THE PREVALENCE AND PRACTICE OF GEOPHAGIA IN MKHANYAKUDE DISTRICT OF KWAZULU-NATAL, SOUTH AFRICA

BY

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ABSTRACT

Geophagia is defined as the practice of eating soil and occurs in the whole world. Literature suggests that there are potential advantages and disadvantages of geophagia, including nutritional benefits and harm to human health, respectively. The suggested effects of geophagia on human nutrition and health seem to vary with type of soil eaten and other factors such as the intensity of the practice. On the other hand, it is not clear whether or not soil consumers are aware of the potential effects of geophagia on their health. Whatever perceptions the soil consumers have with regard to geophagia may depend on several factors, including socio-cultural factors and their level of scientific education. The aim of this study was to investigate the prevalence and practice of geophagia in Mkhanyakude District, and the perceptions of the soil consumers about the practice.

A total of 94 women from Mkhanyakude District were interviewed with the aim of investigating the occurrence of geophagia, determining its prevalence and investigating perceptions about the practice. A combination of both qualitative and quantitative study design was used. Qualitative methods (based on literature) were used to enable the understanding of the feelings, values and perceptions that underlie geophagia. Furthermore quantitative methods (expressed by means of statistical data) were used because of the biographical information e.g. gender, age, education level and income that was requested from respondents. Samples of Soil samples used for geophagia were analysed for microbial load and mineral composition.

The majority of the respondents were unemployed and single women, with half of them reporting the consumption of soil, which they indicated was motivated by several factors, advice from relatives and pregnancy being the major ones. The frequency of eating soil ranged from 4-10 times per day and the amount eaten per day ranged from 57 g to 88 g.

The majority (33.0%) of the soil consumers preferred red, black and brown coloured soils- red soils were the most consumed. The methods of collecting soil reported include digging with a knife and hand hoe, buying from street vendors, collecting from house walls and selective picking by hand. The local name for the soil used for geophagia included *umcaka*, *isiduli*, *ibomvu*, *isibomvu*, *isidaka*, *umgabadi*, *ihlabathi* and *inkwali*.

The majority (87.2%) of the respondents indicated that they perceived eating soil as not helpful, but as an addiction like smoking, because it had bad consequences like cancer, acute bladder pains, appendicitis, painful heavy bleeding during menstruation, painful defecation, gallstones, fibroids, blood stool, worms and stomach pains.

The findings of the study indicated that the microbial content of the soil varied with soil type (9.3×10^3 cfu/g to 2.4×10^{10} cfu/g in high clay content soil and low clay content soil, respectively), indicating that high clay soils had the lowest microbial content. Therefore, further studies should be conducted to identify different microbial species present in these soils, especially those that are pathogenic to human health.

The soils consumed contained several minerals, including nutrients such as zinc, and mineral composition varied with soil type. Soil samples with the highest zinc content were from Somkhele (15.00 mg/kg), Ibomvu (1.94 mg/kg), Tin town (1.57 mg/kg) and Mbhodla (1.20 mg/kg) had medium zing amounts. The soil samples with low zinc content were from Bhambanana (0.08 mg/kg). However, the mineral nutrients identified in the soils did not meet daily recommended intake. Health education is highly recommended for geophagists to improve their awareness with regard to geophagia. In addition, baking of the soil used for geophagia is also recommended to reduce the risk of microbial infection.

PREFACE

The work reported in this dissertation was conducted in the School of Agricultural, Earth and Environmental Sciences at the University of KwaZulu-Natal from April 2012 to May 2014 under the supervision of Dr. Annette van Onselen, Dr Mthulisi Siwela and Dr. Pauline Chivenge.

Signed.......................... Date....30/03/2015...

Agnes Thembisile Msibi (candidate)

As supervisors of the candidate we agree to the submission of this dissertation.

Signed.......................... Date....30/03/2015...

Dr. Annette van Onselen (Supervisor)

Signed.......................... Date 30/3/2015...

Dr. Mthulisi Siwela (Co- supervisor)

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DECLARATION

I, Agnes Thembisile Msibi identity number 650422 0242 080 and student number, 212561498, declare that the work in this dissertation submitted to the University of KwaZulu-Natal, School of Agricultural, Earth and Environmental Sciences is my own independent work, except where otherwise stated. The work in this dissertation has not been submitted for any degree before to any tertiary institution by me or any other person. Data from other sources used in this dissertation has been appropriately acknowledged and referenced.

Signed: .... Date: 30/03/2015

Agnes Thembisile Msibi (candidate)

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CHAPTER 1
INTRODUCTION, THE PROBLEM AND ITS SETTING

1.1 Background and the importance of the study

Geophagia is a Greek word formed from two Greek words geo-meaning earth and phag-meaning eat (Halstead, 1968). It is described as deliberate eating of earth, clay or soil due to cravings (Abrahams & Parsons, 1997; Ekosse, Ngole, Jager & Songca, 2010). The practice and prevalence of geophagia may vary with ethnic groups and available soils. Soil consumption has been done for centuries and it cuts across socio-economic, ethnic, religious and racial divides (Ekosse & Ngole, 2012). Soil eating has been internationally practised throughout the world in all age groups, races, socio-economic environment and in both sexes (Reid, 1992; Halsted, 1968). The issue of benefits and problems related to geophagia raise questions to researchers, policy makers and societies (Ekosse & Jumbam, 2010).

Studies on geophagia have been conducted in other African countries like Zambia, Zimbabwe, Zanzibar, Tanzania, Swaziland, Ghana as well as in some provinces of South Africa, including Free State and Limpopo (Ekosse, de Jager & Ngole, 2010; Ngole, Ekosse, de Jager, Songca, 2010 & Brand, 2009) . On the other hand, in KwaZulu-Natal (KZN) province, geophagia seems not to have been investigated, except one study that was conducted in one of the schools at Ingwavuma and was only among school kids (Saathoff, Olsen, Kvalsvig & Geissler, 2002). Through undocumented personal observation, it was noticed that there are people consuming soils in Mkhanyakude District. However, there is no detailed information on geophagia in this District. The lack of documented evidence with regard to geophagia in Mkhanyagude district motivated the researcher to conduct this study in this district.

Perceptions lead to attitudes, beliefs and practices. This suggests that the practice of geophagia might also be founded on certain perceptions. Perceptions about geophagia may vary with ethnic groups therefore may lead to different reasons for eating soil. In sub-Saharan Africa, soil eating is common among child-bearing women and breast-feeding women (Kutalek, Wewalka, Gundacker, Auer, Wilson, Haluza, Huhulescu, Hillier, Sager & Prinz, 2010). Reasons for eating soil are not the same, for instance, in Malawi it is regarded as very strange for an expecting woman not to eat soil, because the practice of eating soil is believed to be the norm amongst pregnant women. Geophagia is believed to have the capacity to boost a pregnant woman's feelings or confidence with regard to being pregnant, and the taste of the soil is perceived to be capable of decreasing morning sickness, which is the feeling of discomfort, nausea and vomiting (Diamond, 1998). Geophagia has been found to be more common among certain demographic groups of subsistence farming communities such as poorly nourished and expecting mothers (Simon, 1998). Geophagia also occurs in the absence of hunger, because environmental and cultural reasons are more dominant (Vermeer & Frate, 1979). The etiology of geophagia includes psychological, cultural, physiological, medicinal reasons, traditional and religious beliefs. Furthermore, soil is believed to be the treatment for intestinal parasites and diarrhoea (Vermeer, 1985).

Soil preferences for geophagia vary from termite moulds, clay, soft stones, roasted, smoked, and baked clay soils (Shinondo & Mwikuma, 2009). The chemical and nutrient composition of soil varies with geographical region and types of soil. Different kinds of clay soils used for geophagia possess different colours ranging from creamy, whitish, grayish, brownish, blackish, yellowish to reddish (Ngole, de Jager & Ekosse, 2010; Woywodt & Kiss, 2002; Stokes, 2006). White clay contains kaolin, which has the capacity to absorb toxins and bacteria (Yount, 2005). It is therefore commercially processed to produce a medicine which is a remedy for diarrhoea. Soils that are commonly used for geophagia contain a lot of mineral nutrients, including iron, zinc, copper, magnesium and manganese, and toxic minerals such as lead and mercury (Ngole *et al.*, 2010). Soil composition is influenced by the composition of the parent (consolidated) rock (Manson, 1994). Beside the consolidated rock, soil can be also developed from unconsolidated deposits, which might have been transported by water, wind or gravity and ice (Bardgett, 2005). Dolomite is the rock formed through the consolidation of volcanic magma and due to its high iron content, its weathering result in red soils with high iron oxide content (Manson, 1994). The nutritional composition and colour of soils used for geophagia in Mkhanyakude had never been studied before. In part, this motivated the researcher to conduct this study.

There are millions of microorganisms found in the soil (Starr & Taggart, 1995). These microorganisms can be divided into five groups, namely: bacteria, viruses, algae, fungi and protozoa (Baudoin *et al.,* 2002). Geophagia is associated with infections, especially geohelminth infections that cause about 135 000 deaths in the world each year (WHO, 2002). Worldwide, approximately two billion people are infected with geohelminth (worm found in the soil) annually leading to two million clinical cases and 60 000 deaths occurring every year (Glickman *et al*., 1999). The microbial composition and load of soil vary with soil types, regions and soil segment (Starr & Taggart, 1995). Some microorganisms are pathogenic because they invade and multiply in other organisms causing diseases (Starr & Taggard, 1995). Prior to this study, soil microbial composition and load in Mkhanyakude District had not been determined.

1.2 Statement of the problem

Through personal observation, it was found that there are people in Mkhanyakude District who practise geophagia. However, the extent of this practice and its prevalence were not known. In addition, the researcher observed that different types of soils were consumed which may have different nutrient content and possibly undesirable substances. While plants have developed mechanisms to take up nutrients from the soil, the bioavailability of these nutrients to humans is unknown. Therefore research was required to determine the prevalence and the practice of geophagia in Mkhanyakude District and to investigate the nutrient content and microbial load of the preferred soils.

1.3.Study objectives

The objectives of the study were:

- To investigate the practice and determine the prevalence of geophagia in Mkhanyakude District.
- To explore the perceptions of people about eating soil.
- To determine the microbiological load in different types of soil used for geophagia in Mkhanyakude District.

- To investigate the nutrient content and colour of different soils used for geophagia in Mkhanyakude District.

1.4. Hypotheses

- The practice of geophagia is likely more prevalent in KwaZulu-Natal (KZN) than we know
- Geophagia might be more common to people who most of the time use to eat food from plants material in their diet than those always include meat in their diet.

1.5. General Assumptions

- Conceptual framework is a reflection of the phenomena under investigation.
- Soils used by these people are not toxic substances.
- Some geophagists would not answer some of the questions properly because they are shy.
- Data collecting tools to be utilized will increase respondent's participation.

1.6. Abbreviations

KZN KwaZulu-Natal
MID Mid Infrared Reflectance
DM27 Mkhanyakude District
UKZN University of KwaZulu-Natal
LBW Low Birth Weight
GiP Geophagy in Pregnancy

1.7. Definition of Terms

Geophagia: Woywodt and Kiss (2002) defined geophagia as "deliberate consumption of earth, soil or clay".

Geophagist: Geophagist is a person who consumes soil**.**

pH value**:** This is the acidity and alkalinity of substances that are soluble in water.

Microbial load: Is an estimation of the number of living microorganisms present in soil.

Microorganisms**:** Are very small living organisms that cannot be seen by naked eyes but can only be seen under microscope.

Nutrients: Are substances in food that are required to keep a living organism alive or maintain its life and help it grow.

Pathogenic organisms**:** Organisms that have the ability of causing diseases.

Recommended dietary allowance**:** Is an estimation of nutrients required per day for the maintenance of good health as recommended by the Food and Nutrition Board of the National Research Council.

1.8. Outline of the dissertation

The layout of the dissertation is as follows:

Chapter 1: Introduction, the problem and its setting

Chapter 2: Literature review

Chapter 3: Methodology

Chapter 4: Results

Chapter 5: Discussion

Chapter 6: Conclusions and recommendations

CHAPTER 2
LITERATURE REVIEW

2.1 INTRODUCTION

Pica is a Latin word for the bird called Magpie, famous for eating non- food substances (Woywodt & Kiss, 2002). There are many kinds of pica, including eating of ice (Phagophagia), eating of hair (trichophagia) as well as eating of earth and clayey soils (geophagia). Some other items that are ingested include cigarette butts, ashes, paint chips, paper and other things like rotten or frozen foods (Ashworth, Martin & Hirdes, 2008.)

The Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) defines pica as "the persistent eating of non nutritive substances for a period of at least one month, without an association with an aversion to food (Trivedi, Daga & Yeolekar, 2005). Pica is serious problem because it causes health complications such as heavy metal poisoning, metabolic abnormalities (e.g. iron deficiency), intestinal obstructions, nutritional deprivation and parasitic infestation (Rose, Porcerelli, & Neale, 2000).

