Ascaris lumbricoides* infections are commonly asymptomatic, although clinical complications of extra-intestinal or high numbers of ascarids have been observed (Holcombe, 1995). Furthermore *Ascaris lumbricoides* infection has been associated with impaired fat digestion, reduced vitamin absorption and temporary lactose intolerance, and treatment has shown to improve nutritional status (Stephenson, *et al*, 2000; WHO, 2002).

2.4 Conceptual Frame work

The conceptual frame work (figure 1) shows the relationship of variables determining the heavy metals and parasitic geohelminths exposure among geophagous pregnant women. The independent variables include the geophagous phenomenon, type of material being consumed, amount and the source of the material. The type of material being consumed and the source determined the type of heavy metal present. The amount consumed determined the concentration of the heavy metals exposure. The source and the amount also determined the parasitic geohelminths- *Ascaris lumbricoides, Trichuris trichiura, Taenia Spp* and Hookworms- *Necator americanus* and *Ancylostoma duodenale* exposure.

The intervening variables in the study entailed the consumer characteristics:-age, level of education and income, trimester of pregnancy and frequency of consumption. The level of education and income may influence the type, source and amount of material being consumed. The frequency of consumption may influence the exposure levels of both the parasitic geohelminths and the heavy metals. The trimester of pregnancy may greatly influence the heavy metals and geohelminths effects to the pregnant woman and foetus e.g. lead intoxication will have adverse effects in the first trimester of pregnancy. Data on these intervening variables was collected and analysed in the study. The consequences of exposure though not part of this study, may include helminthiasis due to parasitic geohelminths exposures, pre-term births, low birth weights, lead poisoning, anaemia and other long term effects like mental retardation, hypertension and renal failure to the child and the mother.

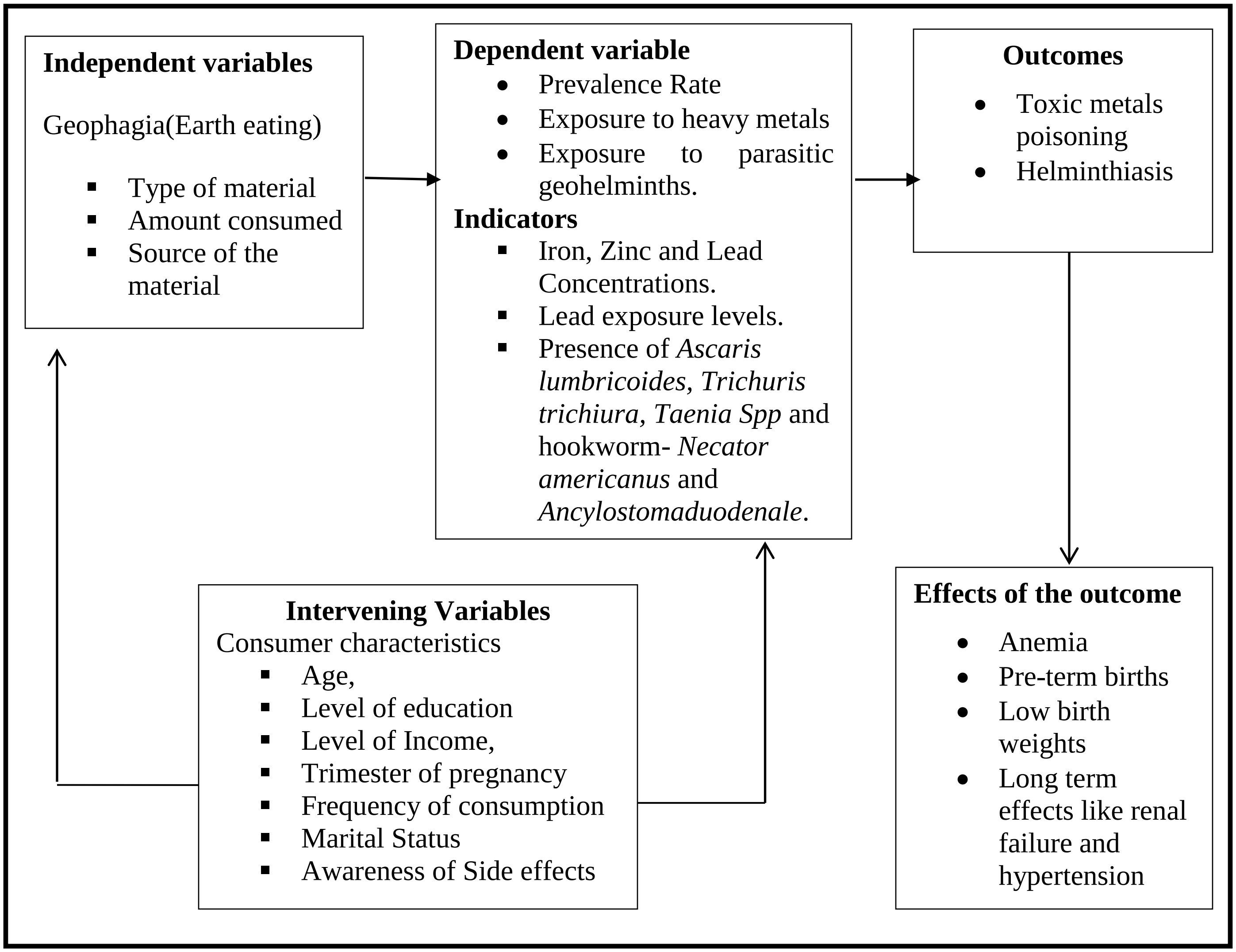

Figure 1. A representation of conceptual framework

CHAPTER THREE

3.0 METHODOLOGY

3.1 Study Area

The study was done in Nakuru Municipality located 160 kilometres northwest of Nairobi, along the Kenya-Uganda highway. It is the headquarters of Nakuru County and the fourth largest town in Kenya after Nairobi, Kisumu and Mombasa (Figure 2). It is a cosmopolitan town with its population originating from all the ethnic groups around the country. It is situated at an altitude of 1850 m above sea level between the Menengai Crater to the north and Lake Nakuru national park to the south. Nakuru's population has been growing at the rate of 5.6% per annum. From a population of 38,181 in 1962, the population reached 163,927 in 1989 and 289,385 in 1999 and 473,288 in 2009 population and housing census report (GOK, 2000; KNBS, 2010). By the year 2015, the population is projected to rise to 760,000, which is approximately 50% above the present levels (MCN, 1999).

Geological foundations of the municipality are related with the volcanic eruptions and tectonic activities associated with the formation of the Great Rift Valley. Situated within the municipality is Menengai Crater which is a dormant volcano. The soils are loose volcanic soils with volcanic rocks associated with host of minerals and construction materials. These volcanic-Sedimentary accumulations have deposits of Clays, Trona, Diatomite, Gypsum and other minerals.There are a number of sand, gravel and stone quarries within the municipality. The products from these quarries are not only utilized in the construction industry in the town but also exported to other regions outside the municipality (Kibet, 2004).

The total area of the municipality is about 292 km^2 of which the lake covers 44 km^2 (Foeken and Owuor, 2000). Nakuru's municipal boundary is identical to that of the Nakuru Municipality Division. The division is divided into five administrative locations: Lanet, Afraha, Kaptembwo, Baharini and Barut (Nyasani, 2009). The study sites comprised the public government facilities within the Nakuru Municipality. This covered level 2 and 3 healthcare facilities.

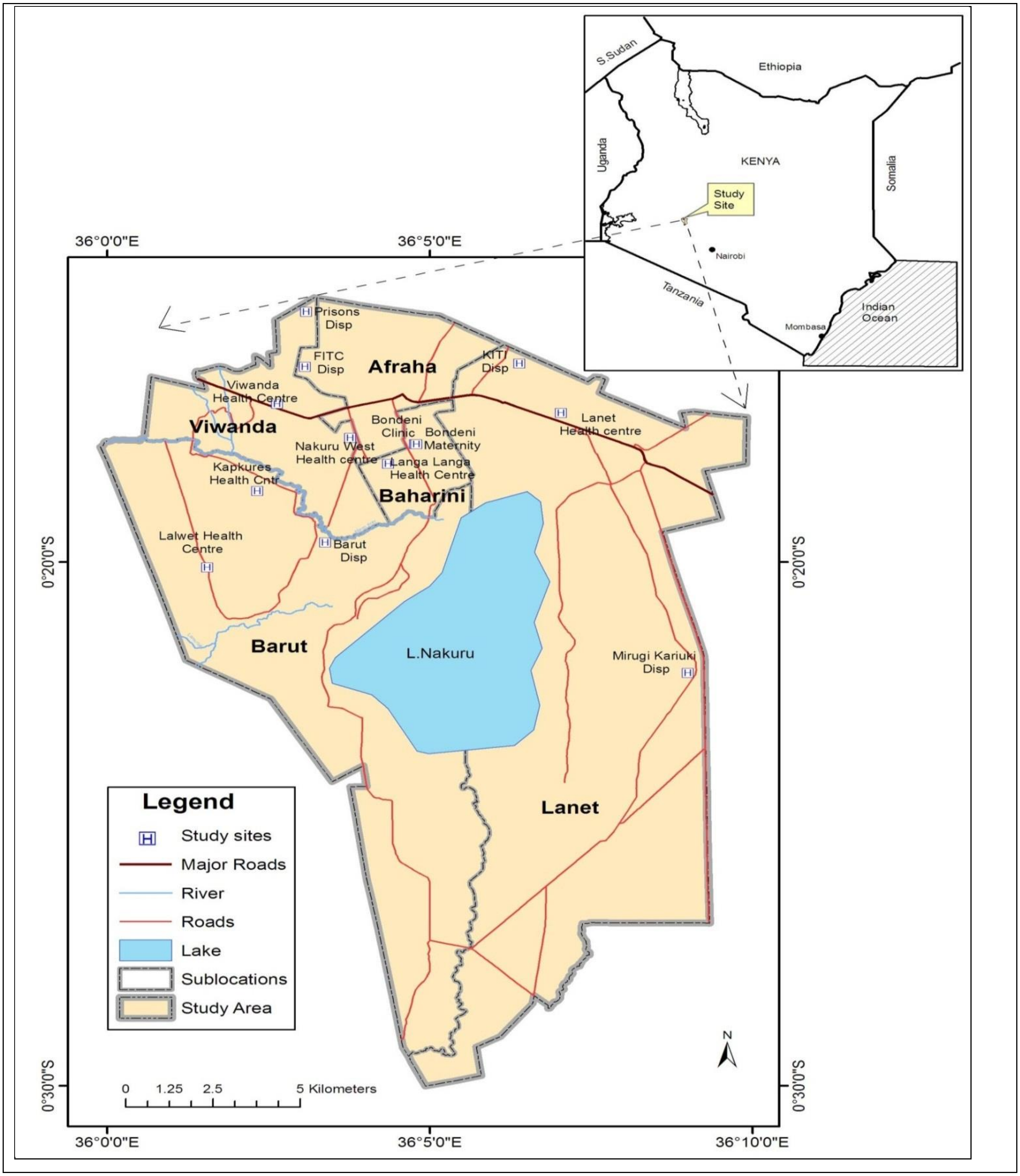

Figure 2. Map showing Nakuru Municipality and the locations of the health centres

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3.2 Study Design

A cross-sectional descriptive study was employed in the study. The information on geophagic behaviour, attitudes, family income, family history and geophagic episodes of various purposive sampled pregnant women in various trimesters of pregnancy attending the antenatal care in the various clinics was collected using a questionnaire. Thereafter scientific laboratory analysis of the obtained geophagic materials for both heavy metals-zinc, iron, lead and geohelminths was done.

3.3 Materials and Methods

3.3.1 Validity and reliability of research instruments

The validity of the research instruments was ensured by checking the format and content of the questionnaire by the supervisors and other qualified experienced researchers. The reliability of the instruments was verified through test-retest technique which gave cronbach reliability index of 0.51. A pilot study was conducted at Njoro health centre which is a level 3 health facility with antenatal care services similar to the study sites. This enabled the adjustment of the questionnaire accordingly which made it more relevant through incorporating missing information, omitting irrelevant questions and paraphrasing questions that appeared ambiguous to the respondents.

3.3.2 Determination of Prevalence rate of geophagia

Questionnaires establishing the prevalence of the geophagia and the identity of the geophagic materials consumed were administered to the sampled pregnant women in different stages of pregnancy visiting the antenatal clinics in each of the selected level 2 and 3 health care facilities within the municipality. The questionnaires were administered by trained research assistants conversant with the health centres and the local dialects. The sources and amount of the material consumed, experience of the geophagous behaviour, the pregnancy stages during which the behaviour is most experienced and the socioeconomic factors that might be influencing the practice, the perception and the health problems experienced or being experienced as a result of the practice were determined. Quantities of the geophagic materials were estimated by the respondents who used visual judgment by comparing weighed packaged samples with what they normally consume.