Geophagia is a Greek word formed from two Greek words geo- meaning earth and phag (eat), so it is the practice of eating earth (Halstead, 1968). Geophagia is a form of pica, resulting from the consumption of clay or soil by humans and animals (Dominy, Davoust & Minekus, 2004). Geophagia is described as intentional consumption of clay soil (Shinondo & Mwikuma, 2009). The word geophagy or geophagia is exclusively used to define deliberately eating of soil (Geissler, Mwaniki, Thiong & Friis, 1997).

Soil eating is common among child bearing women and breastfeeding women in sub-Saharah Africa (Kutalek, Wewalka, Gundacker, Auer, Wilson, Haluza, Huhulescu, Hillier, Sager & Prinz, 2010). This practice occurs in poor families (Horner, Lackey, Kolash & Warren, 1991; Simon, 1998). Eating of clayey soils has been done by all age groups, societies, and all races (Reid, 1992).

Clay soils of different colours such as creamy, whitish, greyish, brownish, blackish, yellowish and reddish are used for geophagia (Ngole, de Jager & Ekosse, 2010; Woywodt & Kiss, 2002; Stokes, 2006;). Soils that are commonly used for geophagia contain a lot of mineral nutrients including iron, zinc, copper, magnesium, manganese, silicon and even mineral nutrients with toxic substances such as lead and aluminium (Ngole *et al.*, 2010).

Common reasons for geophagia practice include the belief that it acts as a remedy for diarrhoea as well as a means of alleviating nausea in pregnant women (Hunter, 1993; Tayie & Lartey, 1999; Dominy, Davoust & Minekus, 2004). Sometimes geophagia is associated with satisfaction of cravings among child bearing women and a strong belief that it increases fertility (Derman, Okstuz-Kanbur, Yenicesy & Klink, 2005). It is also believed to enhance a beautiful light complection among young women, making a person to be more attractive (Woywodt & Kiss, 2002).

Food that is contaminated with clay soil may not be harmful to human life but the deliberate ingestion of clay soil may cause health threats such as maternal death (Committee on Research Priorities for Earth Science and Public Health, National Research Council, 2007).

2. 2 ETIOLOGY OF GEOPHAGIA

Geophagia is a complicated behaviour with etiology including psychological, cultural, physiological, medicinal reasons, traditional and religious beliefs. Soil eating is believed to be the treatment of intestinal parasites and diarrhea (Vermeer, 1985). Geophagia is perceived to be more common in certain groups in subsistence communities e.g. poorly nourished and expecting mothers (Simon, 1998). The etiology of geophagia will be discussed under five different hypotheses namely, cultural expectations, physiological needs for micronutrients, boosting immunity, gastrointestinal upset and time dependent theory.

2.2.1 Cultural expectations

In many people soil eating is a common indigenous habit, although it is practiced by many groups of people but the most common group is pregnant women. In the study that was conducted in Kenya 32% of women said that the reason for eating soil is pregnancy (Geissler, Prince & Levene, 1999). In Africa, geophagia is the practice mostly found in pregnant women (Hunter, 1973). Reasons for eating soil are not the same for instance in Malawi it is indicated that it is very amazing for an expecting women not to eat soil because it is believed that is the way for any women to realize that she is pregnant and the taste of soil is used to decrease "morning sickness" which is the feeling of discomfort, nausea and vomiting (Diamond, 1998).

Soil consumption is the link between good health, fertility and culture belief of ancestor's blessings (Njiru, Elchalal & Paltiel, 2011). Soil consumption is a traditional cultural practice which is used as remedy or treatment for illnesses (Dominy, Davoust & Minekus, 2004; Vermeer & Frate, 1979). Geophagia is normally a culture to other communities but at the same time regarded as harmful to human health. This practice is increasing from generation to generation because it emanated from having seen their mothers and relatives eating soil (Mcloughlin, 1987).

Geophagia was popular among the slaves, the contended workers as well as the poor but the abundance of food does not avoid it (Livingstone, 1970). The migration of black rural communities from rural to urban areas did not eliminate the habit of soil consumption because if friends and relatives fail to send clay from home (birth place), other commercial non-food substances were used e.g. laundry starch and that perpetuated the practice even more (Edwards, McDonald, Mitchell, Jones, Mason, Kemp, Laing & Trigg, 1959). Furthermore geophagia is considered as a physiological response towards calcium and iron deficiency in the human body (Abraham & Parsons, 1997).

2.2.2 Physiological needs for micronutrients

During pregnancy, the requirements for nutrients are very high such that expecting women with nutrient deficiencies develop cravings for earth, as the way of supplementing deficient nutrients like iron, zinc and calcium **(**Young, Wilson & Hillier, 2010). Also, successive child bearing and parasitic diseases reduces the amounts of nutrients reserved in the human body resulting in geophagia especially in pregnant women (Hunter, 1973).

Soil consumers are very choosy when collecting soil for consumption as they use certain criteria such as flavour, colour, smell and texture of the soil (Reilly & Henry, 2000). It has also been noted that some women practice geophagia simply because they like the odour, taste and texture of clay (Simpson, Mull, Longley & East, 2000). The beliefs that geophagia make the skin beautiful contribute to the occurrence of the practice of geophagia among young women (Woywodt & Kiss, 2002).

Iron deficiency is common among earth eating people and that leads to the idea that iron deficiency causes geophagia (Danford, 1982). Red clay (rich in iron) can be useful to avoid iron deficiency anaemia due to iron content, but the bioavailability of this (nonhaem) iron may be limited (Harvey, Dexter & Darnton-Hill, 2000).

The effect of non-food items may result in reduced appetite for nutritious food items leading to inadequate/ malnutrition of essential mineral nutrients (Crosby, 1982). Soil eating (grey and white clay) is related to health and developmental problems such as iron (Fe) deficiency, anaemia, parasitic infections, and developmental problems (nutritional dwarfism) (Danford, 1982). Geophagy reduces bioavailability of potassium, zinc and iron by the means of clay binding with nutrients and eventually leads to the lack of micronutrients in the human body (Young, Wilson & Hillier, 2010).

Therefore it is possible that soil eating may be also common in other community groups that are poorly nourished, particularly the shortage of iron (Simon, 1998). The relationship between soil consumption, hunger and poverty has been acknowledged. However, the practice of geophagia is not limited to poor people, as it cuts across socio-economic, ethnic, religious and racial divides (Wywodt & Kiss, 2002). In times of famine and poverty, geophagia serve as an appetite suppressant and is common in people suffering from anorexia nervosa (Vermeer & Frate, 1979).

Although clay soil is a source of calcium, copper, iron, potassium, manganese, magnesium and zinc, no one can guarantee, the accuracy of nutritional significance to human being (Hunter, & de Kleine, 1984).

2.2.3 Boosting immunity

If the immune system of pregnant women declines, yet it is needed to protect the fetus from harmful substances, it often leads to geophagia in pregnancy. Geophagia causes pregnant women to be exposed to microorganisms which in turn may lead to the fetus developing antibodies that fight against the micro organisms that they have been exposed to (Abrahams, 2005; Young, 2007).

Geophagic clay possesses high cation-exchange capacity and in that way it has capacity to absorb plant toxins e.g. tannins, glycoalkaloids and phytotoxins. As such, geophagic clay may act as a detoxifier for the indicated toxins. Other types of clay soil such as diatomaceous earth, fuller's earth, kaolin-pectin and termite earth have properties of binding microbes, and by so doing they give protection to the individuals exposed to the microbes. The called smectite clays have got the properties of binding mucus in the intestines causing intestinal linings to be impermeable to toxins and pathogens (Young, 2010). That is why sometimes even if people are eating soil, not all of them will suffer the consequences.

2.2.4 Gastrointestinal upset

Soil is used to heal common illnesses of gastro intestinal tract (GIT) because they possess medicinal properties (Carretero, 2002; Tateo, Summa, Boneli & Bentivenga, 2001). *Kaolin* and *smectite* are officially used in modern pharmaceuticals to prevent nausea, vomiting and gastrointestinal disorders (Young, 2007).

Most of the earth eaters have got problem of intestinal worms. However, it is not clear whether geophagia causes intestinal parasite or vice versa (Saunders *et al*., 2009). In addition, the belief that earth eating is a remedy for intestinal parasites and diarrhoea also promotes the practice of geophagia (Vermeer & Ferrell, 1985).

In the Southern parts of the United States of America (USA) eating non- food substances such as clay, baking soda and corn starch is associated with assisting the babies to grow well, ensuring beautiful children and also serving as a treatment for swollen legs (Mcloughlin, 1987).

2.2.5 Time dependent theory

During the infancy period when hand to mouth activity is still high, geophagia is regarded as normal whereas in older human beings it is viewed as abnormal (Fessler, 2004; Abrahams, 2002).

Some studies have indicated that geophagia perform different functions depending on the time of pregnancy such that in the first trimester, clay soil binds teratogenic toxins in the diet, by so doing preventing morning sickness (nausea and vomiting) which normally disappears, in the second trimester (Wiley & Katz, 1998). Geophagia serve the function of supplementing the nutrients demand of calcium which is the formation of foetal skeletal system, whereas in the third trimester geophagia soften the pelvic bones in pregnant women thus causing the birth of the baby much easier (Wiley & Katz, 1998). Furthermore during the whole pregnancy period, the abundant availability of calcium prevents hypertension induced by pregnancy (Wiley & Katz, 1998).

2.3 The prevalence of geophagia in the world

In various parts of the world and at different periods of history, entire populations have been involved in soil eating (Hunter, 2003). In China, during times of severe food shortages, clay was eaten by large segments of the population (Hunter, 2003). Geophagia is widely practiced in America, United States of America, Asia, India, Nigeria Australia and Europe (Simon, 1998).

Soil consumption is common in Africa (Woywodt & Kiss, 2002); North American, (Grisby, Thyer, Waller & Johnstone, 1999); Central America (Hunter & Klein,1984); South America, (Abraham & Parsons,1996); Asia (Aufreiter, Hancock, Mahaney, Stambolic, & Sanmugadas, 1997 and Europe together with the Middle East (Hollriegel, Greiter, Giussani, Gerstman, (Michalke, Roth, & Oeh, 2007). A total of 46 of the 150 women in the USA and 33 of the 75 in Mexico interviewed, practiced geophagia (Geissler *et al*., 1997).

2.3.1 Prevalence of geophagia in Africa

Soil eating is mostly common in women of child bearing age, in developing countries including those in Africa (Brand *et al*., 2010.). It has been reported in Botswana, Cameroon, Ghana, Guinea, Ivory Coast, Kenya, Malawi, Nigeria, Senegal, Sierra Leone, Tanzania Uganda, South Africa and Swaziland on African continent (Ngole *et al*., 2010). In countries like Zimbabwe, Zambia, Tanzania, and Ghana, the study concerning geophagia has been done and documented (Brand, 2009).

In Nigeria, the prevalence of these practices in child bearing women was estimated to 50%, citing nausea, vomiting, heart burn, and the need for relief from stress as a reasons for engaging in geophagia. In Kenya, more than 70% of school children were practicing geophagia (Simpson *et al.*, 2008). In the Western Kenya alone, out of 285 school children aged 5-18 years, 73% were found to practice soil eating) (Geissler *et al*., 1997).

During the study of Zambia for detecting helminthes ova in soil, it was found that out of eighty five pregnant women of ages 15-44 years interviewed, 84 of them were consuming soil. It was also noted that soil eating is not only practiced by pregnant women because others revealed that soil consumption was also practiced long before pregnancy due to cravings (Shinondo & Mwikuna, 2009).

In West Africa especially in Ghana and Togo a creamy white loamy clay soil, locally named as ayebo (Lartey, 1999; Stokes, 2006) is commonly used for geophagia. The indicated clay soil is mined in a town called Anfoega in Ghana and when wet, the clay soil is molded into lumps of 20g to 200g blocks. These blocks are oven dried and sold for traditional and cultural applications and some are used for consumption.

The Council for Scientific and Industrial Research (CSIR), (1993) indicated that people who consume the soil in Ghana are making use of shale type soil consisting of 67% silicate, 15% aluminums oxide, 3,4% iron oxide, 3.64% potassium oxide, 0.6% titanium oxide and other amounts of other oxides (Tayie *et al*., 2013).

In Kumasi Ghana a study that was conducted to determine the prevalence of various forms of pica such as among pregnant women, revealed that 47% of pregnant women were practicing pica (Faustinah,Twumasi, Amenawonyo, Larbie & Baffo, 2010). About 30% of the indicated women practiced geophagia.

Geophagia has been also reported in Swaziland and the study conducted involved the collection of soil samples that were analyzed for mineral identification and chemical composition. Findings were supportive of quartz and kaolinite dominance in the samples, meaning that dental enamel damage, abrasion of the gastro intestinal tract and rupturing of the colon are possibly occurring among people who practice geophagia in Swaziland as a result of the soil ingestion (Ekosse & Ngole, 2012).