3.3.3 Sample size determination

The sample size was determined using the formula

$$N=\frac{(Z\alpha+Z\beta)^2 X\ 2\ X\ \dot{P}(1-\dot{P})}{(d)^2}$$ (Dawson and Trapp, 2004; Chow, *et al*, 2007)

Where N = Calculated sample size

$Z\alpha$ = alpha value (1.96)

$Z\beta$ = beta value (0.84)

d = degree of difference (10%)

$\dot{P}$ = Proportion of pregnant women that practice geophagia (50%)

$\dot{P}$ (1-$\dot{P}$) = Variance (proportion)

These were at 95% confidence level with a statistical power of 80% and an attrition rate of 10% included in the calculation.

Sample size Calculation

$$N = \frac{(1.96+0.84)^2 X 2 X 0.5(1-0.5)}{(0.1)^2} = 392$$

Attrition rate of 10% was included to give a sample size of 431

3.3.4 Sampling Procedure

Purposive sampling was used to select public health centres and dispensaries within the Municipality. A rapid preliminary survey was conducted in all the public health centres and dispensaries within the Municipality to collect preliminary data on those offering the antenatal care services and to establish the number of pregnant women visiting these clinics, annual attendance of the new visits was considered and proportionate ratios calculated to determine the sample size in each health facility (Appendix 2).The pregnant women were sampled from thirteen healthcare facilities. All the visiting pregnant women in different trimesters of pregnancy were interviewed. The total number interviewed per facility depended on the calculated proportionate ratio.

3.3.5 Sample collection and Analysis of geophagic materials

All the geophagic materials consumed by the geophagous pregnant women in their possession were collected. The materials subjected for both biological and chemical laboratory analysis were obtained from the collected samples through random sampling. A total of one hundred and fifty one pregnant women were geophagous (Appendix 3). One hundred and fifty one samples were collected and twenty five percent i.e. thirty eight samples subjected to laboratory analysis. Depending on the percentage of geophagous pregnant women per health facility (Appendix 3), the samples were constituted as follows:-eight from Langa Langa,Five each from Kapkures,F.I.T.C and Lanet,two each from Nakuru West,Mirugi Kariuki, KITI and Barut, Four from Bondeni Maternity and three from Bondeni Clinic.

Plate 1: A sample of geophagic material analysed

3.3.5.1 Analysis of Heavy metals

3.3.5.1.1 Sample Preparation and Digestion

The samples were analysed at the chemistry department-Egerton University. Each sample was crushed and grounded in a mortar into fine powdered sample of uniform thickness. 1.00g of each sample was weighed in duplicate using analytical balance and transferred into a 125ml conical flask; these were then labeled according to the health centre from which the sample was collected. In each conical flask, 30ml of Aqua regia (3HCl:1NO_3) digestion mixture was added and left overnight for cold digestion to take place. After cold digestion the samples were further digested by heating at 300-370^{O}C on a hot plate for 30 minutes. On cooling, the samples were then filtered into 125ml plastic containers using fluted filter papers of Whatman paper no1.Distilled water was used to top the eluent solution to 50ml.Standard procedures for the preparation of stock solutions (1000ppm) for Fe, Zn, and Pb were employed. The standard stock solutions were used to prepare serial solutions for the determination of these elements in the samples using AAS (Okalebo *et al*, 2002).

Plate 2: Samples analysis using Atomic Absorption Spectrophotometer.

3.3.6 Sample collection and Analysis of geohelminths

The samples were analysed at the department of Biological Sciences Egerton University. Within 24 hours of collection the samples for geohelminths examination were preserved in 5% formalin. Simple flotation method with use of McMaster technique (Hansen and Perry, 1987), was employed for the examination. In the method, 4g of each crushed sample was weighed using analytical balance and transferred into a plastic container, this was then mixed with 56ml distilled water. The mixture was stirred thoroughly with an electric agitator for 5 minutes. The mixture was then filtered using a tea strainer into a second container and later subjected to centrifugation at 1500 rpm for 5 minutes. The supernatant was discarded using a Pasteur pipette and 40ml of the flotation fluid added to 10ml of the sub-sample sediments. After shaking the mixture, both sides of the Mc Master counting chamber were filled with the sub-sample. The sub-sample was then examined under a light microscope at 10 x 10 magnifications. This procedure was repeated for all the 38 samples.

3.4 Ethical Considerations

Ethical approval was obtained from Egerton University Ethical committee and research permit from National Commission for Science, Technology and Innovation (NACOSTI), Ministry of Health and the health care facilities (Appendix 8).Written informed consent was also obtained from the sampled pregnant women who voluntarily participated in the study.

3.5 Data Analysis

A standard calibration curve of absorbance versus concentration was obtained and used to calculate the concentrations for each metal in the various samples (Appendix 4). Statistical package for social sciences (SPSS) and Microsoft excel were used to analyze the data. Descriptive statistics was used and results presented in frequencies, percentages, statistical charts, tables and means employed to present results from the field survey and laboratory analysis. This gave the prevalence rates of geophagia, the geohelminths exposure and the concentrations and exposure of iron, zinc and lead. Based on the amount of consumed geophagic materials and on concentrations obtained after laboratory analysis, lead exposure levels were compared with the WHO standard to determine the health risk.

Table1: Summary of data analysis

Research questions	Variables	Data Analysis
What is the prevalence of geophagia among pregnant women attending antenatal clinics in Nakuru Municipality.	Age, education, income, Trimester of pregnancy Accessibility, Source Frequency of consumption.	Descriptive statistics, Pearson's Chi-square Test
What is the concentration of lead, zinc and iron in the geophagic materials consumed by the pregnant women.	Type consumed Source Amount	Descriptive statistics, ANOVA
What is the lead exposure to the pregnant women who practice geophagia and how is the exposure compared to the World Health Organization (WHO) limits.	Lead concentration of samples Amount consumed Type consumed Source	Descriptive statistics One Sample t-test
Is there exposure to geohelminths (*Ascaris lumbricoides*, *Trichuris trichiura*, *Taenia Spp* and hookworm- *Necator americanus* and *Ancylostoma duodenale*) among the pregnant women who practice geophagia.	Geohelminths observed in samples Type consumed Source Amount of material	Descriptive statistics

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Age, education, income and trimester of pregnancy among the study population.

Fifty five point seven percent (n=431) of the pregnant women were in the age bracket of 18-25 years majority of whom were married (figure 3 and table2). This was followed by 25.8% who were in the age bracket 25-30 years. Ten point nine percent were between 30-35 years, 3.7% were under 18years and 3.5% were between 35-40 years. Only 0.5% was above the age of 40year (figure 3). Ten out of sixteen(62.5%) of the under 18 years pregnant women were married (table 2) thus indicating early marriages in the study area; this might be attributed to observed low levels of education, high levels of unemployment and poverty.

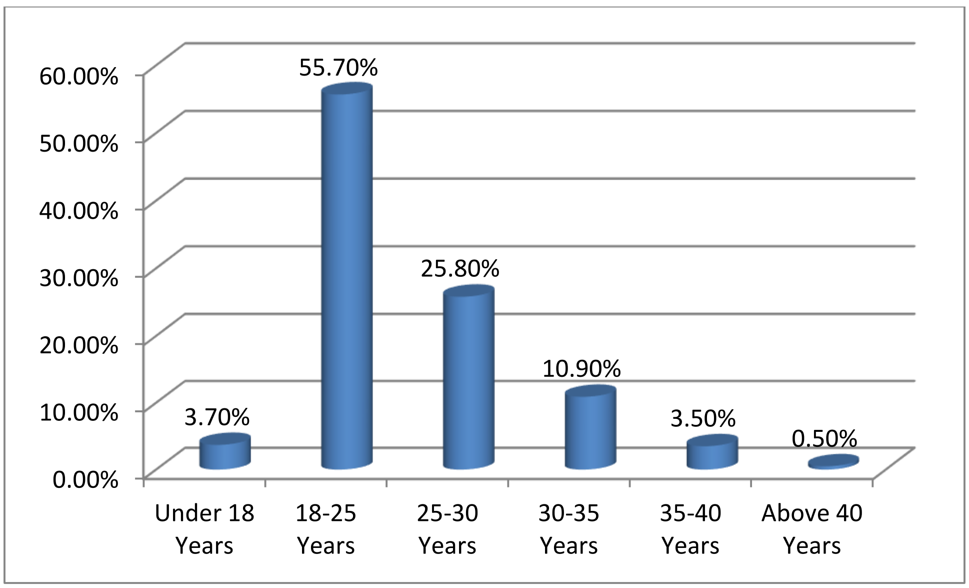


Figure 3 .Age distribution

In the study population 84.2% (n=431) of the pregnant women were married and 15.6% (n=431) single while only 0.2% (n=431) had a consensual union (table 2).

Table 2: Age * marital status Cross tabulation

Age	marital status			Total
	Single	Married	Consensual Union	
Under 18 Years	6	10	0	16
18-25 Years	45	195	0	240
25-30 Years	6	105	0	111
30-35 Years	7	39	1	47
35-40 Years	3	12	0	15
Above 40 Years	0	2	0	2
Percentage (%)	15.6	84.2	0.2	100

Majority of the pregnant women attending the clinics at the health centres in the study area had low level of education. Most of the pregnant women had either attained secondary or upper primary level of education at 40.4% (n=431) thus an indication that majority were either primary or secondary school drop outs. Fifteen point one percent (n=431) had tertiary education and 2.1% (n=431) had either no education or had lower primary education (figure 4). The study results is in congruence with the Kenya economic KIPPRA report (2013) which noted that literacy levels are still low in some counties with Primary education recording the highest participation rate, while access rates at ECDE, secondary and tertiary education were still low.

The continued implementation of Free Primary Education (FPE) from 2003 has led to improvement in access to primary school education and thus the observed numbers. Primary school completion and transition levels dropped to 76.8% in 2010 and further to 74.6% in 2011.Poor people are more likely to have low education levels. Primary and secondary school completion rates are the lowest amongst the poorest individuals (KIPPRA, 2013).

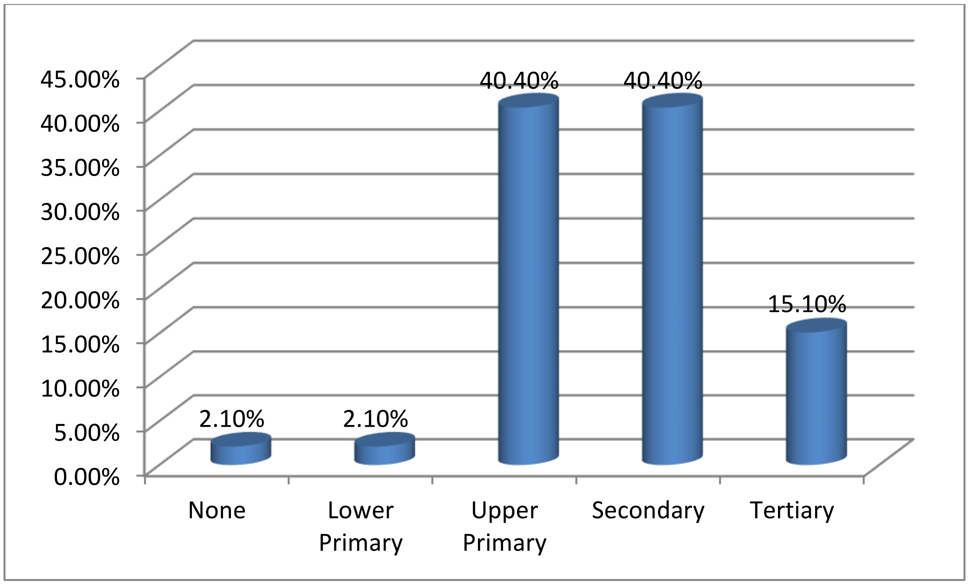


Figure 4: Distribution of levels of education

The average family income per month among the study population was relatively low. Only 4.5% (n=431) had an average family income of Ksh 20,000 and above. Majority of the families, 26.5% and 25.5% had an average monthly income of Ksh 2000-4000 and Ksh 4000-6000 respectively (figure 5).Poverty and well-being are often understood in terms of income. In 2005, close to 17 million Kenyans (47% of the populations) were estimated to be living in poverty (KIPPRA, 2013).In the same year(2005), the cost of basic food and non-food needs per month for one adult was established at Ksh 1,562 for rural areas and Ksh 2,913 for urban areas. Poverty rate may be referred to people living in households with per adult equivalent expenditures below these amounts. Today's most widely used measure of poverty is the number of people living on less than 1.25 dollars a day—the extreme poor (KIPPRA, 2013).The study results indicated high poverty levels among the study population.

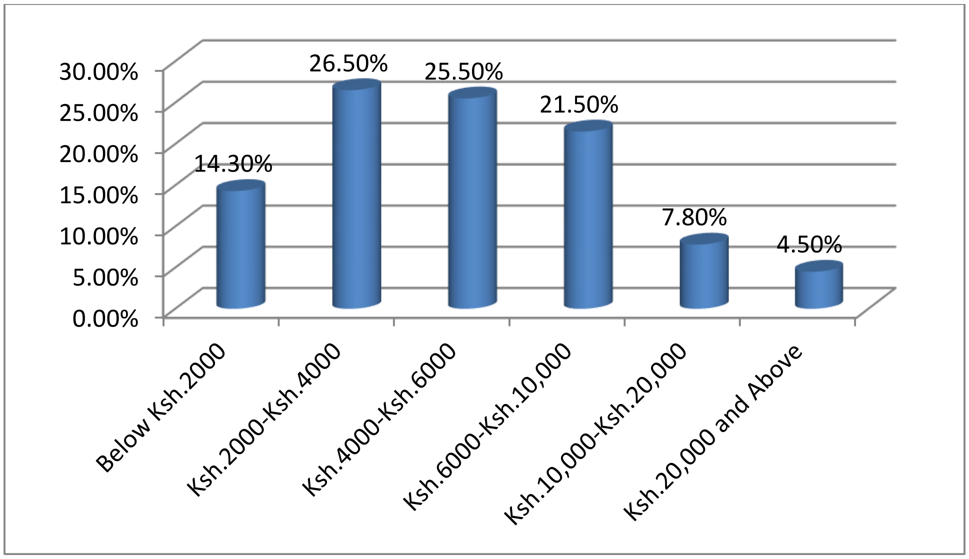


Figure.5: Distribution of average family income per month

Sixty point three percent (n=431) of the pregnant women in the study were unemployed and 10.9% (n=431) self-employed on small scale businesses (figure 6).This reflects the low family income and high poverty levels exhibited in the study area. According to the Kenya Economic Report 2013 (KIPPRA, 2013), youth unemployment is more acute in urban areas, and in 2005/06 it was estimated at 35.8% among those aged 20-24 years. Majority of the pregnant women in the study population were of this age group. Across all the age groups, women have lower unemployment rate relative to men. This is likely a reflection of the study results.

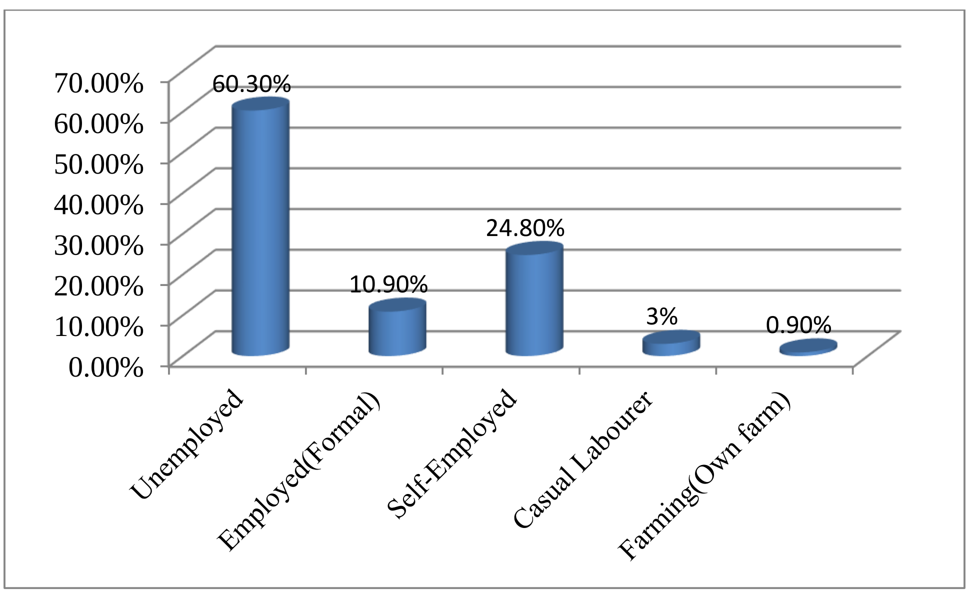


Figure.6: Distribution of economic activity of the pregnant women

Majority of the pregnant women studied at 53.7% (n=431) were in their 3rd trimester of pregnancy. This was an indication that majority attend antenatal care clinics in the last stage of pregnancy. Forty point four percent (n=431) were in the 2nd trimester while only 5.8% (n=431) were in their first trimester of pregnancy (figure 7).

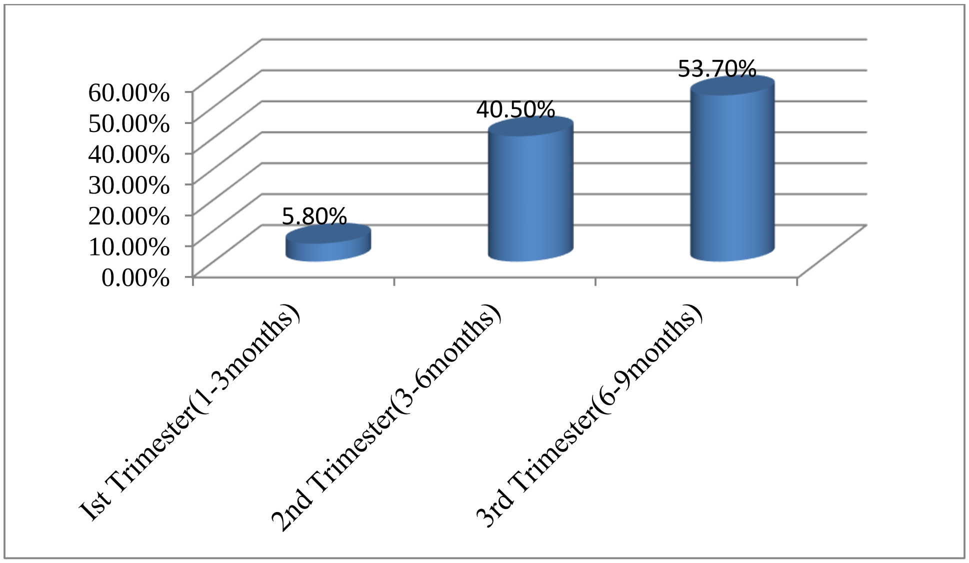


Figure.7: Trimester of pregnancy distribution graph

4.2 Prevalence rate of geophagia

Of the 431 respondents 151 (35%) were geophagous and 99 (23%) had experienced geophagia in their previous pregnancies. The study thus revealed that a substantial number of the respondents practiced geophagia. Both point and period prevalence rates were calculated. Point prevalence which refers to the prevalence measured at a particular point in time was 35 per 100 pregnant women i.e. the proportion of pregnant women who practiced geophagia at the time of the study. Period prevalence on the other hand refers to prevalence measured over an interval of time i.e. in this study the proportion of pregnant women who were geophagous in their previous pregnancies and at the time of the study. These were calculated as below.

$$\text{Point Prevalence rate} = \frac{\textit{All geophagous pregnant women during the study period}}{\textit{Total sampled population}} \times 100$$

$$= \frac{151}{431} \text{x} 100$$

= 35 geophagous pregnant women per 100 pregnant mothers

Period Prevalence rate

$$= \frac{\textit{All pregnant women who had experienced geophagia in the previous and current pregnancy}}{\textit{Total sampled population}} x100$$

$$= \frac{250}{431} x100$$

= 58 geophagous pregnant women per 100 pregnant mothers

The prevalence rates in this study are an indicative that geophagous behaviour might be more common and widespread in this society. Evidence from other studies in the country has recorded high prevalence rates of geophagia during pregnancy to be a common phenomenon. In a study by Ngozi (2008) involving 171 pregnant women in Pumwani Maternity Hospital-Nairobi, 74.0% reported eating soil regularly.

4.2.1 Point Prevalence rate per Trimester of Pregnancy

Point prevalence were calculated per trimester and results indicated in (figure 8). Geophagia was most prevalent at the 3rd trimester of pregnancy (table 3, figure 8). This corresponds with a period of high nutritional requirements and physiological changes of pregnancy.

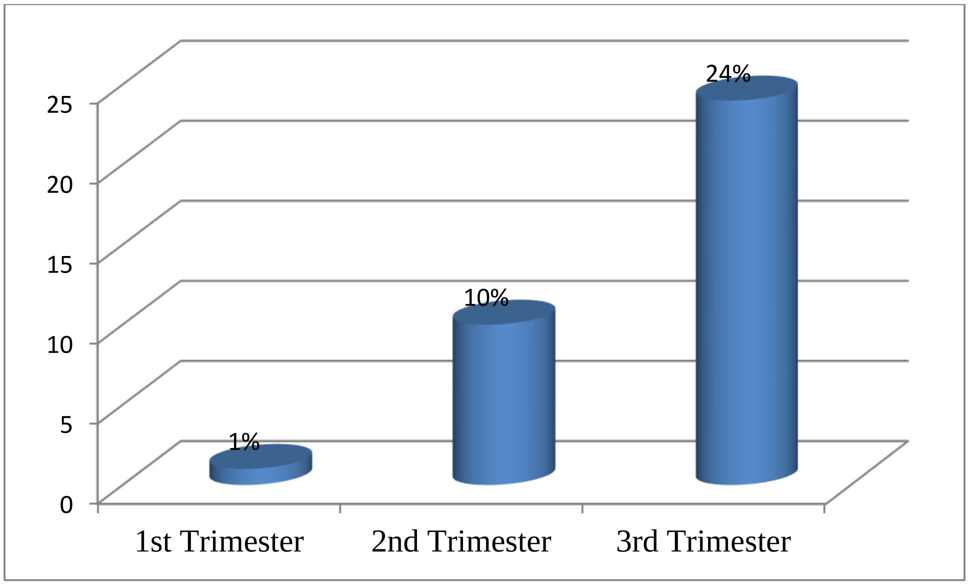


Figure.8: Point prevalence rate per trimester of pregnancy

Table 3: Experienced geophagia in the Pregnancy *Trimester of Pregnancy Crosstabulation

			Trimester(Period) of Pregnancy			
			Ist Trimester (1-3months)	2nd Trimester (3-6months)	3rd Trimester (6-9months)	Total
Experienced geophagia in the Pregnancy	Yes	Count	6	43	102	151
		% of Total	1.3%	10.0%	23.8%	35.0%
	No	Count	20	131	128	279
		% of Total	4.7%	30.5%	29.8%	65.0%

There was a statistical significant difference in the prevalence rate among the geophagous pregnant women in the different trimesters of pregnancy, (ρ=0.00,x^2=19.41). The observed high prevalence at the 3rd trimester corresponds with a period of high nutritional requirements and physiological changes of pregnancy.

4.2.2 Point Prevalence rate compared to the Age of the pregnant women

Point prevalence per age groups were calculated and the study results indicated that geophagia was most prevalent at age group 18-25 years (22%) and lowest with 1% at age group 35 years and above (table 4, figure 9). It is thus evident that geophagia was most prevalent among the youthful pregnant women.

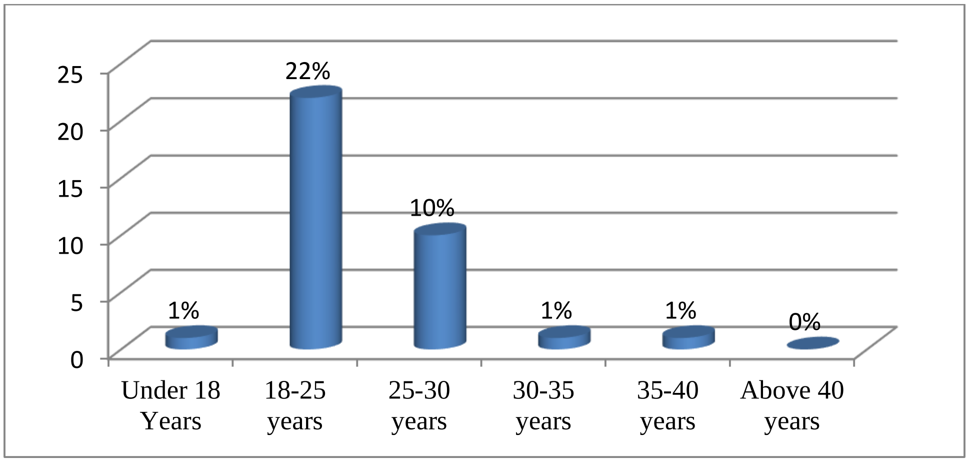


Figure.9: Point prevalence rate per age the pregnant women

Table 4:Experienced geophagia in the Pregnancy * Age Crosstabulation

			Age						Total
			Under 18 Years	18-25 Years	25-30 Years	30-35 Years	35-40 Years	Above 40 Years	
Experienced geophagia in the Pregnancy	Yes	Count	5	94	43	5	4	0	151
		% of Total	1.2%	21.9%	10.0%	1.2%	0.9%	0.0%	35.1%
	No	Count	11	145	68	42	11	2	279
		% of Total	2.6%	33.7%	15.8%	9.8%	2.6%	0.5%	64.9%

There was a statistical significant difference in the prevalence rate among geophagous pregnant women in different age groups, (ρ=0.006, x^2=16.519).A greater percentage (83.9%) of the age 18-25 years were geophagous compared to other age groups indicating that the habit was more prevalent among the young aged in the study population. This corresponds to high metabolic rate among the young aged compared to the old aged pregnant women. The high geophagia prevalence among the young mothers might result to lead accumulation in the body and thus adverse health effects during pregnancy.