2.3.2 The prevalence of geophagia in South Africa

Limited research has been done in South Africa except for few documented studies that were conducted in the Free State and Limpompo Province, where the study was aimed at investigating the demographic characteristics of geophagic individuals. The study was conducted in four areas, Qwaqwa (rural) and Mangaung (urban) of the Free State Province, and the Polokwane (urban) and Sekhukhune (rural) in Limpopo Province, South Africa. The belief was that geophagia is common among uneducated women but the findings of the study from four areas of two Provinces were that geophagic women investigated were educated. However, geophagia is also prevalent among lower economic class and also more common among single than married women (Ngole, Songca, Ekosse & de Jager, 2010).

2.3.3 The prevalence of geophagia in KwaZulu-Natal

The study of geophagia and its association with geohelmith infection in rural school children was conducted between March 1998 and July 1999 in Ingwavuma District (Maputaland) a rural and underdeveloped part of Northern KwaZulu-Natal, in South Africa. Findings revealed a higher prevalence of geophagia among girls (52.6%) in comparison to boys (39.4%). There was a positive association between geophagia and the socio-economic status of the school children's families. Children from socio- economically advantaged backgrounds were more geophageous in comparison to those who were from socio-economically disadvantaged households. Furthermore, geophagia decreased with age in boys, but not in girls (Saathoff, Olsen, Kvalsvig & Geissler, 2002).

Even if documentation is not available but through observation and discussions it has been found that, there are people consuming soils in Mkhanyakude District. This brings the need for conducting research which will give insights of the extent of the practice. In addition, different types of soils that are consumed may have different nutrients. Therefore research needs to be conducted to determine different types of clay preferred for geophagia, their nutrient content and presence of microorganisms that may cause harm to human health in these soils.

2.4 Nutritional implications of geophagia

2.4.1 Nutritional benefits of geophagia on human health

Soil ingestion in human beings maintains homeostasis in the body by correcting mineral nutrients imbalance (John & Duquete, 1991). Clay soils are ingested due to nutrient and mineral deficiency (Eastwood, 1999). Red earth has got properties used to prevent iron deficiency anemia although iron bioavailability is still not clearly understood (Dreyer, Chaushev & Gledhill, 2004; Harvey, Dexter & Darton-Hill, 2000.)

Clay nutrient minerals act as a valuable treatment for ulcer and other bacteria treatment (Haydel, Remenih & William, 2008). Some edible soils have some useful pharmaceutical usage such as white clay (kaolin) used as a remedy for diarrhea (Martindale, 1993). Soil consumption is sometimes used in the same manner as commercially prepared medication (Aufreiter, Hancock, Mahaney, Stamolic-Robb & Sanmugadas, 1997). Soils that are rich in clay have the ability to prevent intestinal disorders (Dominy *et al.*, 2004). Several studies have reported the good functioning of probiotic bacteria to prevent the development of harmful bacteria, boost immune function and also increase resistance to infection (Simov, Reznik & V' iunitskaia, 1993).

Some clay has got kaolinite and therefore acts as a potent antidiarrheal by binding toxins and bacteria and forms a protective coat on the intestines (Simpson, Mull, Longley & East, 2000).

Consumption of clay soils in pregnant women improves metabolism function and protects foetus against toxins (Profet, 1992).

2.4.2 Nutritional disadvantages of geophagia on human health

Soil consumption has been known for its advantage of nutrient supplement to others but mineral deficiencies like iron, potassium and zinc has been recognized (Smith, Spargo & Francis, 1981). Growth retardation and premature births are closely related to Low Birth Weight (LBW) and decreased foetal head circumference, which are more common in cases where geophagia is practiced during pregnancy (GiP). This in turn leads to poor development and poor academic performance leading to poverty (Saunders, Padilha, & Della, 2009; Horner, Lackey & Kolasa, 1991). Poisoning resulting from the ingesting of soil contaminated with herbicides and pesticides may cause maternal death (Abrahams, 2005).

Due to the nature of particles, course particles of soils that are used in geophagia can negatively affect the dental enamel and can cause the rupturing of the sigmoid colon (Ngole *et al.*, 2010). Geophagia may cause severe constipation by binding to the mucus inside the intestinal mucosa (Young, 2007). The effects of eating soil also include dental injury, intestinal obstruction, toxemia, interference with the absorption of minerals, lead poisoning and hyperkalemia (Rothernberg, Maalox & Jiand, 1999).

Geophagia can lead to the ingestion of minerals along with dangerous toxic and non toxic substances causing electrolyte imbalances, toxicity and furthermore consumption of excess cadmium can cause kidney damage (Young, 2007). Toxic elements eaten along with soil such as lead and copper from contaminated soil can also be ingested together with soil (Smith, 1998). Geophagia causes toxicity problems to both pregnant mother and foetus and the most common is lead followed by potassium and fluorine (Abraham, 2006).

Another human body disorder caused by soil consumption is irregular pulse (Kslal, Kanbur, Derman & Kutluk, 2003). Some clay soils have high cation exchange capacity. This prevents the utilization of iron in individuals who practice geophagia. Therefore soil properties vary with clay type (Talking, Gant, Scott & Pritchard, 1970).

Iron deficiency is common where geophagia is being practiced (Halsted, 1968). Like other nutrients iron is absorbed from small intestines in two forms i.e. haem iron and non haem iron, of which haem iron is present in animal foods and non-haem in plant foods (Haem iron is easily absorbed compared to non-haem iron which needs to be changed to another form before it could be absorbed) (Hallberg, Bjorn-Rasmussen & Rossander, 1983). Iron from animal food is well absorbed by the body and its absorption is fully independent because it is not affected by other constituents in the diet (Hazell, 1985). Iron can also be obtained from sources that are extrinsic to food such as soil, dust and metals (Harvey, Dexer & Darnton-Hill, 2000). Iron from these sources need to be first soluble at the pH of the intestines and factors contributing to solubility of iron are critical because it also depends on the constituents of the diet and other factors like transit period and amount of already existing iron (Cook, 1990 & Bothwell, 1995). Therefore, iron absorption from the consumed soil still needs in depth study (Bayness, 1994).

Geophagia is sometimes described as both a cause (Minnich, Okcuoglu & Tarcon, 1968) and a consequence of anaemia (Federman, Kirsner & Federman, 1997). Soil consumption affects iron status in the following ways (Harvey *et al.,* 2000). Firstly, soil constituents might become insoluble in the intestines and the absorption of iron is totally disturbed. Secondly soil ingestion might also lead to infectious diseases like ascariasis and trichuriasis (Wong, Bundy & Golden, 1991). Over and above all these factors, the most important thing that also affects absorption is the kind of food consumed simultaneously or close to the time of soil ingestion (Lee, 1982)

Beside that, even the soil mineralogy also inhibits its solubility of iron in the gastrointestinal tract (Bothwell, Charlton, Cook & Finch, 1979). Although no in depth study has been conducted, it has been noted that the eating of food containing ascorbic acid during soil consumption may cause iron to be soluble, resulting in improved absorption process (Harvey, Dexter & Darton-Hill, 2000).

2.5 Introduction to soil

Soil is the mixture that consists of rock particles, air, water, organic matter and living soil organisms (Asafp-Adjei et al., 2013). Soil consists of organic, minerals, water and air phases but the mineral and organic phase forms the solid matrix (body) of the soil (Lavelle & Spain, 2005). Organic matter refers to substances in the soil that contain molecules of the elements, carbon, hydrogen and sometimes oxygen and inorganic particles are rock particles and mineral particles (Asafp-Adjei *et al*., 2013).

Soil is the medium that keeps water for soil organisms and plants, so it acts as a home for microorganisms and plants (Asafp-Adjei *et al.,* 2013). Soil provides a habitat for organisms, acts as a medium for plant growth, functions as a recycling system, act as engineering medium and it also act as water reservoir because when it is raining the soil store water for later use (Singer & Munns, 2000). The soil also acts as a purifier because it is able to suppress toxins that may result from microorganism's activities or chemical reactions (Buol, 1995).

2.5.1 General properties of soil

2.5.1.1 Soil Texture

Soil texture refers to the size of the soil particles that make up the soil matrix of which is the coarseness or fineness of the soil and the sizes of soil particles are different, (large particles, namely gravel; smaller ones, namely sand; further smaller ones, namely silt and the microscopic ones are clay (Olson, 1981; Singer & Munns, 2000). Fine earth fraction has been classified as follows: sand (0.05-2.0 mm); silt (0.002-0.05mm) and clay is (<0.002mm) within the soil matrix (Singer & Munns, 2000). Soil texture plays an important role in nutrient management because it influences nutrient and water retention capacity (Olson, 1981). Clay soil has got high water retention capacity meaning that it holds water for longer period compared to other soil particles and has high cation exchange capacity **(**Poesen & Lavee, 1994). It retains cations like Ca, Mg, and NH^{4+} meaning that clay soil can hold negatively charged surfaces of which is the ability of holding nutrients for plants and microorganisms. Therefore good soil structure allows the free movement for biota, penetration of plants enables microbial activities (Bardgett, 2005).

Soil texture is stable and acts as the important feature of soil because it is related to other soil properties. For example the more clayey the soil, the higher the fertility status and the higher water holding capacity (Lavelle & Spain, 2005).

According to (Lavelle & Spain, 2005) the relationship between soil structure is as follows:

Table 2.1: Properties of sandy and clay soils

Properties of sandy soils	**Properties of clayey soils**
Low water-holding capacity	High water holding capacity
Well aerated	Poorly aerated
Fast drainage	Slow drainage
Lower in organic matter than clay	Higher in organic matter than in sand
Poor supply of plant nutrients (infertile)	Excellent supply of plant nutrient (fertile)
Low Cation Exchange Capacity	High Cation Exhange Capacity
Chemically and physically inactive	Chemically and physically active
Loose when wet and soft when dry	Hard when dry and sticky when wet
Poor buffer against pH changes	Well buffered against pH changes

2.5.1.2 Soil Structure

Soil structure is described as arrangement of soil particles (Singer & Munns, 2000). Soil structure is the arrangement of soil particles into groupings called aggregates and is important because it reflects the manner in which soil was formed and other aspects of soil like infiltration rate (Olson, 1981).

According to **(**Oades, 1993) soil particles usually cling together to form large aggregates. Cracks separate this aggregates and that phenomenon gives the structure of soil.

According to (Singer & Munns, 2000) the following types of structures can be differentiated in soils:

1. Crumb structure: Round aggregates with pores.
2. Granular structure: Round non-porous aggregates

3. Sub angular blocky structure: Cubic aggregates with round corners
4. Angular blocky structure: Cubic aggregates with angular corners
5. Columnar structure: Aggregates with rounded tops but longer than their width
6. Prismatic structure: Aggregates with flat tops but longer than their width
7. Platy Structure: Aggregates that are wider than they are thick

There is also a structure grade which is described in terms of the clarity with which the aggregates can be distinguished. There are four defined structure grades.

1. Structure less: If the sand does not cling together like sea sand is single grained because that sand is just loose. When it cling together it is massive
2. Weak: When the aggregates are, poorly formed, not definable in undisturbed soil.
3. Moderate: When the aggregates are well formed, but not clearly observable in undisturbed soils.
4. Strong: When aggregate are clearly observable in undisturbed soils.

2.5.1.3 Soil Colour

Color is also among the important properties of soil and has got good relationship with other soil properties (Olson, 1981; Singer & Munns, 2000). Soil colors range from reddish, brown, yellow, blue- green, white and black. Soil color differs between the soil horizons and varies in the form of mottles that are brighter than the surrounding soil. Red yellow and brown color is derived from iron oxide minerals. Quartz is whitish in color. The color for organic matter is black.

Soil colour is useful during soil classification to differentiate between soil horizons. Top soil is usually darker than the subsoil. Properties of soil like mineralogy, organic matter content and stage of weathering can be identified through soil color (Olson, 1981). Soil colors interpret the oxidation status of the soil. If the soil color is bright (red or yellow), it indicate that soil is well drained meaning that water and air pass freely through the soil. Grey and low-chroma colors indicate the water logging condition. The book called a Munsell Soil Color Chart has got colored chips that are arranged systematically on pages by hue, value and chroma and the comparison of soil colors can be properly observed under the open shade (Olson, 1981).

2.5.2 FACTORS DETERMINING TYPE OF SOIL CONSUMED

Most common reasons forwarded by soil consumers for eating soil are the attractiveness of smell and texture of the soil. The location of the soil is also important because it should come from a good clean area. Soil is obtained from a specific area such that, if it is removed from the walls of the house, they prefer the area that is higher up where people and animals under normal circumstances could not reach to make it dirty. Those consuming white wash select the area near the top of the wall for it to be accepted as clean. Other geophagists scrap away the top soil before digging up particular soil for consumption. Some soil consumers prepare or process soil before consumption and some of the processing methods being used includes sun-drying (Young, Goodman, Farag, Ali, Khatib, Khalfan, Tielsch & Stoltzfus, 2007).

Colour, geomorphological environment, mining techiques, texture, processing methods and heat treatment of soil used for consumption are further discussed in the sections that follow:

2.5.2.1 Colour

Color is the most important criteria used by the consumers during soil collection (Mbiko *et al.*, 2004). Geophagist is very much specific about color when selecting clay for mining (Ekosse *et al.*, 2010). The color and texture of clay play a very important role on the type of soil selected for consumption (Reilly & Henry, 2000).