4.2.3 Point Prevalence rate per the level of education

Point prevalence was also calculated per the level of education and results indicated in table 5 and figure 10below. Geophagia was most prevalent at 15% among the pregnant women with upper primary and secondary education. These were also the majority among the study population.

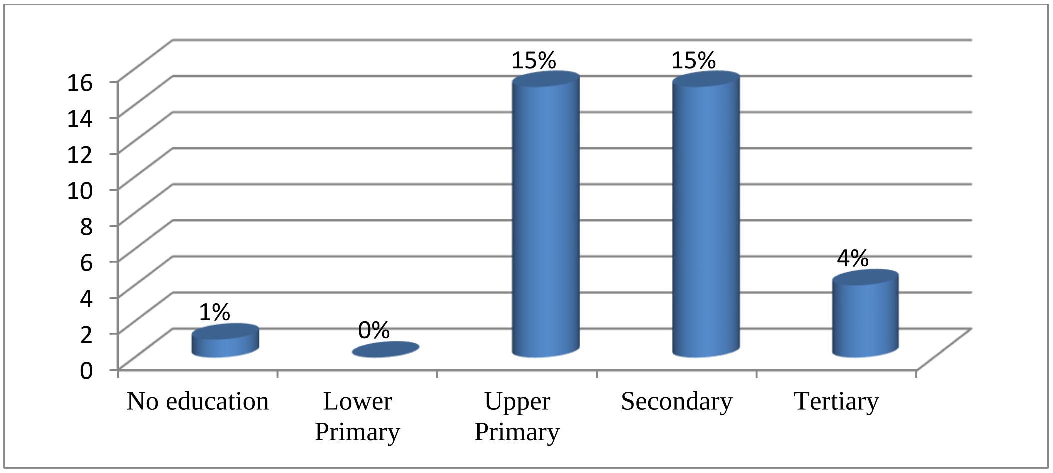


Figure.10: Point Prevalence rate per the level of education

Table 5: Experienced geophagia in the Pregnancy * Level of Education Cross tabulation

			Level of Education					Total
			None	Lower Primary	Upper Primary	Secondary	Tertiary	
Experienced geophagia in the Pregnancy	Yes	Count	3	1	65	64	18	151
		% of Total	0.7%	0.2%	15.1%	14.9%	4.2%	35.1%
	No	Count	6	8	109	109	47	279
		% of Total	1.4%	1.9%	25.3%	25.3%	10.9%	64.9%

There was no statistical significant difference in the prevalence rate among the geophagous pregnant women with different levels of education, (ρ=0.34, x^2=4.51). This is an indication that geophagia is a common practice independent of educational levels in the society.

4.2.4 Point Prevalence rate per family income

The most prevalent monthly family income among the study population was Ksh 4000-6000 at 10% and the least prevalent at 1% was Ksh20, 000 and above (table 6, figure 11).

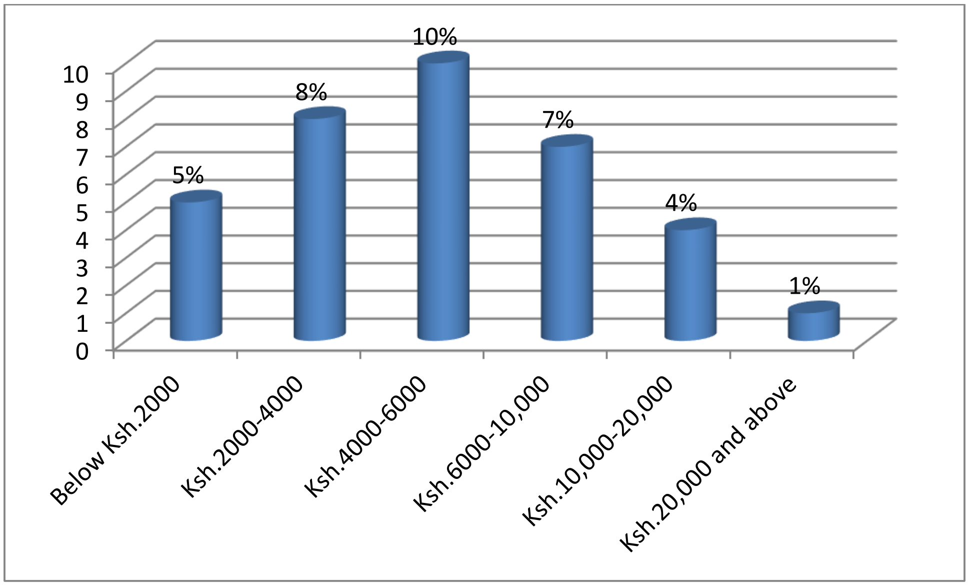


Figure11: Point Prevalence rate per monthly family income

Table 6: Experienced geophagia in the Pregnancy * Average Family income per Month Cross tabulation

			Average Family income per Month						
			Below Ksh.2000	Ksh.2000-4000	Ksh.4000 - 6000	Ksh.6000 - 10,000	Ksh. 10,000-20,000	Ksh. 20,000 and Above	Total
Experienced Pica in the Pregnancy	Yes	Count	18	31	41	30	15	5	140
		% of Total	4.5%	7.8%	10.3%	7.5%	3.8%	1.3%	35.1%
	No	Count	39	74	61	56	16	13	259
		% of Total	9.8%	18.5%	15.3%	14.0%	4.0%	3.3%	64.9%

There was no statistical significant difference in the prevalence rate among the geophagous pregnant women with different monthly family income, (ρ=0.33, x^2=5.74). This indicates that geophagia is independent of family income.

4.2.5 Perception and factors that may influence geophagia

Among the perceived reasons for the choice of the geophagic material included strong desire to eat i.e. craving, prevention of heartburn and spitting of saliva, lack of minerals, prevention of nausea, improvement of appetite, sweet aroma or odour, lack of minerals while others had no particular reason. Seventy four percent had a strong desire while 2.7% said they lacked mineral elements in the body (Table 7).

Table 7: Reason for the choice of the geophagic material

	Frequency	Percent (%)
Improves appetite	5	3.4
Lack of minerals	4	2.7
No particular reason	3	2.1
Prevents heart -Burns	13	8.9
Prevents nausea	5	3.4
Prevents spitting of saliva	2	1.4
Strong desire to eat	108	74.0
Sweet aroma or odour	6	4.1

Nineteen point five percent (n=431) of family members of the geophagous pregnant women were not geophagous while 14.9% (n=431) of family members of the geophagous pregnant women were also geophagous. Six point five percent of this percentage was their sisters, 5.8% their mothers and the remaining being other family members (table 8). Family members are likely to influence the behaviour due to family, peers and community shared habits and tendencies. This finding supports a study done among pregnant women in Zaria-Nigeria on characteristics of women with geophagous behaviour (Sule and Madugu, 2001). Mothers and other women in the household play a primary role in the transfer of geophagous behaviour from one generation to the next and in adulthood geophagia is exclusively associated with women (Vermeer and Frate, 1979). In Africa, the habit is widespread and is passed from one generation to another because of cultural beliefs and genuine enjoyment of the habit (Giessler *et al*, 1997).The findings confirm that geophagia might be a cultural practice passed from one generation to another within the family and in the community.

Table 8: Percentage of geophagous family members

	Frequency	Percent (%)
Mother	25	39.1
Child	3	4.7
Sister	28	43.8
Aunt	7	10.9
Grand mother	1	1.6

Fourty one point nine percent (n=431) of the geophagous pregnant women had no known positive reason towards their behaviour implying that geophagia might be a cultural behaviour. Thirty six point eight percent perceived satisfaction while 13.2% said that earth eating prevents or reduces heart burn (table 9).

Table 9: Positive aspects of geophagia as perceived by the respondents

	Frequency	Percent (%)
Increases appetite	4	2.9
No known positive reasons for geophagous behaviour	57	41.9
Perceived satisfaction	50	36.8
Prevents or reduces heart burn	18	13.2
Prevents spitting of blood	1	0.7
Provides Iron	1	0.7
Reduces abdominal pain	1	0.7
Stops or reduces nausea	4	2.9

According to Silverman and Weinberger (2008) geophagia places pregnant women at risk for parasitic infection, abdominal obstruction, vitamin and mineral deficiency, dental complications and constipation. In the study 26.4% perceived constipation as a negative aspect of geophagia while greater percentage (59.3%) of the respondents cited no known negative aspects of geophagous behaviour (Table 10).

Table 10: Negative aspects of geophagia as perceived by the respondents

	Frequency	Percent (%)
Causes Heart Burn	2	1.4
Causes Vomiting	2	1.4
Causes abdominal pain	3	2.1
Causes constipation	37	26.4
Causes decreased appetite	1	0.7
Causes Diarrhoea	1	0.7
Causes stomach ache	11	7.9
No known negative aspects for geophagous behaviour	83	59.3

4.3 Sources and types of consumed geophagic materials

The most preferred type of geophagic material for consumption at 88.8% was the soft earth stone also called "monyo" or "odowa" in local dialects. Ash from charcoal cooker or "Jiko'' in local dialect constituted 5.6% and 2.8% was either Soil from termite nests obtained from bark of trees or soils from walls of huts (table 11).

Table 11: Geophagic materials consumed by geophagous pregnant women

	Frequency	Percent (%)
Soft earth stones ('Monyo' or 'Odowa')	127	88.8
Ash from a charcoal cooker "Jiko"	8	5.6
Soils from Termite nests -bark of trees	4	2.8
Soils from Walls of huts	4	2.8

Majority of the respondents (43.1%) obtained the geophagic materials from kiosks/shops and thirty two percent from open air markets (figure 12). The materials obtained from the supermarkets were mainly soft stones. The findings corroborates a study by Crosby (1976), who reported that earth eating has spread from rural areas into the cities where the materials are sometimes obtainable from supermarkets.

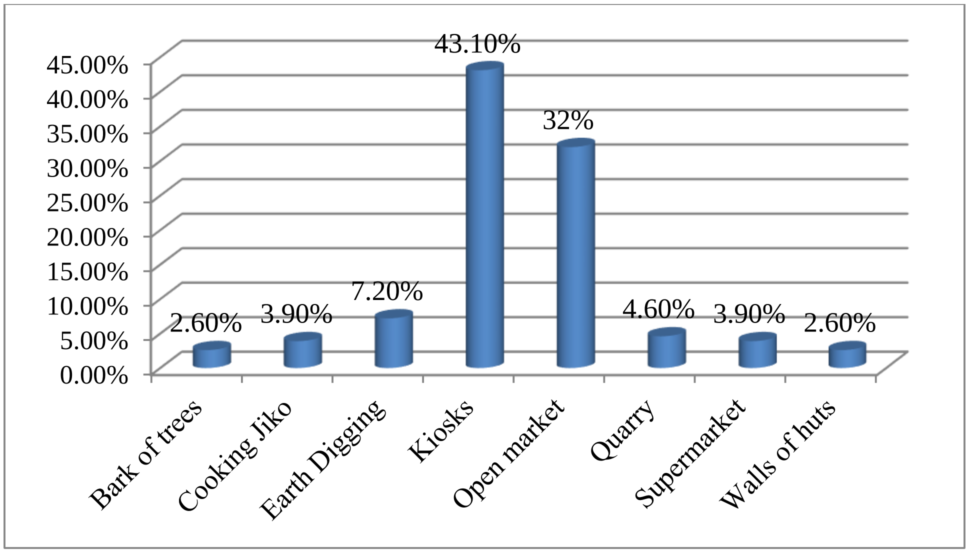


Figure12: Sources of geophagic materials

The substances and their sources reported to be ingested as presented are consistent with most of the commonly reported in the literature. A study done by Ngozi (2008) in Nairobi reported that 89.9% of the respondents ingested soft stones (odowa) regularly during pregnancy.Louba *et al*. (2004) observed in his study that the preferred type of earth eaten by Kenyan women was soft stone, known locally as odowa and earth from termite mounds. Other studies by Giessler *et al*. (1997) reported that the eaten geophagic soils were mainly from termite nests, weathered stones and walls of huts. The findings on the sources and types of geophagic substances reported by the respondents (figure 12 and table 11) showed that the materials are readily available and accessible in the respondents' environment. It is possible that the high accessibility to the substances has a positive influence on the prevalence and persistence of geophagia among the respondents. In this study 26.8% of the respondents treated the geophagic materials before consumption. The methods of pretreatment included; 12.4% burning in charcoal cooker i.e. "Jiko", 11.8% drying on the sun and 2.6% addition of salt to the material (table 12).The pretreatment methods may render the biological contaminants like geohelminths harmless and thus could influence the practice before consumption.

Table 12: Pretreatment methods done to geophagic materials before consumption

	Frequency	Percent (%)
Burning in a charcoal cooker (Jiko)	19	12.4
Drying in the sun	18	11.8
Addition of salt	4	2.6
No pretreatment	112	73.2

Such findings were also reported by Shinondo and Mwikuma (2008) in their study among pregnant women in Lusaka-Zambia. According to their study the clay was usually eaten in dry form, and sometimes smoked, roasted, or baked before consumption in order to enhance the flavour. This shows that pretreatment of geophagic materials is a practice among geophagous pregnant women.

4.4 Concentrations of heavy metals in the geophagic materials

Table 13 shows the mean concentrations of the heavy metals in various sampled geophagic materials collected from the geophagous women at different health facilities.

Table 13: Heavy metals concentrationsin geophagic materials in ppm

S/NO	Health Facility	Lead(Pb)		Zinc(Zn)		Iron(Fe)	
		$\bar{x}$	S.E	$\bar{x}$	S.E	$\bar{x}$	S.E
1	Langa Langa	1.38± 0.34		1.91	±0.27	79.68	±39.95
2	Kapkures	0.20±0.12		2.14	±0.11	76.43	±4.24
3	FITC	1.00	± 0.27	1.78	±0.41	68.39	±16.51
4	Lanet	2.80	± 0.68	1.88	±0.08	66.43	±5.82
5	Bondeni Maternity	3.13	± 0.43	1.15	±0.52	58.21	± 22.58
6	Bondeni Clinic	4.50	± 0.50	2.19	±0.19	90.48	±22.04
7	Mirugi Kariuki	4.25	± 0.25	1.90	±0.52	100.45	±38.84
8	Nakuru West	5.00	±0.50	1.17	±0.92	112.5	±33.93
9	KITI	5.00	±1.00	1.64	±1.01	62.68	±55.18
10	Barut	5.50	±0.50	2.35	±0.28	85.71	± 14.28

4.4.1 Lead

The average lead concentrations in one gram of the sampled geophagic materials at the various health centres ranged from 0.20ppm to 5.50ppm with mean of 3.28 (SE $\pm$ 0.59) ppm (table 13). High lead concentrations were observed in samples from the open air markets, kiosks and quarries (Appendix 5), an indication of high pollution of these geophagic substances with either vehicular substances or pollution from industries in the study area. The samples at Barut had the highest mean lead concentration of 5.50ppm with samples at Kapkures having the least lead concentration of 0.20ppm (table 13). It was observed that there is a lot of quarrying activities which involve sand harvesting at Barut. These quarries are some of the sources of the geophagic materials in the study site. The quarries might be polluted with vehicular substances and water run-off from industries which could contribute to the high lead concentrations. Small scale agriculture is the major activity in Kapkures. Low lead content on the geophagic materials at the site implies minimal lead contamination of the sources of these materials at the site.

4.4.2 Zinc

Considering all the health centres, the concentration of Zinc in one gram of the samples ranged from 1.15ppm to 2.35 ppm with mean concentration of 1.811 (SE $\pm$ 0.13) ppm (table 13). The samples at Barut had the highest Zinc concentration of 2.35ppm with samples at Bondeni Maternity having the least Zinc concentration of 1.15ppm (table 13). The relationship between zinc concentration in the geophagic materials with the sources (Appendix 6) and types (Appendix 7) of the materials was analysed by use of analysis of variance (ANOVA). The results of the analysis showed that there was no statistical significant difference in zinc concentrations among the different sources of geophagic materials (F-cal = 0.43, p=0.95) and also that there was no statistical significant difference in zinc concentrations in the different types of geophagic materials (F cal = 0.134, p=0.94).

4.4.3 Iron

The overall results showed that the sampled geophagic materials in the study area had high average concentrations of Iron of 80.096 (SE ±5.50) ppm per gram of sample (table13). This could be attributed to high Fe concentrations in the soils, implying high iron oxides in the geophagic materials.

Considering all the centres, the concentration of iron in the samples ranged from 58.21ppm to 112.5ppm. Samples at Nakuru West had the highest Iron concentration of 112.5 ppm with samples at Bondeni Maternity having the least Iron concentration of 58.21 ppm (table 13). The relationship between Fe concentrations and the type (Appendix 7) and the sources (Appendix 6) of the geophagic materials was analysed by use of ANOVA.

The computed statistical results showed that neither was there statistical significant difference in iron concentrations among the different sources of geophagic materials (F-cal = 0.86, p=0.61) nor was there statistical significant difference in iron concentrations in the different types of geophagic materials consumed (F-cal = 1.67, p=0.19).

4.5 Heavy metals exposure to geophagous pregnant women.

Table 14 shows the frequency of the total quantity of geophagic materials consumed per day by the geophagous pregnant women. Twenty four point eight percent of the women consumed an average amount of 20 grams of the geophagic materials per day while 16.8% consumed 110 grams and above per day.

Table 14: Frequencies of total quantity of geophagic material consumed per day

Amount (gms)	Mean	Frequency	Percent (%)
Below 10gms	10gms	28	18.8
10-30gms	20gms	37	24.8
30-50gms	40gms	24	16.1
50-70gms	60gms	10	6.7
70-90gms	80gms	15	10.1
90-110gms	100gms	10	6.7
110gms and Above	110gms	25	16.8

4.5.1 Lead exposure

The mean daily exposure ranges (table 15) calls for concern since ingesting any of the identified substances at that rate could lead to serious health problems and complications which may include premature birth, low birth weight, miscarriage and still birth. Other health problems may include impaired neurobehavioral development, decreased intelligence and impaired hearing acuity to the growing foetus. "Lead is an undisputed neurotoxin; it is poisonous to the foetus growing and developing brain" (CDC, 2005).

Table 15: Average daily exposure ranges of Lead

Pb conc. = 3.27ppm(SE ± 0.59) per gram of sample		
Daily consumption of geophagic material(grams)		Exposure per daily consumption(ppm)
Range	Mean	Mean daily exposure
Below 10gms	10	32.76
10 to 30gms	20	65.52
30 to 50gms	40	131.01
50 to 70 gms	60	196.56
70 to 90 gms	80	261.82
90 to 110gms	100	327.6
110gms and above	110	360.36

Twenty four point eight percent of the geophagous pregnant women consumed an average of 20grams per day of the geophagic materials (table 14). This was equivalent to 65.52ppm daily lead exposure. The exposure exceeded the World Health Organization recommended daily tolerable intake of 25 ppm per day for pregnant women (WHO, 2000). The computed results of one sample t- test showed that there was a statistical significant difference in the mean daily lead exposure compared to the WHO daily tolerable intake limits,(t-cal = 3.58, p=0.012). Lead is toxic at very low exposures and even the lowest doses can impair the nervous system.

Table 16 shows the approximate average total amount of the materials consumed by the pregnant women in a day at different trimesters of their pregnancy. Generally women in the 3^{rd} trimester of pregnancy consumed large amount of the materials for example seventeen out of twenty five pregnant women who consumed an average total quantity of 110 gms and above were in their 3^{rd} trimester of pregnancy (table 16). However it was observed that there was no statistical significant difference on the quantities of the material consumed at different trimesters of pregnancy, (ρ=0.84, x^2=7.21).

Table 16: Trimester of Pregnancy * Total quantity of geophagic material consumed per day Cross tabulation

		Total Quantity consumed per day						
		Below 10gms	10-30 gms	30-50 gms	50-70 gms	70-90 gms	90-110 gms	110 gms and Above
Trimester of Pregnancy	Ist Trimester (1-3months)	1	1	0	0	0	1	2
	2nd Trimester (3-6months)	10	9	7	4	4	2	6
	3rd Trimester (6-9months)	17	27	17	5	11	7	17

Considering the modes in (table 16), the total average daily lead exposure across the three trimesters exceeded the WHO safety data on lead for example two pregnant women in their 1st trimester consumed an average of 110 grams per day which was equivalent to daily lead exposure rate of 360.36ppm. It is thus evident from the study that a significant number of pregnant women, and presumably their infants, are being exposed to high lead concentrations in the study area. Chronic lead exposure may cause irreversible dysfunction and morphologic changes, resulting in eventual renal failure and death, besides lead intoxication have adverse effects in the first trimester of pregnancy since during the period, there is extensive cell division and development of the central nervous system (Middendorf and Williams, 2000). Geophagia will therefore increase the risk for lead exposure. The findings are of concern since lead exposure is estimated to account for 0.6% of the global burden of disease, with the highest burden in developing regions (WHO, 2009).

4.5.2 Zinc exposure

Adequate Zinc is extremely important during the 1st trimester when organs are formed and may play a role in assisting in immune system development. The tolerable daily Zinc intake during pregnancy is 11000 ppm (Shah and Sachdev, 2006). The daily Zinc exposure levels (table 17) were of no toxic concern to the study population for example considering the modes in (table 16) two pregnant women in their 1st trimester consumed an average of 110 grams per day which is equivalent to zinc concentration of 199.21 ppm per day. Depending on the bioavailability this may supplement the dietary intake though if there is sufficient dietary intake this can lead to zinc toxicity. The human health effects associated with zinc deficiency are numerous, and include neurosensory changes, impaired neuropsychological functions, growth retardation, delayed wound healing, immune disorders and dermatitis. These conditions are generally reversible when corrected by zinc supplementation.

Zinc is not stored in the body and excess intakes result in reduced absorption and increased excretion. Nevertheless, if usual zinc intake is above the upper levels of intake (UL of 25000 ppm zinc per day)an individual may be at risk of adverse effects from excessive nutrient intake. An excess of zinc can result in a decreased availability of dietary copper, and the development of copper deficiency(Cousins, 1990), When ingested zinc levels are very high, zinc is believed to inhibit copper absorption through interaction with metallothionein at the brush border of the intestinal lumen (Festa 1985).

Prolonged intakes of zinc supplements ranging from 50000 ppm/day up to 300000 ppm/day have been associated with a range of biochemical and physiological changes which include hypocupraemia, leucopaenia, sideroblastic anaemia, decreased concentrations of plasma copper and decreased activity of the copper containing enzymes-superoxide dismutase, altered lipoprotein metabolism and impaired immune function (Sandstead, 1995). Excessive intake of zinc (300000 ppm/day) for six weeks can impair immune responses i.e. reduction in lymphocyte stimulation response to phytohaemaglutinin as well as chemotaxisand phagocytosis of bacteria by polynuclear leucocytes (Chandra, 1984).

Table 17: Average daily exposure ranges of Zinc

Zn conc. =1.811ppm (SE ± 0.13) per gram of sample		
Daily consumption of geophagic material(grams)		Exposure per daily consumption(ppm)
Range	Mean	Mean daily exposure
Below 10gms	10	18.11
10 to 30gms	20	36.22
30 to 50gms	40	72.44
50 to 70 gms	60	108.66
70 to 90 gms	80	144.88
90 to 110gms	100	181.1
110gms and above	110	199.21

4.5.3 Iron exposure

Pregnant women in the 3rd trimester of pregnancy consumed large amount of geophagic materials for example seventeen out of twenty five pregnant women who consumed an average total quantity of 110gms and above were in their 3rd trimester of pregnancy (table 16). This corresponds to high nutrient requirements for example iron at this period of pregnancy. The daily exposure limits for iron during pregnancy is 27000 ppm/day (Beard, 2008). Considering the modes in (table 16), twenty seven pregnant women in their 3rd trimester consumed an average of 20grams per day an equivalent of 1601.92 ppm per day. The observed iron exposure levels were therefore of no toxic concern among the study population. This is also illustrated in (table 18) below which shows the mean daily exposure per daily amount of consumption. Pregnant women require increased amounts of iron, and absorption of dietary iron from the gut is normally increased (Baker, 2006). If bioavailable the observed concentrations may supplement the dietary intake although in cases where medicinal iron supplement are used by the pregnant women this might result to excessive intakes. It has been theorized although never proved, that geophagia may signal iron deficiency (Mills, 2007). Though too much geophagic material can result to blocked bowels and crowd out, preventing absorption of the nutrients like iron needed by the baby.