White clay contain kaolin and smectite (Kikouama, Konana, Katty, Bonnel, Balde & Yagoubi, 2009). In the study conducted in Limpopo and Free State, white geophagic clays preferred by most respondents were dominated by kaolinite and smectite (Ekosse *et al.*, 2010). Soil with kaolinite possesses the ability to absorb toxins and bacteria (Yount, 2005) and it is manufactured as a treatment for diarrhoea (Knishinsky, 1998).

In Kenya, pregnant women preferred clay soil material dug from excavation sites (Ngozi, 2005).
The reddish geophagic clay contains iron and that is the reason why it was consumed as a source of iron (Abraham & Parsons, 1997).

2.5.2.2 Geomorphological Environment

Some geophagists obtain soil for consumption from excavation sites (where construction projects or building structure have been erected). Excavation site is the place where soil has been loosened such that it is easily identified and picked up. Others obtain geophagic soils from termitaria, which is rich in iron (Allport, 2006). Geophagic clays are mostly obtained from river banks and such clays are full of waterborne bacteria and pathogens (Geissler, Mwaniki, Thiogo, Michaelsen & Friis, 1998).

2.5.2.3 Mining Techniques

Mining sites for clay in the study done in Limpopo and Free State were not far away from human settlements and the tools used for mining clay were: spades, hoes, shovels, forks, pickaxes, machetes, crowbars and cutlasses (Gosselain, 1999).

Some geophagic people use very awkward tools like dry sharpened sticks, broken bottles and edges of used cans. Forks, pickaxes and crow bars are mostly used for digging. The hoes, spades and cutleries are used for scrapping. The shovel are used to gather the scrapped geophagic clays and where undesirable material and impurities are visible, the hand is used to select and grab all unwanted material away and some mining of clay is achieved through gallery and pit extraction. (Gosselain & Smith, 2005).

2.5.2.4 Favourable Textures

Most clay consumers in the study done in Limpopo and Free State preferred soft, powdery and silk textural feel. Furthermore some geophagic clay contains silt and fine particles from quartz and feldspars which negatively affects dental enamel of geophagic people because of the hardness of the particles (King, Andrews & Boz 1999). Quartz particles erode gastro-intestinal lining and perforate the Sigmoid colon (Woywodt & Kiss, 1999).

To avoid the above mentioned problems imparted by grittiness, course grained fine sand and silt particles should be removed away through the application of Stoke's Law of Sedimentation of particles (settling velocity of small particles) (Anastacio *et al*., 2005; Tateo *et al*., 2006).

2.5.2.5 Processing Methods

There are several kinds of processing methods used for processing geophagic clays. Pounding is usually done with a stone, wooden mortar, pestle or wooden harmer in some of the areas of Sub Sahara Africa, and it is usually followed by sieving of geophagic soils with the aim of separating course particles and silt particles (Gosselain & Smith, 2005).

Grinding is another popular processing method, which forces all geophagic clay to possess almost same size particles (Mahaney, Milner, Mulyomo, Hancock, Aufreiter, Reich & Wink, 1993). Furthermore, grinding increases causes the toxic elements to be readily available for absorption (Mahaney *et al*., 1993).

2.5.2.6 Heat Treatment

Heat treatment is done through boiling, baking and burning of soil to improve the smell and taste (palatability) of geophagic soils (Ekosse *et al.,* 2010). The heat treatment reduces water content, making the soil to attain that powdery, chunky nature preferred by most soil consumers and enhances desirable colour. Yellowish clays changes to brick red after heat treatment due to transformation of goethite to haemotite. Heat treatment is somehow good because it eliminate microbes, bacteria and pathogens (Ekosse *et al.,* 2010).

2.5.3 EFFECTS OF GEOPHAGIA ON HUMAN HEALTH

2.5.3.1 Microorganisms

Microorganisms are mostly single-celled organisms too small to be seen without the aid of a microscope (Star & Taggart, 1995). These microorganisms are divided into groups: bacteria, virus, algae and fungi (Baudoin et al., 2002). There are millions and millions of microorganisms found in the soil (Starr & Taggart, 1995). Bacteria are the smallest organisms which outnumber all other organisms (Starr & Taggart, 1995).

2.5.3.2 Bacteria

Many kinds of bacteria are pathogens (disease- causing agents / infectious), with three basic bacterial shapes i.e. cocci (spheres), bacilli (rods) and spirals and are capable of damaging the tissues of other organisms and at the same time multiply in the same organism (Starr & Taggart, 1995). Virus and protozoans can also be pathogenic (Madigan & Martinko, 2006). The *Escherichia* coli bacteria is pathogenic to human and commonly occur in the intestines of humans where they cause diseases, mainly diarrhea, which causes between 4 and 6 million death each year in the world (Jeffery & van der Putten, 2011).

2.5.3.3 The Role of microorganisms

Microorganisms outnumber all groups of organisms in the world, as they are found everywhere i.e. in the ocean and every person's skin (Willey et al., 2008). No life forms could exist in the absence of microorganisms because even the oxygen we breathe is the result of the microbial activities (Madigan & Martinko, 2006).

The elements that are important to life are recycled by microorganisms as others assist in the photosynthesis (Willey et al., 2008). Microorganisms have got an impact even in soil genesis because although the weathering of rocks is physical and chemical it is biologically driven by microbial activities and soil is a natural medium in which microorganism's lives, multiply and dies (Buscot & Varma, 2005). They also help in the production and the digestion of food (Willey et al., 2008).

The system of agriculture depends on microbial activities. They keep soil healthy because they decompose organic matter, replenish soil nutrients, form humus, promote root growth, and increase nutrient uptake and breakdown herbicides together with pesticides (Starr & Taggart, 1992). The major crops classified under the groups of legumes are associated with bacteria forming nodules on their roots because the bacteria convert atmospheric nitrogen (N_2) into fixed nitrogen (NH_3) which is used by plants for growth, so in that way bacteria activity reduce the requirement for expensive plant fertilizer (Madigan & Martinko, 2006). Although most microorganisms are beneficial, some of them are harmful to human life (Willey et al., 2008).

2.5.3.4 Types of microorganisms

Bacteria are single celled microscopic organisms that are found in great numbers on earth and they perform various actions in the environment of which some are beneficial and some harmful (Madigan & Martinko, 2006).

Microscopic studies have identified two different kinds of microorganisms, namely: organisms with true nucleus (eukaryotes/ organism consisting of cell with the genetic material is DNA), which include algae, fungi and protists, and prokaryotes (less complex cell /cellular organism without nuclear membrane). Prokaryotes consist of the following microbial groups: eubacteria (bacteria found in the interstines of vertebrates and in the soil / a heterogeneous group of microorganisms). These microorganisms have got beneficial roles to mankind. Eubacteria are the dominant group of microorganism in various kinds of soil. They are available in all types of soil but their population decreases as the depth of soil increases (Duineveld, Kowalchuk, Keizer, Elsas & van Veen, 2001). Therefore there are more microorganisms available in horizon A (soil with high organic matter content) compared to horizon B (soil with silicate clay minerals plus organic matter and horizon C (weathered parent material).

Bacteria are divided into two broad categories, namely the autochthonous and zymogenous organism. The authochthonous or indigenous population derived their nutrition from organic and mineral matter (Herman *et al*., 1993). The most common bacteria are *Pseudomona*s, *Arthrobacter*, *Clostridium*, *Achromobacter*, *Bacillus*, *Micrococcus*, *Flarobacterium*, *Corynebacterium, Sarcina*, *Mycobacteria* (Lynch, 1987).

Escherichia is rarely available in soil except when it is found as contaminant from sewage but the *Aerobacter* is frequently found in certain soils (Subba Rao, 1997). This bacteria can withstand extreme climate, below freezing point and very high temperatures. *Escherichia* bacteria is capable of forming spores with tough outer covering for their survival in adverse conditions (Moreno, Gonsalez & Vela, 1986). Beside temperatures, other factors affecting bacteria are pH, farm practices, organic matter amendments, fertilizer and pesticides applications (Barber & Lynch, 1997).

2.5.3.5 Impact of microorganisms on human health

Soil ingestion causes microbiological infections like helminthiasis (Kawaik, Saathoff, Antelman, Msamanga & Fawzi, 2009). Tetanus is a disease caused by bacteria called *Clostridium tetani* (Sutter, Orenstein & Wassilak, 1998). The protozoa species with the name of *G. Lamblia* that is usually found in the contaminated stools in the form of cysts interferes with the absorption of fats in the intestines, furthermore this species remains alive for a longer period in humid conditions and infection occurs when soil associated with poor hygiene and sanitation has been ingested (Heresi, Murphy & Cleary, 2000).

There are also soil transmitted Helmith infections caused by *Necator* and *Ancylostoma* that stay in small intestines. Under favorable climatic conditions pathogenic soil- transmitted helminthic species may be available in any soil where contaminated stools have been placed (Bethony, Brooker, Albonico, Geiger, Loukas, Diemert & Hotez, 2006). In Nigeria the most parasitic infection caused by geophagia is ascariasis which is caused by the worm called *Ascaris Lumbriocoides* and the most common symptom is intestinal obstruction (Hunter, 2003 Clayey soils from termite mounds causes *Ascaris Lumbricoides* infection (Clickmann, Camara, Clickmann & Mccabe, 1999).

If by mistake *Ascaris lumbricoides* and *Trichuris* trichiura eggs have been ingested together with soil, it results in ascariasis and trichiuriasis. Ascariasis is characterised by abdominal pain and nausea, further resulting in chronic impact on growth, nutrition and physical fitness (Abrahams, 2002; Abraham, 2006). Microbial agents such as *Yersinia enterocolitica*, *Escherichia coli*, *Streptococcus faecalis*, Helicobacterpylori and Mycobacteria have been reported to play a role in the etiology of a disease characterized by chronic inflammation of the intestinal wall **(**Lamps, Madhusudhan, Havens, Greenson, Bronner, Chiles, Dean & Scott, 2003; Rubery, 2002).

Geohelminth infection was linked to iron deficiency among HIV infected women who was ingesting soil (Kawai *et al*., 2009). Anaemia which is caused by soil consumption is believed to be caused by the worm encountered by eating soil (Chan, 1997).

The complications caused by geophagia are not common but linked to the amount of soil consumed and usually involve parasitic infestation, electrolytes disturbances and intestinal obstructions but perforation of intestines and peritonitis are associated with high mortality (Woywodt & Kiss, 1999). Parasites like plasmosis and round worms are sometimes passed to soil with animal fecal matter and might be consumed leading to parasitic infestation (Wong, Bundy & Golden, 1988). Geophagist that uses processing methods like baking before soil ingestion can be able to avoid such diseases because parasitic organisms are destroyed by heat (Wong, Bundy & Golden, 1991).

According to (Jeffery, & van der Putten, (2011) there are Euedaphic pathogenic organisms (EPOs), potential pathogens which are true soil organisms. The following list consists of soil borne infectious diseases and their causative agents:

Anthrax: *Bacillus* anthracis
Botulism: *Clostridium* botulinium
Campylobacteriosis: *Campylobacter* jejuni
Leptospirosis: *Leptospira* interrogans
Tetanus: *Clostridium* tetani
Blastomycosis: *Blastomyces* dermatitidis
Histoplasmosis: *Histoplasma* capsulatum
Strongyloidiasis: *Strongyloides* stercoralis

There are different kinds of microorganisms that are available in the soil, therefore soil is sometimes called a vehicle for transmitting human pathogens (Herrewegh, Roholl, Overduiiin, Giessen & van Soolingen, 2004).

CHAPTER 3
MATERIALS AND METHODS

The main objective of this study was to determine the prevalence and the practice of geophagia in Mkhanyakude District (Northern part of KwaZulu-Natal). To achieve this, a survey was conducted to investigate the practice of geophagia in Mkhanyagude district and soil samples from this district were evaluated to determine its nutritional composition and microbial load in the soils eaten. The study was approved by the Humanities & Social Science Research Ethics Committee / Ethical Committee of the University of KwaZulu-Natal (Appendix A; ethnic number: HSS/1040/012M). All respondents were given informed consent (Appendix B) before administering the questionnaire. The content in the informed consent was properly explained to the respondents and signed prior the study.

3.1 Study site

The study was carried out in Mkhanyakude District (Figure 3.1), situated in the north-eastern part of KwaZulu-Natal, extending from Mfolozi River up to the Mozambique boarder. KwaZulu-Natal Province consists of 11 District Municipalities and Mkhanyakude is one of them. Mkhanyakude District encompasses the whole of the former Pongola sub region and part of the Umfolozi sub region. This district municipality is a newly formed entity in terms of the recent demarcation process and incorporates some of the poorest and most underdeveloped regions of KwaZulu-Natal (Mkhanyakude District Integrated Development Plan, 2008/9).

According to the Mkhanyakude District Integrated Development Plan (2008/9), this district has an estimated population of 573 341, out of which 97 percent reside in rural areas. Unemployment rate is 63 percent, with only about 13 percent of the population formally employed. The population is made up of 45.2 percent males and 54.8 percent females. The district is largely rural with the only formalized town of Mtubatuba in the south. However, there are small several towns, which are growing rapidly such as Hlabisa, Hluhluwe, Mkhuze, Jozini, and Manguzi and to a lesser extent, Mbazwana. The district experiences severe backlogs in the provision of infrastructure and services.