Table 18: Average daily exposure ranges of Iron

Fe conc. = 80.096 ppm(SE $\pm$5.50) per 1 gram of sample		
Daily consumption of geophagic material(grams)		Exposure per daily consumption (ppm)
Range	Mean	Mean daily exposure
Below 10gms	10	800.96
10 to 30gms	20	1601.92
30 to 50gms	40	3203.84
50 to 70 gms	60	4805.76
70 to 90 gms	80	6407.68
90 to 110gms	100	8009.6
110gms and above	110	8810.56

4.6 Geohelminths exposure to the geophagous pregnant women

Geophagia may be a risk factor for parasitic infections. In this study there were no observable eggs, larvae or adult *Ascaris lumbricoides*, *Trichuris trichiura*, *Taenia Spp* and hookworm-*Necator americanus* and *Ancylostoma duodenale* in the sampled geophagic materials examined in the laboratory. The results showed that there was no contamination of the sampled geophagic materials from their various sources by geohelminths. It might have also been as a result of pretreatment of the materials before consumption (table 12) or as a result of storage and transportation of the materials in the markets, kiosks, supermarkets or homes by the geophagous women and the traders. The finding supports a parasitological study done by Shinondo and Grace (2008) in Lusaka-Zambia, the study indicated that the types of soil ingested by geophagous pregnant women did not contain helminth ova. Geohelminths ova of *Ascaris lumbricoides* and *Trichuris trichiura* require moisture to survive and embryonate (Shinondo and Grace, 2008). The pretreatment, storage and transportation might hinder their survival. The findings in this study also corroborates a similar study among school children in Western Kenya which showed that geophagia does not directly contribute substantially to the infections with soil-transmitted helminths at least in the dry season (Giessler, *et al* 1997).

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study has provided baseline data for further research on geophagia and related issues among pregnant women in Kenya.In conclusion:-

1. There was relatively high point and period prevalence rate of geophagia at 35% and 58% respectively. Geophagia was most prevalent at the age of 18-25 years and lowest at the age of 35 years and above, it was also most prevalent at the 3rd trimester of pregnancy, a period during which there is increased iron deficiency anaemia.
2. The geophagic materials consumed contained heavy metals-Iron, Zinc and Lead thus the women were exposed to these heavy metals. High concentrations of Fe were observed compared to the other heavy metals.
3. The daily lead exposure exceeded the WHO recommended daily tolerable intake of 25 ppm per day for pregnant women.
4. There were no ova or adult geohelminths- *Ascaris lumbricoides*, *Trichuris trichiura*, *Taenia Spp* and hookworm-*Necator americanus* and *Ancylostoma duodenale* recovered from any of the soil types preferred by the pregnant women, and as such geophagia was an unlikely risk for geohelminth infections among the study population.

5.2 Recommendations

Assisting women to deal with unpleasant behaviour in pregnancy like geophagia should be a focus of antenatal care to prevent any complications that may occur in pregnancy, labour, delivery and post-partum. As a result of the study the following were recommended:-

1. Geophagia, lead screening and testing in pregnancy should be integrated in antenatal support care systems. This will curb the possible adverse birth outcome as a result of lead and other harmful exposures from geophagia.
2. Studies are necessary to establish possible health consequences of geophagia on mother and child.Further studies should be conducted to ascertain the bioavailability of these heavy metals and their possible adverse health impacts to the mother and the foetus.

REFERENCES

Abrahams, P, Parsons, J. (1996). Geophagy in the Tropics,A literature review. *Geogr J* , 162:63-72.

Abrahams, P, Follansbee, M., Hunt, A., Smith, B.,Wragg, J. (2006). Iron nutrition and possible lead toxicity:an appraisal of geophagy under-taken by pregnant women of UK Asia communities. *Appl Geochem*, 21:98-108.

Al-Kanhal,M.A;Bani,I.A. (1995). Food habits during pregnancy among Saudi Women. *Int.J.Vitam Nutr Res* , 65:206-10.

Aneli, B, Lagercrantz, S. (1958). Geophagical Customs. *Almquist and Wilksells Boktryckeri,Uppsola*.

Ashley, P, Heather, F., Mackenzie, S., Shawn, L.,Gerstenberger. (2012). Lead Poisoning due to Geophagia:the consumption of Miniature Pottery. *Open Journal of Pediatrics 2*, 60-66.

Baker.N, Phillip. (2006). *Obstetrics by Ten Teachers.* Manchester, UK: BookPower.

Beard, J. (2007). Recent Evidence from Human and Animal Studies Regarding Iron Status and Infant Development. *J.Nutr.*, 137:524S-530S.

Beard.J.L. (2008). Why Iron deficiency is important in infant development. *Journal of Nutrition*, 138(12),2534-2536.

Barteson.E;Lebroy.T. (1978). Clay eating by Abroriginals of the Northern Territory. *The Medical Journal of Australia*, 1(1):1-3.

Bhowmik, D, K.P, C, Kumar, S. (2010). A Potential medicinal importance of zinc in human health and chronic Disease. *Int J Pharm Biomed Sci2010*, 1(1),05-11 .

Bothwell, T. H. (2000). Iron requirements in Pregnancy and strategies to meet them. *Am JCl Nutr*, Vol.72,No.1,257s-264s.

Bouchet, F. (1997). Recovery of helminth eggs from Archaeological Excavations of the Grand Louvre(Paris France). *The journal of Parasitology*, 81:785-787.

Cavdar, A, Arcasory, A, Cin, S, Babacan, E, Gozdasoglu, S. (1983). Geophagia in Turkey:iron and Zinc deficiency,iron and zinc absorption studies and response to treatment with zinc in geophagia cases. *Prog Clin Biol Res 129*, 71-97.

Chandra.R.K. (1984). Excessive intake of zinc impairs immune responses. *JAMA*, 252:1443-1146.

Chow, SC;Wang H;Shao J. (2007). *Sample Size Calculation in Clinical Research,2nd ed.* New York: Chapman and Hill/CRC.

Cousins.RJ;Hempe.JM. (1990). *Zinc in Brown ML,ed.Present knowledge in nutrition.* Washington,DC: International Life Sciences Institute.

Crosby.W.H. (1976). When friends and patients ask about pica. *JAMA*, 235,2765.

Dawson, B;Trapp.R.G. (2004). *Basic and Clinical Biostatistics,4th ed.* New York: Lange Medical Books/Mc Graw-Hill.

Dean, J, Deary, M, Gbefa, B, Scott, W. (2004). Characterization and analysis of persistent organic pollutants and major,minor and trace elements in Calbash chalk. *Chemosphere*, 57:21-5.

Diemert,DJ;Bethony,JM;Hotez,PJ. (2008). Hookworm vaccines. *Clin Infect Dis 46:*, 282-288.

Festa.D;Anderson.H.L;Dowdy.R.P;Ellersieck.M.R. (1985). Effects of Zinc intake on copper excretion and retention in men. *American journal of clinical Nutrition*, 41:285-292.

Fessler, D. (2002). Reproductive immunosuppression and diet. *Curr.Anthropol.*, 43:19-60.

Flaxman, S, Sherman P. (2000). Morning sickness:a mechanism for protecting mother and embryo. *Q.Rev.Bio*, 75:113-148.

Foeken, D. W., Owuor., S. O. (2000). *Urban Farmers in Nakuru Kenya.* Leiden,The Netherlands: African Studies Centre.

Fraser M.Diane;Margaret A.Cooper;Anna G.W.Nolte. (2006). Textbook for Midwives. In *Problems of pregnancy* (pp. Pg 284-285). London UK: Churchill Livingstone,Elsevier.

Giessler, A., Mwaniki, D., Thiongo, F., Friis, H. (1997). Geophagy among school children in Western Kenya. *Trop Med Int Health*, 2:624-630.

Giessler,P,W.Shulman,C.E.Prince;R.J. (1998). Geophagy,Iron status and anaemia among pregnant women on the coast of Kenya. *Trans.R.Soc.Trop.Med.Hyg.*, 92:549-553.

Glickman, L, Chaudry, I, Costantino, J, Clack, F, Cypress, R, Winslow, L. (1981). Pica patterns,toxocariasis and elevated blood lead in children. *Am J Trop Med Hyg*, 30:191-195.

Government of Kenya, KNBS. (2000). Demographic Survey. Nairobi.

Government of Kenya, KNBS. (2010). Population and housing census. Nairobi.

Gupta, R,Gupta, R. (2005). Clinical Profile of Pica in Childhood. *JK Science 7,* 61-63.

Habold, C, Reichart, F, Le, M, Angel, F, Liewig, N, Lignot, J. (2009). Clay ingestion enhances intestinal triacyglycerol hydrolysis and non esterified fatty acid absorption. *Br J Nutr*, 102:249-57.

Halsted, J. (1968). Geophagy in man;its nature and Nutritional effects. *AM J Clin Nutr* , 21:1384-93.

Holtzman, D, DeVries, C, Nguyen, H, Bensch, K. (1984). Maturation of resistance to lead encephalopathy:cellular and subcellular mechanisms. *Neurotoxicology*, 5,97-124.

Hood, P, Henry, J, Seyoum, T, Armstrong, L, Fowler, M. (2002). The potential impact of geophagia on the bioavailability of iron,zinc and calcium in human nutrition. *Environ Geochem Health*, 24:305-19.

Holcombe, C (1995) Surgical emergencies in tropical gastroenterology. Gut 36: 9–11.

Hunter.J.M. (1993). Macroterme geophagy and pregnancy clays in Southern Africa. *J.Cultural Geography*, 14:69-92.

Ilich, J. Z., Kerstetter, J. E. (2000). Nutrition in Bone Health Revisited:A story Beyond Calcium. *American College of Nutrition*, Vol.19,No.6,715-737.

John, T.,Duquette, M. (1991). Detoxification and mineral supplementation as functions of geophagy. *Am J Clin Nutr*, 53;448-56.

Jorgen Hansen;Brian Perry. (1987). *The epidemiology,Diagnosis and Control of Helminth Parasites of Ruminants.* Addis Ababa,Ethiopia: International Laboratory for Resarch on Animal Diseases.

Kibet L. (2004).Use of environmental accounting to estimate optimal extraction levels for quarries: Case of Nakuru Municipality.Beijer Institute of Ecological Economics Addis Ababa.

KIPPRA. (2013). *Kenya Economic Update.* Nairobi: KIPPRA.

Kuwai, K., Saathoff, E., Antelman, G., Msamanga, G., Fawzi, W. (2009). Geophagy (soil eating) in relation to anaemia and helminth infection among HIV infected pregnant women in Tanzania. *Am J Trop Hyg*, 80:36-46.

KNBS. (2008-2009). *Kenya Demographic Health Survey.* Nairobi: KNBS.

Kuwai, K., Saathoff, E., Antelman, G., Msamanga, G.,Fawzi, W. (2009). Geophagy (soil eating) in relation to anaemia and helminth infection among HIV infected pregnant women in Tanzania. *Am J Trop Hyg*, 80:36-46.

Lacey, E.P, (1990). Broadening the perspective of pica:Literature review. *Public Health Rep*, 105:29-35.

Luoba, A., Giessler, P., B, E., Ouma, J., Alusala, D., Ayah, R. (2005). Earth -eating and reinfection with intestinal helminths among pregnant and lactating women in western Kenya . *Trop Med Int Health* , 10:220-7.

Luoba, A., Giessler, P., Estambale, B., J.H, O., Magnussen, P., Alusala, D. (2004). Geophagy among pregnant and lactating women in Bondo District,western Kenya. *Trans R Soc Trop Med Hyg* , 98:734-41.

Malhotra,I;Ouma,J;Wamachi,A;Kioko,J;Mungai,P. (1997). In utero exposure to helminth and mycobacterial antigens generates cytokine responses similar to that observed in adults. *J Clin Invest 99*, 1759-1766.

Markov, J.,Goldstein, G. (1988). Picomolar concentrations of Lead stimulate brain protein kinase C. *Nature*, 334:71-73.

Melville.B;Francis.V. (1992). Dietary habits and Superstitions of Jamaican Women during pregnancy. *Euro.Journal Clinical Nutrition*, 463:373-374.