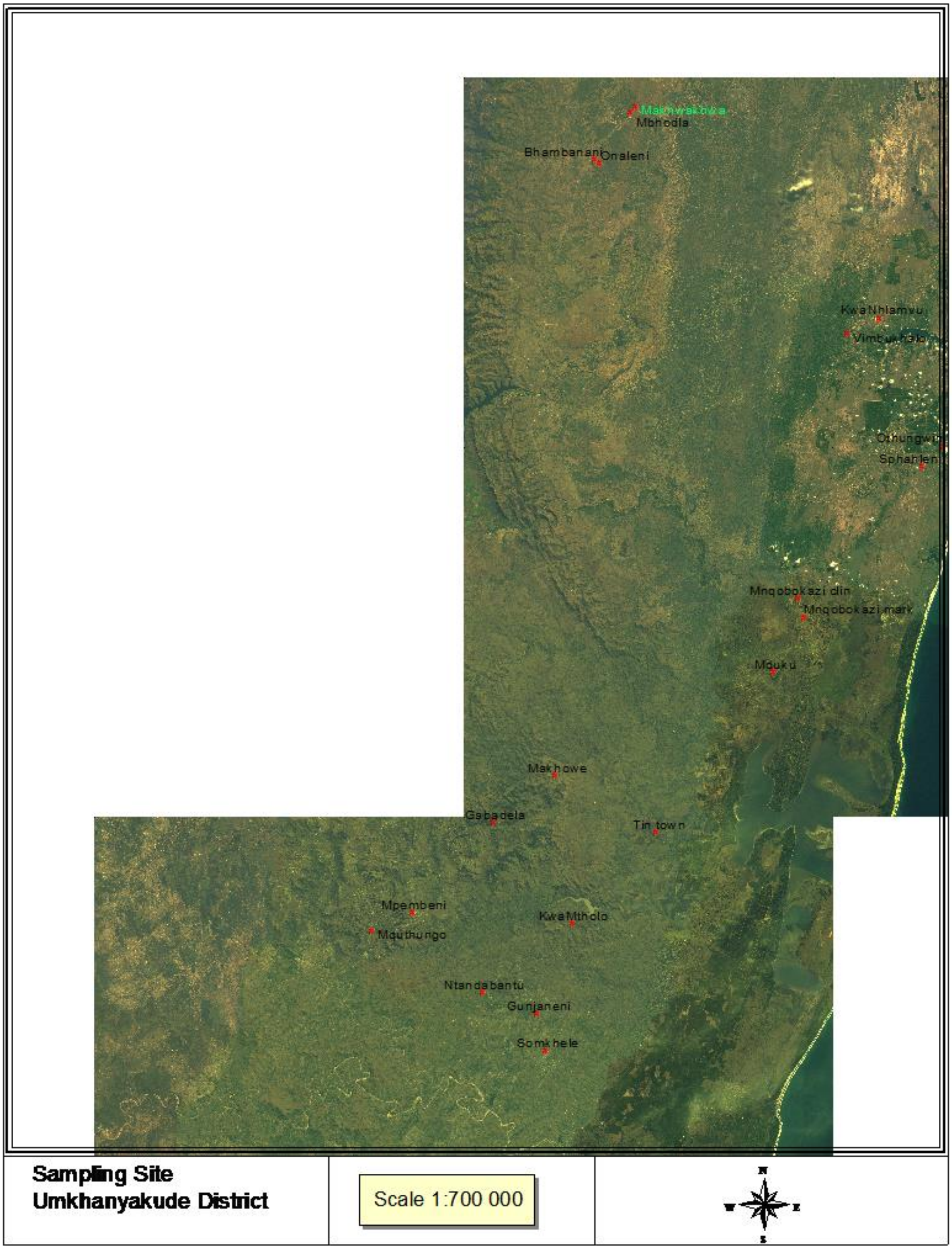

Figure 3.1: Map of Umkhanyakude District indicating the sites for soil collection

3.2 Research design and data collection techniques

A combination of both qualitative and quantitative study design was used. Qualitative methods (based on literature) were used to enable the understanding of the feelings, values and perceptions that underlie geophagia. Furthermore quantitative methods (expressed by means of statistical data) were used because of the biographical information e.g. gender, age, education level and income that was requested from respondents. The questionnaire developed consisted of closed and open ended questions. Three questionnaires were answered: Annexure C consisting of biographical information, Annexure D with prevalence and practice of geophagia and Annexure F were all about perceptions and values underlying geophagia.

Questionnaires were administered to household heads with ages ranging from 14 and 69 years. Respondents were obtained from all five local municipalities of Mkhanyakude District. Hlabisa municipality had 11 respondents, Mtubatuba (21), Big five (22), Jozini (20) and Mhlabuyalingana had 20 respondents. The total number of respondents was 94. Information on individual soil-eating habits was collected through interviews.

Before conducting the survey, information meetings were held with the local headmen (iziNdunas) and some of the Agricultural staff located in the wards with people involved in the study. Meetings for each community were organized in order to have informal talks with members as a group. Members were informed about the objective of the study. Snowballing sampling method (non probability sampling technique where existing study subject recruit future subjects from among their acquaintances) was used to select geophagists from the communities, based on information provided by the community members present during focus group discussions. To avoid bias usually associated with snowballing sampling method, not more than five respondents were identified through one respondent. To facilitate the interviews, enumerators were selected per local municipality.

Initially people were reluctant to openly discuss the issue of soil consumption, due to fears that the researcher was from the department of health. However, the initial conversation removed the barrier and the community members contributed freely, with some acknowledging that their individual efforts to stop the practice of eating soil had failed, thus they feared that they possibly are addicted to this practice.

Each municipality was visited twice prior to interviews; members were informed about the purpose of the study and were interviewed on a voluntary basis. Rapport was firstly established between the researcher, and the interviewees to enable a smooth interaction with them. Questionnaires were composed in English but translated by the researcher into Zulu, the local language.

During the interviews people were requested to bring their favourite soil type that they often consume and asked to take the amount they would eat at a time. The soil was then weighed to establish the quantity that an individual would eat a time. Respondents were also asked to state how often they consume that amount. Different types of tools like (spade, hand hoe, dry sharpened sticks, bush knives, old spoons and knives) are generally used by the community members to collect soil. The community members showed the researchers the sites from which they collect soil for consumption. This facilitated soil sampling for laboratory analyses. Soils were collected from sites such as termite moulds, river banks, mountains, under the trees, in between the trunk and the bark of the tree and walls of the mud houses. From each site where soil was collected, GPS points were recorded for identification purposes. In total, soil samples for laboratory analyses were collected from 20 sites. The samples were submitted to Cedara Laboratory, Pietermaritzburg to be analyzed for colour, nutrient composition, and soil pH. Another set of samples was taken to Life Sciences laboratories to be analyzing for microbial loads. The list of samples collected is given in Table 1. For the samples that were taken to the Life Sciences laboratories, control soil samples from the same municipality that were not used for eating were collected to compare the microbial loads.

Table 3.1: List of soil samples collected from the five municipalities in Mkhanyakude District.

Municipality	Soil Sample ID Number	Coordinates
Hlabisa	1.Gabadela	S28 00. 525 E032 02. 532
	2. Mpembeni	S28 07. 866 E031 55. 911
	3. Mquthungo	S28 09. 319 E031 52. 620
	4. Makhowe	S27 56. 742 E032 07. 562
Mtubatuba	1. KwaMtholo	S28 08. 795 E032 08. 881
	2. Gunjaneni	S28 16. 041 E032 06. 006
	3. Ntandabantu	S28 14. 336 E032 01. 606
	4. Somkhele	S28 19. 101 E032 06. 754
Big Five	1. Mnqobokazi Clinic	S27 42. 352 E032 27. 193
	2. Mnqobokazi Market	S27 43. 894 E032 27. 774
	3. Mduku	S27 48. 373 E032 25. 277
	4. Tin Town	S28 01. 386 E032 15. 772
Jozini	1. Bhambanani	S27 06. 750 E032 10. 746
	2. Onaleni	S27 07. 043 E032 11. 128
	3. Mbhodla	S27 02. 887 E032 13. 664
	4. Makhwakhwa	S27 02. 442 E032 14. 063
Mhlabuyalingana	1. Kwanhlamvu	S27 19. 607 E032 33. 856
	2. Vimbukhalo	S27 20. 849 E032 31. 204
	3. S’phahleni	S27 31. 672 E032 37. 320
	4. Othungwini	S27 30. 017 E032 38. 996

3.3 Laboratory analyses

Soil sample analysis was done at the Soil Fertility and Analytical Services of KwaZulu-Natal Department of Agriculture and Environmental Affairs, Cedara.

3.3.1 Sample Preparation

Soil samples were air dried at room temperature by spreading out in drying trays. After drying the samples were crushed between rubber belts on a soil crusher and passed through a 2-mm sieve. Materials coarser than 2 mm were discarded because it was assumed that the soil consumers would also discard them during sorting done before consuming the soil. The samples were stored in dry boxes until analyses were done.

To measure the pH for each sample, 10 mL soil was scooped into sample cups. 25mL of 1M KCI solution was added and the suspension was stirred at 400 r.p.m. for 5 min using a multiple stirrer. The suspension was allowed to stand for about 30 minutes, and the pH was measured using a gel-filled combination glass electrode while stirring.

3.3.2 Extractable calcium, magnesium and acidity

2.5mL of soil was scooped into sample cups. 25mL of 1 M KCI solution was added and the suspension was stirred at 400 r.p.m. for 10 min using a multiple stirrer. The extracts were filtered using Whatman No. 1 paper. 5mL of the filtrate was diluted with 20 mL of 0.0356 M $SrCl_2$ and then Ca and Mg were determined by atomic absorption. To determine the extractable acidity of the soils, 10mL of the filtrate was diluted with 10mL of de-ionised water containing 2-4 drops of phenolphthalein, and titrated with 0.005 M NaOH. (Soil Fertility and Analytical Services, KwaZulu-Natal Department of Agriculture and Enveromental Affairs –Cedara 2014).

3.3.3 Extractable phosphorus, potassium, zinc, copper and manganese

25mL of Ambic-2 solution (which consists of 0.25 M NH_4CO3+0.01 M Na_2EDTA+0.01 M NH4F+0.05gL-1Superfloc (N100), adjusted to pH8 with a concentrated ammonia solution) was added to 2.5 mg soil, and the suspension was stirred at 400 r.p.m. for 10 min using a multiple stirred (Soil Fertility and Analytical Services, KwaZulu-Natal Department of Agriculture and Enveromental Affairs –Cedara 2014). The extracts were filtered using Whatman No. 1 paper. Phosphorus, in a 2 ml aliquot of the filtrate, was determined using a modification of the Murphy and Riley (1962) molybdenum blue procedure (Hunter, 1974). Potassium was determined by atomic absorption spectrophotometer on a 5 ml aliquot of the filtrate after dilution with 20 ml de-ionised water. Zinc, Copper and Manganese were determined by atomic absorption spectrophotometer on the remaining undiluted filtrate (Soil Fertility and Analytical Services, KwaZulu-Natal Department of Agriculture and Enveromental Affairs –Cedara 2014).

3.3.4 Estimate of clay content by near-infrared spectroscopy

Clay content was estimated for all soil samples routinely analyzed in the soil fertility laboratory, using a combination of Mild-Infrared Reflectance, using the air-dry, milled soil samples and measured sample density.

3.4 Soil colour identification

The colour of all clay soil samples used in geophagia from five local municipalities indicated in table 1 was determined by visually comparing the soil samples with soil colours as displayed in the Munsell Soil Colour Charts (1992).

3.5 Tests for microbial load

Beside colour, soil samples were also collected from the same areas including Umlalazi municipality from Uthungulu District to determine microbial load and for this purpose samples were collected using microbial standard methods as described in the next section to ensure that there was no contamination.

3.5.1 Determination of the Most Probable Number of heterotrophic microbial count

The Most Probable Number (MPN) method as described by Sutton (2010) was used to determine the microbial load of the soil samples (Annexure F). The MPN method uses a number of tubes containing suspensions of the sample being analysed. If all tubes per sample showed growth, then the results will be noted as 333 (Sutton, 2010). If only one tube in each replicate for the top three dilutions showed growth then it would be noted as 111(Sutton, 2010). The pattern of growth is then read from the top three dilutions where growth was observed in each sample and this positive tube combination is used in the provided MPN table to provide the most probable number and 95% confidence interval (Sutton, 2010). For example, the result of 210 (positive tube combination) would reflect a Most Probable Number (MPN) of 21 (see soil sample O), and a result of 320 would give a table MPN value of 93. The MPN table normally only presents results for three dilutions in sequence (e.g., 10^{-1}, 10^{-2}, 10^{-3}), but the dilution series tested might have been from the 10^{-2} to 10^{-4} tubes in this instance one would need to take the dilution factors in the table and in the actual experiment into account to derive the most probable number from this study (Sutton, 2010). The MPN value obtained is represented as a log MPN/g (Sutton, 2010).

3.6 Statistical analysis

Data from the questionnaires was entered onto a spreadsheet and coded for analysis using the Statistical Package for the Social Sciences 21 (SPSS).

CHAPTER 4
RESULTS

In this chapter, data collected from UMkhanyakude District with regard to socio-demographic information, prevalence, practice and perception of geophagia, microbial populations of soil samples and nutritional composition of soil used for geophagia are presented.

4.1 Socio –demographics information

All of the 94 participants' interviewees were females. Out of 94 respondents, 52.2% reported that people permanently living in their household ranged from four to seven and 3.8% of the respondents were living in households that had more than ten people per household (refer Table 4.1a).

The interviewees were also asked about number of children in the nuclear family and 76.5% respondents had from one up to four children, 11.8% respondents had from five up to eight and 3.3% respondents had more than eight children in the nuclear family. Fifty eight percent of respondents had extended family children staying with them ranging from one to four while 5.4% had above eight children with them. A total of 53.2% interviewees revealed that were staying with extended family members ranging from one to four while 10.7% were living with five to eight members as shown in Table 4.1a.

The majority of respondents (67.1%) had one to four household children attending school and 3.1% had no school children. Ninety four percent of respondents were without household members who had attended tertiary education. Only 8.5% had one person who had attended tertiary education (Table 4.1a.)

The respondents were also asked about the number of household members that are working. The mother was predominantly the head of the household as seen in Fig 4.1. Out of 94 interviewee, 59.6% of respondents had no employed household member excluding themselves, 24.5% had only one and others had two or three working household members. Only 1.1% of the participants had six members of families who were employed as indicated in Table 4.1a.

Table 4.1a: Socio-demographic information of participants

Variable	Category	N (94)	% of total
Gender	**Female**	94	98.9
How many persons permanently living in your Household?	1-2	42	44.6
	3-4	49	52.1
	5-6	3	3.2
How many children do you have (nuclear family)?	0	8	8.5
	1-4	72	76.5
	5-8	11	11.8
	>8	3	3.3
Number of extended family children staying with you?	0	26	27.6
	1-4	55	58.5
	5-8	8	8.5
	>8	5	5.4
Number of extended family members staying with you?	0	34	36.1
	1-4	50	53.2
	5-8	10	10.7
Number of the household children attending school ?	0	3	3.1
	1-4	63	67..1
	4-8	23	24.5
	>8	5	5.3
Number of household members attended tertiary?	0	85	90.4
	1	8	8.5
	3	1	1.1
Number of household members that are working?	0	56	59.6
	1	23	24.5
	2	11	11.7
	3	3	3.2
	6	1	1.1
What is your marital stutus?	Unmarried	72	76.6
	Married	21	22.3
	Widowed	1	1.1
What type of water source is used?	Piped (yard/internal)	24	25.5
	Pipes (public tap)	42	44.7
	Bore hole	10	10.6
	River/Stream	10	Io.6
	Water trunk	8	8.6
What type of housing is used?	Concrete	39	41
	Mud	19	20.2
	Stones	24	25.5
	Wood	6	6.3
What type of toilets is used?	Flushed improved	7	7.4
	pit latrines	2	2.1
	Unimproved latrines	53	56.4
	No facility	32	34.0
What is your highest level of education?	Primary level	23	24.5
	Secondary	57	60.7
	Tertiary	6	6.3
	None	8	8.5

Table 4.1b: Socio-demographic information of participants (Cont.)

What is your primary employment status?	Unemployed	71	75.5
	Self employed	6	6.4
	Full time wage	8	8.5
	Part time	9	9.6
Variable	**Category**	**N (94)**	**% of total**
Husband /partner's employment status	Retired by choice	1	1.1
	Unemployment	22	23.4
	Self employed	4	4.3
	Full time wage	11	11.7
	Part time	5	5.3
	Without husband	51	54.3
Who is the head of the household?	Mother	64	68.1
	Father	16	17.1
	Child	9	9.6
	Grandparent	5	5.3
How many meals are you taking per day?	One per day	1	1.1
	Two per day	29	30.9
	Three per day	62	65.9
	Four per day	2	2.1
Are you pregnant?	Yes	3	3.2
	No	91	96.8
Are you breastfeeding?	Yes	10	10.6
	No	84	89.4
If yes how old is the baby?	0-3 three weeks	5	5.3
	4-6 weeks	2	2.1
	Not applicable	87	92.6
		94	**100**

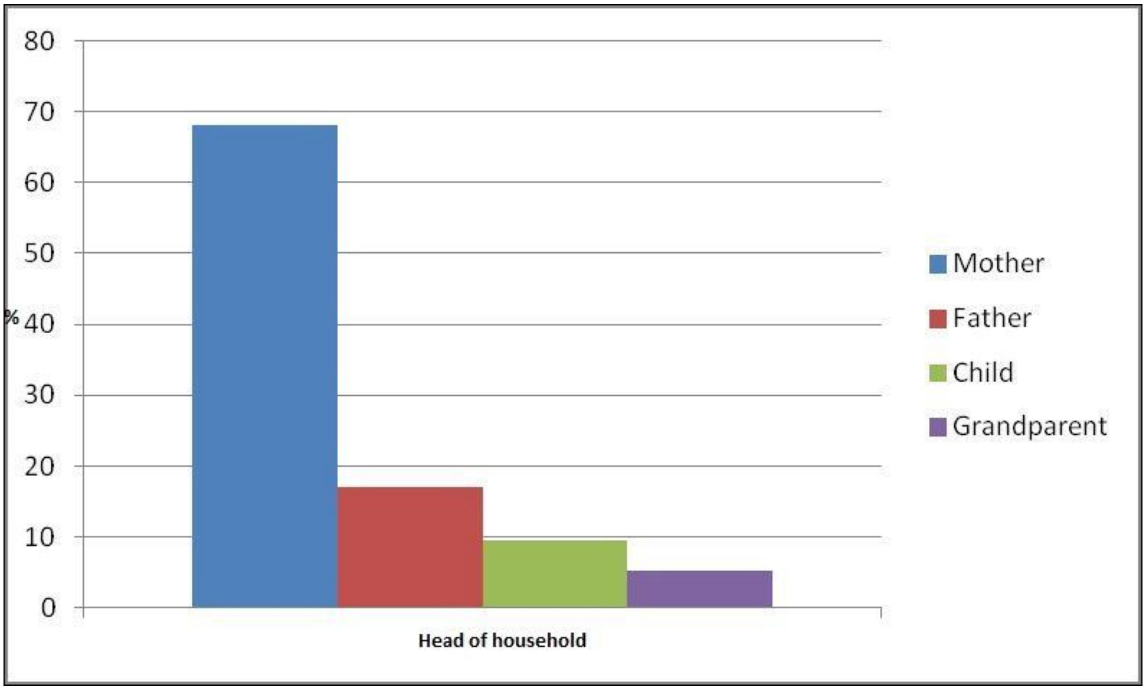

Figure 4.1: Percentage type of head of household

The majority of the respondents 77.7% were single while 22.3% were married. A large number revealed that they were without partners to assist them financially as shown in Table 4.1a.

The main source of water for 44.7% of the participants was public taps. The quality of housing in the area was dominated by concrete blocks (41.0%) followed by mud-walled huts thatched with grass (20.2%) and lastly was stones mixed with wood and mud. Others were eating soil from the walls of their houses (Table 4.1a)

The majority of respondents (56, 4%) were still using unimproved types of toilets (pit toilets used in deep rural areas) and 32 (34, 0%) had no facilities at all. So, it is possible that those geophagists who were eating soil somehow collected closer to the toilets were consuming contaminated soil as indicated in Table 4.1a.

A summary of educational level of geophagists indicated that 60.7% had secondary education, 8.5% had never attended school and only 6.3% had tertiary education. Low level of education can have a negative impact on nutritional education and even on employment opportunities due to the lack of skills, as 75.5% of them were unemployed while only 8.5% were full time wage earners (Table 4.1a)

Economic status of the geophagists was not good at all because 54.3% of the respondents had no husbands who could contribute to income of households and even those who had those (23.4%) were unemployed. That is validated by the percentage of households, (68.1%) which was female headed compared to only (17.1%) male headed (Table 4.1b). Others were headed by children or grandparents.

The majority (64.9%) were taking three meals per day although others 34.1% were taking two or lesser meals per day. This reflected that most of them are regular eaters. Only (3.2%) were pregnant and the rest which is (96.8%) were not pregnant, implying that although soil eating is said to be influenced by pregnancy, there may be other factors contributing towards geophagia (Table 4.1b)

Respondents were asked whether they were breastfeeding or not, (89.4%) respondents answered that were not breastfeeding and only (10.6%) were breastfeeding. Respondents were asked about the age of their babies of which 5, 3% were from new born zero to three weeks, 2.1% were from four to six weeks and the rest had no babies as shown in Table 4.1b.

4.2 Prevalence of geophagia

Geophagists were requested about the frequency of eating soil Findings in Table 4.2 reveal that 83.3% of the participants were consuming soil more than once per day while 15.6% consumed it once per day as shown in Table 4.2. This suggests that most of respondents were addicted to soil eating.

Among 94 geophagists 39.6% have been eating soil for the period of more than ten years, 15, 9% had eaten it for 5 – 10 years and the rest had eaten it for up to five years. They were also asked about the amount of soil consumed at a time and answers reflected that all of them were taking soil above 60g at a time (respondents were requested to bring amount of soil they consume at a time and weight of soil was weighed by a food scale. The total of 60.9% reflected that beside them, there were also other family members eating soil. Only 39.4% were consuming soil alone in their households as indicated in Table 4.2.

Table 4.2: Prevalence of geophagia

		N (94)	% of total
Number of times during which the soil was consumed	Once a day	15	15.6
	Once a week	1	1.1
Number of years during which the respondent had been eating soil	Less than 2 years	9	9.6
	3- 5 years	33	35.1
	6-10 years	15	15.9
	More than 10 years	37	39.4
Quantity of soil consumed	Less than 50g	0	0
	More than 50g	94	100.0
Whether there are other members of household that consume soil	Yes	57	60.9
	No	37	39.4
		94	**100.0**

4.3 Practices of geophagia amongst participants

4.3.1. Sources of influence for the participant's practice of eating soil

People eat soil due to various reasons. 83.0% of interviewees were driven by taste, 3.2% caused by hunger and another 3.2% were eating soil for craving satisfaction (Table 4.3). Others mentioned healing as another reason. An estimate of 45.7% of respondents was influenced by pregnancy and 38.3% were attracted by the smell of the soil. Other reasons listed were addiction, having seen their mothers eating soil and peer pressure, but some respondents were unable to state their reason for soil consumption as shown in Table 4.4 and figure 4.4.

4.3.2 Colour of soil that participants consumed

About 33% of participants preferred soil with red color, followed by 27.7% who were consuming black soil and 22.3% were interested in eating brown soil. Others were eating white, cream white, grey and yellowish soils (Table 4.3).

4.3.3 Types of soils that were used for consumption

As indicated in table 4.3 the total of (46.8%) respondents was consuming soil locally called isibomvu which is red in color and 12.8% of respondents were taking isiduli (termite mould) and is brownish in color. Other locally named soils that were used were umcaka, ibomvu, ihlabathi, umgabadi, isidaka and inkwali as shown in Table 4.3. The sites where these soils are obtained are not the same therefore they differ in texture, particle size and colour.

4.3.4 Tools that participant used to collect soil for consumption

Tools mostly used for collecting soil for consumption from the sites varied; such that the majority of geophagists (52.1%) were digging with knives, followed by 21.3% who were using hand hoes. Estimates of 10.6% geophagists were purchasing soil from street vendors. Other soil consumers were both digging and purchasing, using hands, bush, hand spade and even taking mud from the walls of their houses (Table 4.3 and figure 4.3).

4.3.5 The prevalence of the practice of processing soil prior to using it for consumption

Geophagists were asked whether they were processing soil before consumption. A total of 79.8% respondents were not processing soil for consumption as opposed to 20.2% of the respondents who processed (baked in sun) soil for consumption (Table 4.3).

4.3.6 Other non-food items that participants also consumed

Respondents were also asked about eating other non-food items. Findings in Table 4.3 reflected that 89.4% of the geophagists were not consuming other types of non-food items. Only 10.6% were consuming non-food items like ash, chalk, toilet paper, and coal and goat dung. Soil eaters are normally driven by different situations. 42.6% of the people interviewed were caused by pregnancy, 33.0% started on their own without any influence and 12.8% was influenced by peer group. The rest was influenced by the following: saw somebody else, taste and smell and tradition. Others were influenced by other factors, namely taste, smell, tradition and having noticed somebody else eating soil.