Middendorf, F.,Williams, P. (2000). *Nephrotoxicity:Toxic responses of the kidney.* New York: John Wiley and Sons,Inc.

Mills, M. (2007). Craving more than food:The implications of pica in pregnancy. *Nursing for Women's Health*, 11(3),266-273.

Murrray-Kolb, L. E., Beard, J. L. (2007). Iron treatment normalizes cognitive functioning in young women. *Am J Cl Nutr*, 85:778-87.

Municipal Council of Nakuru. (1999).Census. Kenya National Bureau of Statistics.Nairobi.

Mogongoa.LF,Brand.CE,De jager.L. (2011). Haematological and Iron status of qwagwa women in South Africa who ingest Clays. *Medical Technology SA*, 25(1).

Moturi.W.N,Shivoga.W.A. (2009). Geophagia,a risk factor for diarrhoea in home environment:study of Mauche division,Molo,Kenya. *J Infect Developing Countries*, 3(2):94-98.

Morgan.R.B. (1984). Pica. *JR Soc Med*, 77,1052-1054.

Needleman, H. (2004). Lead poisoning. *Annual review of Medicine*, 55,209-222.

Needleman, H., Schell, A., Bellinger, D., Leviton, A., Allred, E. (1990). The long term effects of exposure to low doses of lead in childhood.An 11 year follow up report. *New England Journal of Medicine*, 322,83-88.

Ngozi,P.O. (Feb 2008). Pica practices of pregnant women in Nairobi Kenya. *East African Medical journal* , Vol.85 No 2.

Nriagu, J. (2007). Zinc toxicity in humans. *Elsevier.B.V.*, 1-7.

Nyasani, I. B. (2009). *Kenya's experience on urban health issues.* Nakuru: Urban HEART pilot-testing project .

Okalebo, J.R;Gathua,K.W;Woomer,L.P. (2002). *Laboratory Methods of Soil and Plant Analysis. A working Manual.* TSBF-CIAT and Sacred Africa. Nairobi,Kenya,pp.22-24

Osendarp,SJ;Van Raaij,JM;Darmstadt,GL;Baqui,AH;Hautvast,JG;Fuchs,GJ. (2001). Zinc supplementation during pregnancy and effects on growth and morbidity in low birth weight infants:a randomized placebo controlled trial. *Lancet*, 357(9262):1080-85.

Patrick, Y. (2007). A case of geophagia. *University College London:Clinical Vignette*, 1-3.

Prasad, A. (1998). Zinc in human health. *J Trace Elem,*, 11:63-87.

Quinnell,RJ,BethonyJ,Pritchard,DI. (2004). The immunoepidemiology of human hookworm infection. *Parasite Immunol 26:*, 443-454.

Silverman,R;Weinberger,H. (2008). Lead Screening and Testing in Pregnancy. Vol 1.Issue 2.

Saathoff, E., Olsen, A., Kvalsvig, J.,Giessler, P. (2002). Geophagy and its association with geohelminth infection in rural school children from northern KwaZulu-Natal,South Africa. *Trans R Soc Med Hyg*, 96:485-90.

Salimi,S;Yaghmaei,M;Joshaghani,HR;Mansourian,AR. (2004). Study of Zinc deficiency in pregnant women. *Iranian J Publ Health,*, Vol 33,No.3,pp.15-18.

Sandstead.H.H. (1995). Is zinc deficiency a public health problem? *Nutrition*, 11:87-92.

Sayetta, R. (1986). Pica:An overview. *Am Fam Physician*, 33;181-185.

Shah.D;Sachdev.H.P. (2006). Zinc deficiency in pregnancy and foetal outcome. *Nutrition Reviews*, 64(1),15-30.

Shah,D;Sachdev,HP. (2001). Effect of gestational zinc deficiency on pregnant outcomes:summary of observation studies and zinc supplementation trials . *Br J Nutr,85 Suppl*, 2:S101-8.

Shinondo, Cecilia, Grace.Mwikuma. (2008). Geophagy As a Risk Factor For Helminth Infections In Lusaka,Zambia. *Medical Journal of Zambia*, Volume 35 number 2:50-51.

Smulian,J.C;Motiwala,S.and Sigma,R.K. (1995). Pica in Rural obstetric population. *South Med J.*, 88:1236-1240.

Stephenson, LS, Latham, MC, Ottesen EA. (2000). Malnutrition and parasitic helminth infections. SupplS23–S38. *Parasitology 121:*, SupplS23–S38.

Stokes, T. (2006). The earth eaters. *Nature*, 444:543-544.

Sule.S;Madugu.H.N. (2001). Pica in pregnant women in Zaria,Nigeria. *Niger J.Med.*, 10:25-27.

Sz ajewska, H, Dz iechciarz, J, Mrukowicz, J. (2006). Meta-analysis:Smectite in the treatment of acute infectious diarrhoea in children. *Aliment Pharmacol Ther* , 23:217-27.

Vermeer, D, Ferrell, R. (1985). Nigerian geophagical clay:A traditional antidiarrheal pharmaceutical. *Science*, 227:634-6.

Vermeer.D.E;Frate.D.A. (1979). Geophagia in rural Mississippi Environment and Cultural Contexts and Nutritional Implications. *AM.J.Clinical nutrition*, 32:212-213.

Viksna, A,Lindgren, E. (1997). Determination of Lead and Cadmium in whole blood of mothers and their babies. *Analytica Chimica Acta*, 353,307-311.

Villar J, Klebanoff M, Kestler E. (1989). The effect on foetal growth of protozoan and helminthic infection during pregnancy. *Obstet Gynecol*, 74: 915–920.

Von Garnier,C;Stunitz,H;Decker,M;Battegay,E;Zeller,A. (2008). Pica and refractory iron deficiency anaemia. *Journal of Medical Case Reports*, 2(324).

Walker,A.R.P;Walker,B.F;Sookaria,F.I;Cannan,R.J.(1997). Pica. *J Ray Soc.Health*, Vol 117 Pos.

Whitney,EN;Rolfes,SR. (1993). Understanding Nutrition 6th edition. *West Publishing Company*, PP411.

WHO. (2009). Global health risks:Mortality and burden of disease attributable to selected major risks. *Geneva,World Health Organization*.

WHO. (2012). *Eliminating Soil-Transmitted Helminthiases as a Public Health Problem in Children.* Geneva: WHO.

WHO, FAO. (2004). *Vitamins and Mineral Requirements in Human Nutrition:13.Iron.* Geneva: World Health Organization.

WHO, UNICEF, UNU. (2001). *Iron Deficiency:Assessment,Prevention and Control.* Geneva: World Health Organization.

WHO. (1995). Lead Environmental Criteria. *World Health Organization,Geneva*.

WHO. (2000). *Lead.In:Safety Evaluation of Certain Food Additives and Contaminants.Joint FAO/WHO expert Committee on Food Additives*,Food Additives Series:44. Geneva,Switzerland: World Health Organization.

Williams, P, James, R, Roberts, S. (2000). *Principles of Toxicology.* New York: John Wiley & Sons,Inc.

Wong, M, Bundy, D, Golden, M. (1988). Quantitative assessment of geophagous behaviour as a potential source of exposure to geohelminth infection. *Transactions Royal Soc.Trop.Med.Hygiene*, 82:621-625.

World Health Organization. (2002). *Prevention and control of schistosomiasis and soil-transmitted helminthiasis.* Geneva,Switzerland: WHO.

World Health Organization. (2012). *Eliminating Soil-Transmitted Helminthiases as a public Health Problem in Children.* Geneva: WHO.

Woywodt, A, A, K. (March 2002). Geophagia:the history of earth eating. *J R Soc Med*, 95(3):143-146.

Young, S. L,Goodman D,Farag T.H,Ali S M,Khatib M R. (2007). Association og geophagia with Ascaris,Trichuris and Hookworm transmission in Zanzibar,Tanzania. *Trans R Soc Trop Med Hyg*, 101:766-772.

APPENDICES

Appendix1: Questionnaire

Instructions: All questions should be answered. Where not applicable, it should be indicated. Where there are choices, tick the correct answer. Where applicable, you may tick more than one answer. Where choices have not been given, fill in the correct answer.

<table>
<tr><th colspan="2">DEMOGRAPHIC DATA</th></tr>
<tr><td colspan="2">Name of enumerator:</td></tr>
<tr><td>SECTION A</td><td>CODE</td></tr>
<tr><td>1. Residential area of the respondent
Estate…………………………………………..
Sub-location…………………………………….
Location…………………………………………</td><td></td></tr>
<tr><td>2. Marital Status
▪ Single
▪ Married
▪ Consensual union
▪ Widowed
▪ Divorced/separated</td><td></td></tr>
<tr><td>3. Age
▪ Under 18 years
▪ 18-25 years
▪ 25-30 years
▪ 30-35 years
▪ 35-40 years
▪ Above 40 years</td><td></td></tr>
<tr><td>4. Level of education
▪ None
▪ Lower primary
▪ Upper primary
▪ Secondary
▪ Tertiary</td><td></td></tr>
<tr><td>5. In addition to housekeeping, what economic activity is mother involved in?
▪ Unemployed
▪ Employed(formal)
▪ Self-employed(small business)
▪ Casual labourer
▪ Farming(own)
▪ Other (specify)</td><td></td></tr>
<tr><td>6. On average, what is your family income per month?
▪ Below Ksh. 2000
▪ Ksh. 2000 to Ksh. 4000
▪ Ksh. 4000 to Ksh. 6000</td><td></td></tr>
</table>

▪ Ksh. 6000 to Ksh.10000 per month ▪ Ksh. 10000 to Ksh.20000 per month ▪ Ksh. 20000 and above	
SECTION B	
7. In what trimester are you in your pregnancy? ▪ 1st Trimester (1st to 12th weeks) ▪ 2nd Trimester (12th to 24th weeks) ▪ 3rd Trimester (24th to 40th weeks)	
8. Have you experienced any complication during this pregnancy? If yes explain	
9. How many past pregnancies have you had?	
10. How many previous births have you had?	
11. Have you experienced any complications during the past pregnancies? If yes explain	
12. Have you experienced any form of pica during this pregnancy?	
13. If yes what non-food items do you ingest?	
14. Have you experienced pica in previous pregnancies?	
15. If yes, what non-food items did you consume?	
SECTION C	
If soil, clay/rocks are part of the non-food items consumed answer questions 18-25	
16. What are the reasons for the choice of these material(s)?	
17. What are the sources of these materials?	
18. What are the reasons for obtaining the materials at the quoted sources?	

19. Is there any pretreatment preparation you do to this material before consumption? ▪ Yes ▪ No	
22. If yes in above, specify the pretreatment	
23. How frequently do you consume this material in a day?	
24. Estimate the total quantity that you eat per day ▪ Below 10gms ▪ 10gms to 30gms ▪ 30gms to 50gms ▪ 50gms to 70gms ▪ 70gms to 90gms ▪ 90gms to 110gms ▪ 110gms and above	
25. Do you have this geophagous behaviour even when not pregnant?	
26. In your view, state the positive aspects of earth eating	
27. In your view, state the negative aspects of earth eating	
28. Are there family members who have been engaged or are currently engaged in earth eating? ▪ Yes or No	
29. If yes in above ,specify who in the family ▪ Mother ▪ Child ▪ Others (specify)	
30. Are you currently on any nutrient supplement? ▪ Yes ▪ No	
31. If yes in above, specify	