Table 4.3: Practices of geophagia amongst participants

		N (94)	% of total
Which colour of soil do you consume most often?	Red	31	33.0
	White	10	10.6
	Grey	2	2.1
	Black	26	27.7
	Brown	21	22.3
	Cream White	3	3.2
	Yellowish	1	1.1
How do you collect soil for consumption?	Digging with knife	49	52.1
	Purchased from vendors	10	10.6
	Digging and purchasing	6	6.4
	Hand hoe	20	21.3
	Hand	3	3.2
	Bush	3	3.2
	Walls from house	1	1.1
	Spade	1	1.1
What is the local name of soil consumed?	Umcaka	11	11.7
	Unknown	5	5.3
	Isiduli	16	17.1
	Ibomvu	7	7.4
	Isibomvu	57	46.8
	Isidaka	4	4.3
	Ihlabathi	4	4.3
	Umgabadi	2	2.1
	Inkwali	1	1.1
Do you prepare/process soil for consumption?	Yes	19	20.2
	no	75	79.8
Do you consume any other non- food items?	Yes	10	10.6
	No	84	89.4
If yes specify	Not applicable	84	89.4
	Ash	4	4.2
	Gold danga	1	1.1
	Chalk	2	2.1
	Toilet paper	2	2.1
	Coal	1	1.1
		94	**100.0**

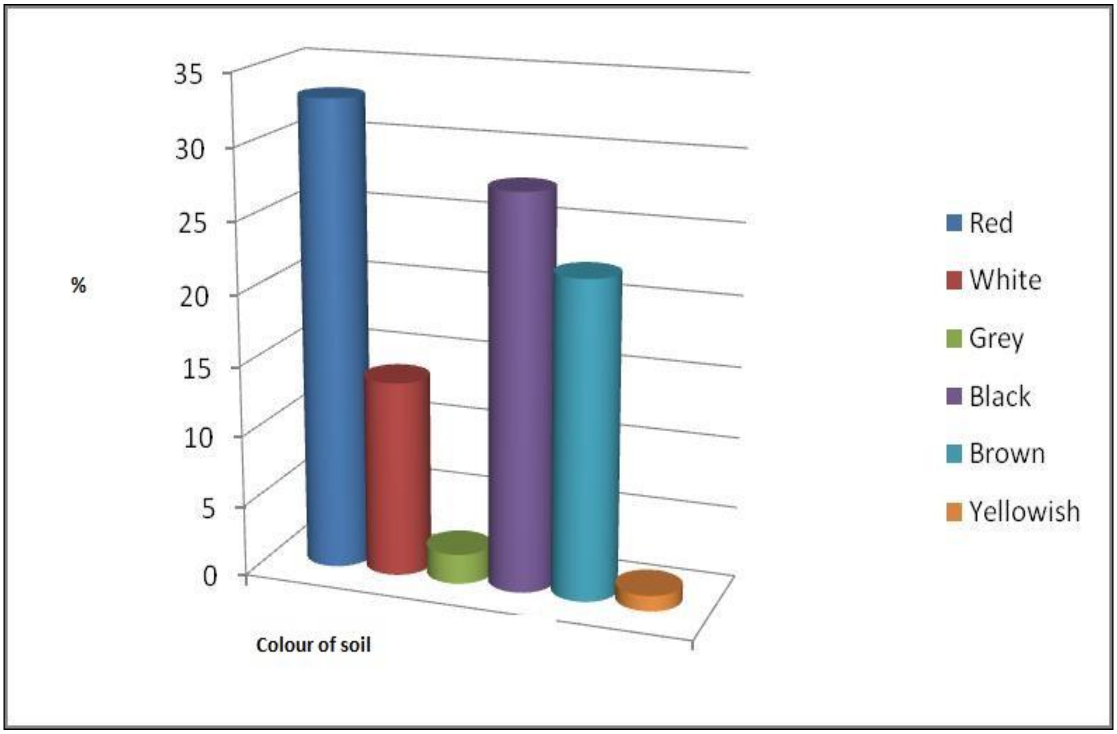

Figure 4.2: Colour of soil consumed by participants

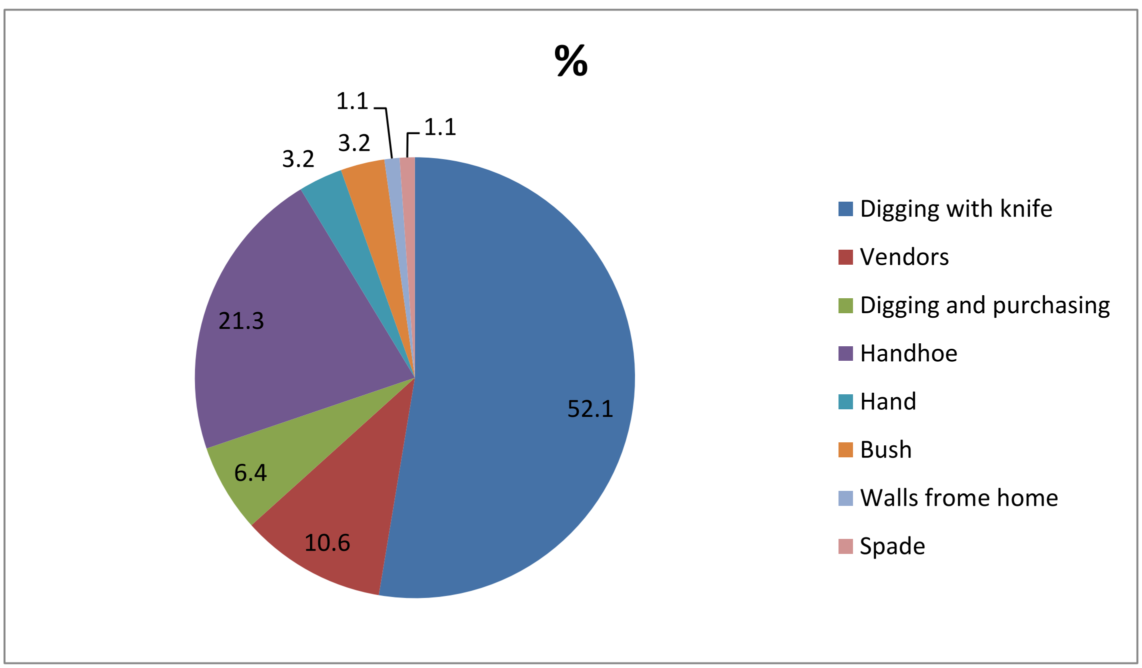

Figure 4.3: Methods of collecting soil from sites

Table 4.4: Practices for geophagia amongst participants

		N (94)	% of total
How did you learn to eat soil?	Peer group	12	12.8
	Tradition	1	1.1
	Started on your own	31	33.0
	Saw someone else	5	5.3
	Influenced by somebody	3	3.2
	Pregnancy	40	42.6
	Taste and smell	2	2.2
		94	**100.0**

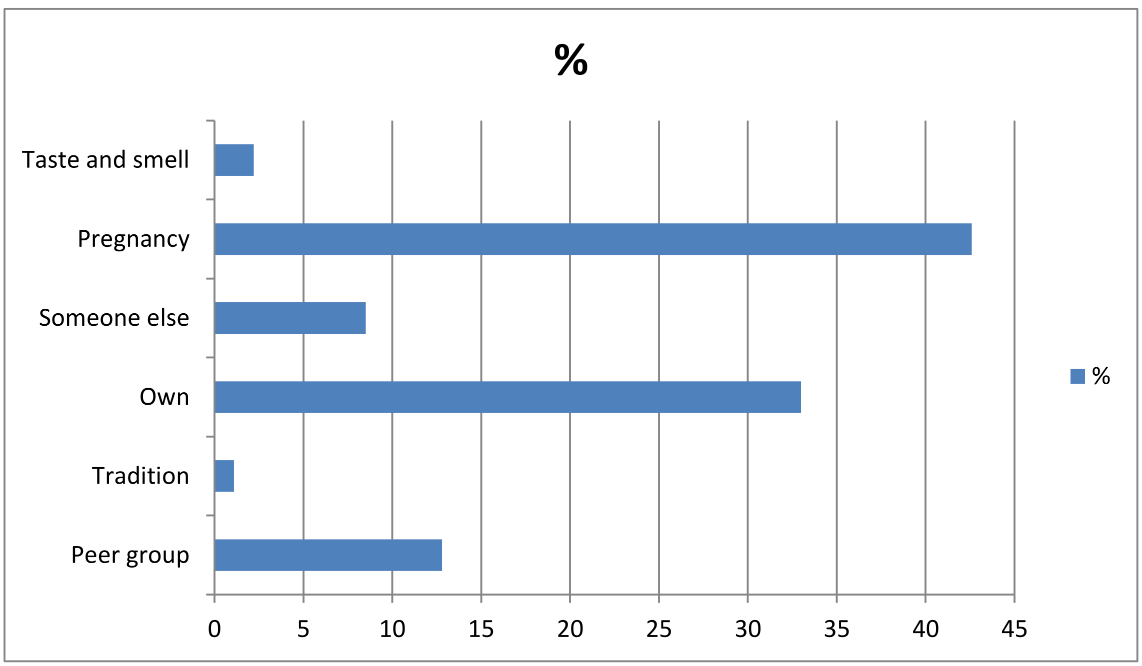

Figure 4.4: Sources of influence that led the participants to start consuming soil

4.4 Participants' perceptions of geophagia

When geophagists were asked whether eating soil was helpful or not, 87.2% stated that it was not helpful at all, although 12.8% geophagists did believe that soil is helpful as shown in Table 4.5. Soil for geophagists was obtained from different selected sites. About 75% of the respondents obtain soil for consumption from termite moulds while 10.6% respondents purchase soil from the street vendors. Other mentioned specific sites where soils are collected for consumption were river banks, area where soil erosion occurred, mud walls of houses, fire place and area of construction.

The geophagists were asked whether they can send somebody else to collect soil consumption and half of them (50.0%) revealed that there is no problem in sending somebody else to get soil for consumption but another half of respondents 47 (50.0%) confirmed that they are afraid of sending anyone to collect soil from the sites for fear that the people they send might not collect the right soil and that they might not be careful with regard to where they collected it (Table 4.5).

The question of experiencing side effects after eating soil was also administered. The total of 66% percent agreed that eating soil has got side effects while (39.4%) had not experienced any side-effects from eating soil as indicated in Table 4.5. The mentioned examples of side effects were the sharp stomach pain, worms, cancer, constipation, *impethwana* (itching symptoms in the buttocks indicating presence of certain types of worms), diarrhoea, appendicitis, gallstones, bloody stools, kidney pains, womb blockage, bladder pains, coughing, anaemia, heavy bleeding and pains during menstruation, becoming sterile, fibroids and difficulty in waste excretion process.

Table 4.5: Participants' perceptions of geophagia

		N (94)	% of total
Why is it important to eat soil?	Healing	2	2.1
	Taste	78	83.0
	Satisfaction	3	3.2
	No reason	1	1.1
	Hunger	3	3.2
Other reasons for eating soil?	Pregnancy	43	45.7
	Smell	36	38.3
	Addiction	2	2.1
	Peer group	8	8.5
	Don't know	1	1.1
	Saw mother eating	4	4.3
Do you think eating soil can be helpful to other people?			
	Yes	12	12.8
	No	82	87.2
Specific sites where soil can be obtained?			
	River banks	4	4.3
	Termites	69	73.4
	Erosion of soil	5	5.3
	Subsoil	2	2.1
	Mud wall of house	2	2.1
	Vendors	10	10.6
	Fire place	1	1.1
	Area of construction	3	3.2
Can you send somebody else to get soil from site?			
	Yes	47	50
	No	47	50
Any side-effects after eating soil	Yes	57	60.6
	No	37	39.4
Examples of side-effects			
		94	**100.0**

Table 4.6: Colours of analyzed geophagic soil samples

Local Municipality	Area where sample collected	Hue value and chroma of samples	Color of samples based on Munsell soil color charts
Hlabisa	Makhowe	2.5YR3/4	Dark reddish brown
	Gabadela	2.5YR3/4	Dark reddish brown
	Mpembeni	2.5YR4/8	Red
	Mquthungo	5YR5/8	Yellowish red
Mtubatuba	Ntandabantu	7.5YR5/4	Brown
	Gunjaneni	10YR5/1	Gray
	Somkhele	5YR4/1	Dark reddish gray
	KwaMtholo	10R3/4	Dusky red
Big 5	Tin Town	2.5YR3/4	Dark reddish brown
	Mduku	7.5YR4/3	Brown
	Mnqobokazi Clinic	10YR4/4	Dark yellowish brown
	Mnqobokazi Market	2.5YR3/4	Dark reddish brown
Mhlabuyalingana	Othungwini	10YR7/1	Light gray
	Sphahleni	10YR5/8	Yellowish brown
	Vimbukhalo	10YR5/3	Brown
	KwaNhlamvu	10YR5/3	Brown
Jozini	Bhambanana	10YR4/3	Brown
	Onaleni	5YR4/1	Dark gray
	Mbhodla	7.5YR4/4	Brown
	Makwakwa	2.5YR3/6	Dark red

4.5 Colour of geophagic samples

Colour of sampled soils varied with geographical regions of Mkhanyakude District (Table 4.6). Sampled soils from Hlabisa local municipality were reddish to yellowish in colour, Mtubatuba were reddish to greyish, Big 5 were brownish to yellowish and from Mhlabuyalingana municipality were brownish to reddish.