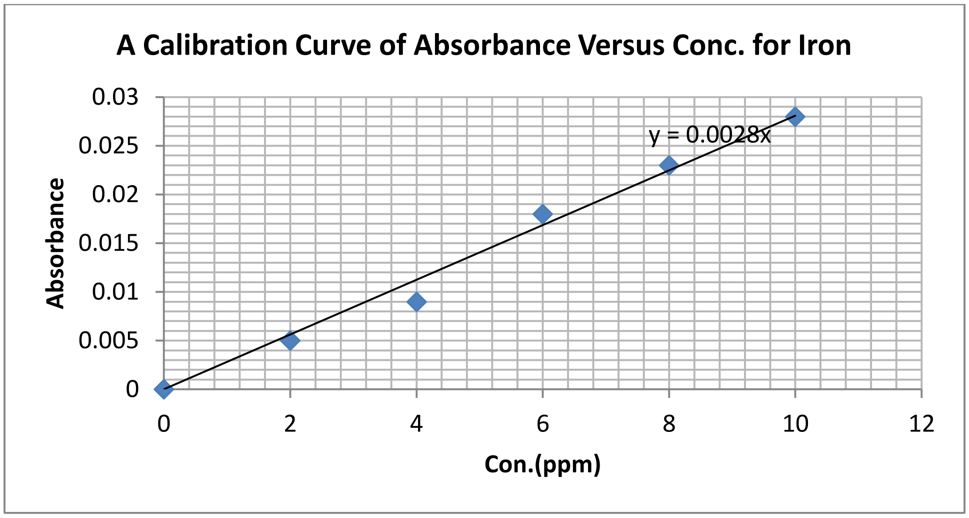
Appendix2: Sample Size Calculations

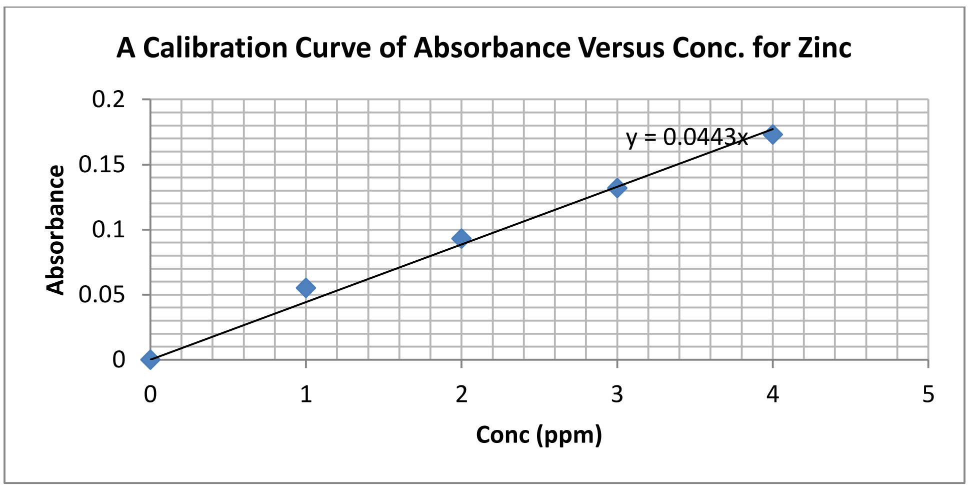
S/No	Health Centre	Annual attendance at ANC (New Visits)	Calculated Sample Size
1	Langa Langa	1147	99
2	Bondeni Clinic	309	28
3	Bondeni Maternity	534	46
4	Nakuru West Dispensary	186	16
5	Kapkures Health Centre	781	68
6	Lalwet Dispensary	51	4
7	Viwanda	63	6
8	Barut	141	12
9	Lanet	591	51
10	Mirugi Kariuki Dispensary	232	20
11	Kiti Health Centre	187	16
12	FITC Dispensary	697	60
13	GK Prisons Dispensary	55	5
	Total	**4974**	**431**

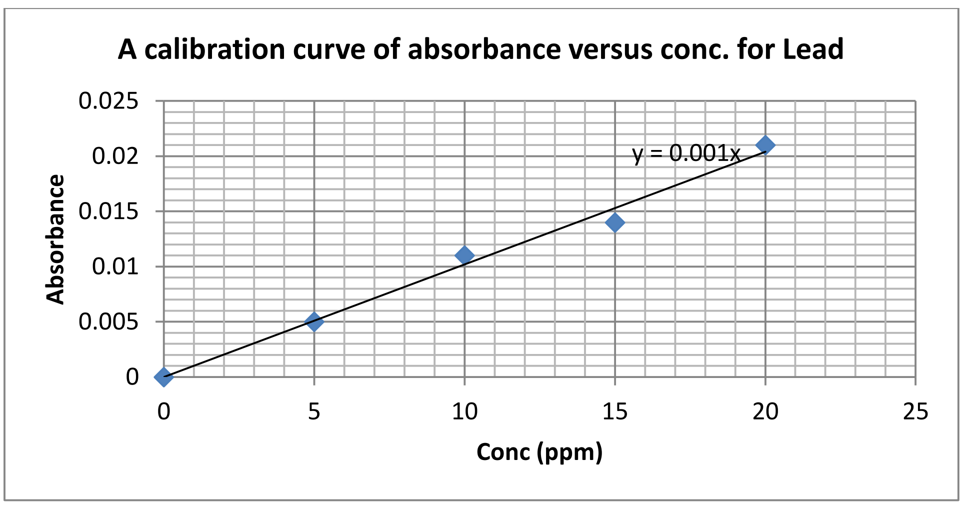
Appendix 3: Frequency of geophagous women per health centre

S/No	Health Centres	Experienced geophagia in the Pregnancy		
		Yes	No	Total
1	Langalanga	29	69	98
2	Kapkures	35	33	68
3	FITC	27	33	60
4	Lanet	12	39	51
5	Bondeni Maternity	18	28	46
6	Bondeni Clinic	8	20	28
7	Mirugi Kariuki	3	17	20
8	Nakuru West	4	12	16
9	KITI	4	12	16
10	Barut	10	2	12
11	Viwanda	0	6	6
12	GK Prison	0	5	5
13	Lalwet	1	3	4

Appendix 4: Standard Calibration Curves for the heavy metals







Appendix5: Concentrations of heavy metals in the sampled geophagic materials per Health Facility

S/No	Health Centre/Sample	Sources/Types	Concentrations(ppm)		
			LEAD	ZINC	IRON
1	Langa Langa sample 1	Wall of hut	2.5	1.38	6.79
2	Langa Langa sample 2	Market Weavers	1.5	2.36	361.61
3	Langa Langa sample 3	Kiosk Top Ten	1.5	2.33	75.00
4	Langa Langa sample 4	Market Kaptembwa	1.5	2.27	104.46
5	Langa Langa sample 5	Ash from Jiko	2.5	2.49	91.07
6	Langa Langa sample 6	Market Kaptembwa	1.5	2.02	56.25
7	Langa Langa sample 7	Supermarket	0.0	0.18	3.21
8	Langa Langa sample 8	Bark of tree	0.0	2.23	83.04
9	Kapkures sample 1	Ash from Jiko	0.5	2.56	83.04
10	Kapkures sample 2	Market Kaptembwa	0.0	2.10	88.39
11	Kapkures sample 3	Quarry Kapkures	0.5	1.94	75.00
12	Kapkures sample 4	Dug from farm	0.0	1.96	64.29
13	Kapkures sample 5	Market Pondamali	0.0	2.13	71.43
14	FITC sample 1	Ash from Jiko	1.0	0.25	9.82
15	FITC sample 2	Wall of hut	1.5	2.73	89.29
16	FITC sample 3	Bark of tree	1.0	1.81	57.14
17	FITC sample 4	Supermarket	0.0	2.00	89.29
18	FITC sample 5	Kiosk Kaptembwa	1.5	2.11	96.43
19	Lanet sample 1	Supermarket	1.0	2.10	78.57
20	Lanet sample 2	Kiosk Pipeline IDP	1.5	1.92	71.43
21	Lanet sample 3	Wall of hut	4.0	1.68	60.71
22	Lanet sample 4	Market Lanet	3.0	1.75	46.43
23	Lanet sample 5	Market Lanet	4.5	1.98	75.00
24	Bondeni Maternity sample 1	Market Weavers	4.0	2.12	100.00
25	Bondeni Maternity sample 2	Kiosk Manyani	3.5	1.98	92.86
26	Bondeni Maternity sample 3	Supermarket	2.0	0.26	31.25
27	Bondeni Maternity sample 4	Bark of tree	3.0	0.23	8.75
28	Bondeni Clinic sample 1	Bark of tree	3.5	1.82	46.43
29	Bondeni Clinic sample 2	Market Top ten	5.0	2.28	114.29
30	Bondeni Clinic sample 3	Kiosk Manyani	5.0	2.46	110.71
31	Mirugi Kariuki Sample 1	Kiosk pipeline	4.0	1.38	61.61
32	Mirugi Kariuki Sample 2	Ash from Jiko	4.5	2.42	139.29
33	Nakuru West sample 1	Supermarket	4.5	0.25	146.43
34	Nakuru West sample 2	Market Municipal	5.5	2.09	78.57
35	KITI Sample 1	Kiosk Mawanga	6.0	2.65	117.86
36	KITI Sample 2	Ash from Jiko	4.0	0.62	7.50
37	Barut Sample 1	Quarry Barut	6.0	2.07	71.43
38	Barut Sample 2	Market Pondamali	5.0	2.63	100.00

Appendix6:Conc. of heavy metals in different types of sampled geophagic materials

S/No	Type of the geophagic material	Lead	Zinc	Iron
1	Soft Earth Stones	2.50	1.38	6.79
2	Ash from a Jiko	1.50	2.36	361.61
3	Soils from Termite nests from bark of trees	1.50	2.33	75.00
4	Soils from Walls Huts	1.50	2.27	104.46
5	Ash from a Jiko	2.50	2.49	91.07
6	Soils from Walls Huts	1.50	2.02	56.25
7	Soft Earth Stones	0.00	0.18	3.21
8	Soils from Termite nests from bark of trees	0.00	2.23	83.04
9	Ash from a Jiko	0.50	2.56	83.04
10	Soils from Walls Huts	0.00	2.10	88.39
11	Soft Earth Stones	0.50	1.94	75.00
12	Soft Earth Stones	0.00	1.96	64.29
13	Soft Earth Stones	0.00	2.13	71.43
14	Ash from a Jiko	1.00	0.25	9.82
15	Soft Earth Stones	1.50	2.73	89.29
16	Soils from Termite nests from bark of trees	1.00	1.81	57.14
17	Soft Earth Stones	0.00	2.00	89.29
18	Soft Earth Stones	1.50	2.11	96.43
19	Soft Earth Stones	2.50	2.10	78.57
20	Soft Earth Stones	1.50	1.92	71.43
21	Soft Earth Stones	0.50	1.68	60.71
22	Soft Earth Stones	0.00	1.75	46.43
23	Soft Earth Stones	4.50	1.98	75.00
24	Ash from a Jiko	0.50	2.12	100.00
25	Soft Earth Stones	3.50	1.98	92.86
26	Soft Earth Stones	2.00	0.26	31.25
27	Soils from Termite nests from bark of trees	3.00	0.23	8.75
28	Soils from Termite nests from bark of trees	3.50	1.82	46.43
29	Soils from Termite nests from bark of trees	5.00	2.28	114.29
30	Soft Earth Stones	5.00	2.46	110.71
31	Soft Earth Stones	4.00	1.38	61.61
32	Ash from a Jiko	4.50	2.42	139.29
33	Soft Earth Stones	4.50	0.25	146.43
34	Soft Earth Stones	5.50	2.09	78.57
35	Soft Earth Stones	6.00	2.65	117.86
36	Ash from a Jiko	4.00	0.62	7.50
37	Soft Earth Stones	6.00	2.07	71.43
38	Soft Earth Stones	5.00	2.63	100.00

Appendix 7: Concentrations of heavy metals per the sources of sampled geophagic material

S/NO	SOURCES	LEAD	ZINC	IRON
1	Bark of tree	2.50	1.38	6.79
2	Cooking Jiko	1.50	2.36	361.61
3	Earth Digging	1.50	2.33	75.00
4	Kiosks	1.50	2.27	104.46
5	Open Market	2.50	2.49	91.07
6	Kiosks	1.50	2.02	56.25
7	Supermarket	0.00	0.18	3.21
8	Walls of huts	0.00	2.23	83.04
9	Open Market	0.50	2.56	83.04
10	Kiosks	0.00	2.10	88.39
11	Quarry	0.50	1.94	75.00
12	Earth Digging	0.00	1.96	64.29
13	Open Market	0.00	2.13	71.43
14	Open Market	1.00	0.25	9.82
15	Bark of tree	1.50	2.73	89.29
16	Walls of huts	1.00	1.81	57.14
17	Supermarket	0.00	2.00	89.29
18	Kiosks	1.50	2.11	96.43
19	Supermarket	2.50	2.10	78.57
20	Kiosks	1.50	1.92	71.43
21	Bark of tree	0.50	1.68	60.71
22	Open Market	0.00	1.75	46.43
23	Open Market	4.50	1.98	75.00
24	Cooking Jiko	0.50	2.12	100.00
25	Kiosks	3.50	1.98	92.86
26	Supermarket	2.00	0.26	31.25
27	Walls of huts	3.00	0.23	8.75
28	Walls of huts	3.50	1.82	46.43
29	Earth Digging	5.00	2.28	114.29
30	Kiosks	5.00	2.46	110.71
31	Kiosks	4.00	1.38	61.61
32	Open Market	4.50	2.42	139.29
33	Supermarket	4.50	0.25	146.43
34	Open Market	5.50	2.09	78.57
35	Kiosks	6.00	2.65	117.86
36	Open Market	4.00	0.62	7.50
37	Quarry	6.00	2.07	71.43
38	Open Market	5.00	2.63	100.00

Appendix 8: Research permits and ethical clearance