4.6 Constituents of soil samples by geophagic location

Table 4.7 shows the nutritional content of sampled soils used for geophagy in Umkhanyakude District. The nutritional content of sampled soils varied with different soils. The following minerals, expressed in milligrams per kilogram (mg/kg) of soil were found:

Phosphorus

Soil samples with higher content of phosphorus were obtained from Gunjaneni (15.09 mg/kg) and Mduku (12.90 mg/kg) while the samples with low content of phosphorus were from Vimbukhalo (4.96mg/kg), Sphahleni (5.15 mg/kg), KwaNhlamvu(5.34 mg/kg) and Ntandabantu (5.79 mg/kg). The mean phosphorus content of sampled soils was moderate in Hlabisa(7.26 mg/kg), Big 5 (8.97 mg /kg) and Mtubatuba (9.21 mg/kg) while it was low in Mhabuyalingana (6.14 7.26 mg/kg) and Jozini(6.87 mg/kg).

Potassium

Soil samples identified with high potassium content were from Bhambanana (335.83 mg/kg), Onaleni (381.03 mg/kg), Mbhodla (388.03 mg/kg), Mnqobokazi Clinic (550.93 mg/kg), Mduku (299.19 mg/kg), Othungwini (130.30 mg/kg), and Somkhele (132.41 mg/kg). Soil samples that were having low potassium content were from KwaMtholo (18.48 mg/kg), Mquthungo (11.82 mg/kg), Ibomvu (16.13 mg/kg), Vimbukhalo (27.66 mg/kg), Mpembeni (25.00 mg/kg), and Ntandabantu (46.28 mg/kg). The mean potassium composition of sampled soil was high in Jozini (294.44 mg/ kg); Big 5 (243.89 mg/kg); Mtubatuba (72.17mg/kg); Mhlabuyalingana(66.84 mg/kg) and Hlabisa (38.54 mg/kg).

Calcium

The geophagic soil samples with highest calcium content were from Ntandabantu (3498.35 mg/kg). High calcium content was also found in soils from Tin town (1788.24 mg/kg), Somkhele (1650.93 mg/kg) and Gabadela (1572.53 mg/kg). The lowest calcium content samples were form Mpembeni (122.41 mg/kg), Mquthungo (2091 mg/kg), Othungwini (176.77 mg/kg), KwaNhlamvu (157.25 mg/kg) and Makhowe (154.26 mg/kg). The mean calcium content of sampled soil was high in Mtubatuba (1666.32 mg/kg) and Big 5 (1035.62 mg/kg) but low in Hlabisa (912.21 mg/kg); Jozini (670.02 mg/kg) and Mhlabuyalingana (259.94 mg/kg).

Magnesium

The high magnesium content samples were from Ntandabantu(1244.63 mg/kg), Gunjaneni (951.89 mg/kg), Makhowe (917.00 mg/kg) and Gabadela (737.36 mg/kg) Mpembeni (155.17 mg/kg), KwaNhlamvu (130.53 mg/kg) and Vimbukhalo (146.10 mg/kg). Samples with low magnesium content were from Othangwini (32.32 mg/kg) and Makwakwa (32.56 mg/kg). The mean magnesium composition was high in four municipalities ie Mtubatuba (795.09 mg/ kg); Hlabisa (509.66 mg/ kg^{-1} soil); Jozini (407.86 mg/ kg^{-1} soil) and Big 5 (370.36 mg/ kg^{-1} soil) whereas was low in Mhlabuyalingana (165.29 mg /kg^{-1} soil).

Zinc

Soil samples with highest zinc content were from Somkhele (15.00 mg/kg), Ibomvu (1.94 mg/kg), Tin town (1.57 mg/kg) and Mbhodla (1.20 mg/kg) had medium zing amounts. The soil samples with low zinc content were from Bhambanana (0.08 mg/kg).

Manganese

Soil samples that had high manganese content were from Bhambanana (11.67 mg/kg), Onaleni (28.45 mg/kg), Mbhodla (68.38 mg/kg), Makwakwa (31.78 mg/kg), Kwamtholo (17.39 mg/kg), Gabadela (10.99 mg/kg) and Mduku (18.55 mg/kg). Those with low manganese content were from Mduku (18.55 mg/kg), Mpembeni (0.86 mg/kg), Mquthungo (0.91 mg/kg), Vimbukhalo (0.71 mg/kg) and Sphahleni (0.74 mg/kg). The mean manganese content was high in Big 5 (10.31 mg/kg) and Jozini (35.07 mg/kg) whereas in Mhlabuyalingana (3.15 mg/kg); Hlabisa (5.19 mg kg) and Mtubatuba (7.73 mg/kg).

Copper

Soil samples that were found to have very high content of copper were from Kwamtholo (27.61 mg/kg), Gabadela (33.85 mg/kg), Makhowe(48.80 mg/kg), and Tin town (29.51 mg/kg) while the soil samples with low content of copper were from Bhambanana (0.92 mg/kg) , Mpembeni (0.34 mg/kg), Mquthungo (0.55 mg/kg), Kwanhlamvu (0.53 mg/kg), Sphahleni (0.15 mg/kg), and Vimbukhalo (0.50 mg/kg). The mean copper content of soils were all low such that in Hlabisa (20.89 mg/ kg); Mtubatuba (10.68 mg/kg); Big 5(8.89 mg/kg) Jozini (1.22 mg/kg) and Mhlabuyalingana (0.83 mg/kg).

4.6.1 The pH of geophagic soil samples

The pH values of soil samples ranged from 4.03 to 7.59 as indicated in table 4.7. It varied with different soils. The sampled soils were grouped according to their pH levels. The majority of soil samples were acidic. Fourteen soil samples were very strong to extremely acid i.e. Makwakwa (4.03), Mpempeni (3.94), Othungwini (4.03), Onaleni (4.99), KwNhlamvu (4.33), Mduku (Mduku), Mquthungo (4.06), KwaMtholo(5.5), Ntandabantu (5.06), Somkhele (5.14), Gabadela (5.34), Vimbukhalo (5.32), S'phahleni (5.31) and Ibomvu (5.06). Four soil samples were slightly to moderately acidc, they include soils collected from Tin Town (6.16), Mbhodla (6.02), Mnqobokazi Clinic (5.82) and Makhowe (5.64). One soil sample (Gunjaneni) had a neutral pH value (7.05) and the last one called Mnqobokazi Market was alkaline with a pH value of 7.59. This confirms that most of the sampled soils were acidic although acidity levels varied.

Soil alkalinity increased with the increase in calcium and magnesium content, whereas soil acidity increased with the decrease in calcium and magnesium content in the soil samples.

4.6.2 Acid Saturation

Acid saturation ranged from 0-33 as indicated in table 4.7. It was generally low and most sites had 0.00 except the few i.e Makwakwa (14), Othungwini (16), Mquthungo (25) and Mpembeni (33) and their pH values were very strong to extremely acid.

4.7 Microbial content of the soil

Table 4.8 shows the presence of microorganisms in different sampled geophagic soils. Microbial content varied with different soils. The microbial content ranged from 9300 to 24000000000 (3 to 9 MPN/g).

Table 4.7: Nutritional composition of sampled soils used for geophagia (mg kg^{-1} soil)

Municipality	Site	pH KCL	Exch acidity	Acid sat%	P	K	Ca	Mg	Zn	Mn	Cu
Hlabisa	Makhowe	5.64	0.05	0	7	58	1933	917	0.3	8	48.8
	Gabadela	5.34	0.04	0	8.79	59.34	1572.53	737.36	0.44	10.99	33.85
	Mpembeni	3.94	0.98	33	6.9	25	122.41	155.17	0.26	0.86	0.34
	Mquthungo	4.06	0.67	25	6.36	11.82	20.91	229.09	0.09	0.91	0.55
	Mean	4.75	0.44	14.50	7.26	38.54	912.21	509.66	0.27	5.19	20.89
Mtubatuba	Ntandabantu	5.06	0.03	0	5.79	46.28	3498.35	1244.63	0.25	3.31	1.07
	Gunjaneni	7.05	0.04	0	15.09	91.51	637.74	951.89	0.19	0.94	8.77
	Somkhele	5.14	0.06	0	8.33	132.41	1650.93	580.56	15	9.26	5.28
	KwaMtholo	5.5	0.05	1	7.61	18.48	878.26	403.26	0	17.39	27.61
	Mean	5.69	0.05	0.25	9.21	72.17	1666.32	795.09	3.86	7.73	10.68
Big 5	Tin Town	6.16	0.04	0	7.84	68.63	1788.24	559.8	1.57	9.8	29.51
	Mduku	4.65	0.07	1	12.9	299.19	420.16	386.29	0.4	18.55	1.05
	Mnqobokazi clnic	5.82	0.08	1	8.33	550.93	958.33	477.78	0.56	8.33	3.7
	Mnqobokazi Mkt	7.59	0.06	1	6.82	56.82	975.76	57.58	0.15	4.55	1.29
	Mean	6.06	0.06	0.75	8.97	243.89	1035.62	370.36	0.67	10.31	8.89
Mhlabuyalingana	Othungwini	4.03	0.28	16	9.09	130.3	176.77	32.32	0.3	8.08	2.12
	Sphahleni	5.31	0.03	1	5.15	73.53	321.32	352.21	0.07	0.74	0.15
	Vimbukhalo	5.32	0.02	1	4.96	27.66	384.4	146.1	0.5	0.71	0.5
	KwaNhlamvu	4.33	0.05	2	5.34	35.88	157.25	130.53	0.15	3.05	0.53
	Mean	4.75	0.10	5.00	6.14	66.84	259.94	165.29	0.26	3.15	0.83
Jozini	Bhambanana	5.59	0.05	1	5.83	335.83	809.17	522.5	0.08	11.67	0.92
	Onaleni	4.99	0.05	1	6.9	381.03	749.14	537.93	0.17	28.45	1.29
	Mbhodla	6.02	0.09	1	8.55	388.03	967.52	538.46	1.2	68.38	1.2
	Makwakwa	4.03	0.21	14	6.2	72.87	154.26	32.56	0.08	31.78	1.47
	Mean	5.16	0.10	4.25	6.87	294.44	670.02	407.86	0.38	35.07	1.22

Exch Acidity= Exchange acidity in cmol kg^{-1}

Table 4.8: Microbial content of sampled geophagic soil

Table showing the log MPN/g for each soil sample

Soil sample	**Total microbial content MPN (cfu)/g**	**log MPN(cfu)/g**
Makhowe	9300	3.97
Gabadela	9300	3.97
Mpembeni	240000	5.38
Mquthungo	9300	3.97
Soil not eaten (control)	240000	5.38
Ntandabantu	9300	3.97
Gunjaneni	4620000	6.66
Somkhele	24000000	7.38
KwaMtholo	240000	5.38
Soil not eaten (control)	240000	5.38
Tin Town	240000	5.38
Mduku	24000000	7.38
Mnqobokazi Clinic	930000	5.97
Mnqobokazi Market	930000	5.97
Soil not eaten (control)	14700	4.17
Othungwini	2400000	6.38
Sphahleni	154000	5.19
Vimbukhalo	240000	5.38
KwaNhlamvu	930000	5.97
Soil not eaten	2400000	6.38
Soil eaten a lot	390000	5.59
Bhambanani	24000000000	9.38
Onaleni	4300000	6.63
Mbhodla	24000000	7.38
Makwakwa	4620000	6.66
Soil not eaten	9300000	6.97
Uthungulu (control)	430000	5.63
Autoclaved (control)	0	0

Tables 4.9: Comparison between geophagic soil samples with relatively lower and high microbial population

Area where soil was collected	Clay %	Soil Colour	Microbial population (MPN(cfu)/g	
			High	Low
Makhowe	>60	Dark reddish brown		3.97
Gabadela	58	Dark reddish brown		3.97
Mquthungo	34	Yellowish red		3.97
Ntandabantu	13	Brown		3.97
Somkhele	22	Dark reddish grey	7.38	
Mduku	12	Brown	7.38	
Mbhodla	25	Brown	7.38	
Makwakwa	29	Dark red	9.38	

Soils with the highest clay content had the least microbial population. There is poor aeration for microbial activity meaning atmosphere is not conducive for them because of the compact soil particles. Soils with the lowest clay content had high microbial population. Soil particles are loose with good aeration. Generally dark soil have high microbial activity, however in most cases colour has no influence in microbial activity.

CHAPTER 5
DISCUSSION

Introduction

In this chapter the observations from the results to identify the practice and prevalence of geophagia as well as the knowledge and perception from the participants in this study are discussed and compared with relevant literature.

5.1 Socio –demographics information

All of the participants (n= 94) interviewee comprised of females with the age ranges from 14 to 65 years. This study resembles other studies that discovered that the practice of geophagia was mostly common in women, although most of them were not pregnant during interviews as it is mentioned in other studies conducted by (Young *et al.*, (2007); Kutalek *et al*., (2010) ; Ekosse *et al*., (2010). The findings of the study conducted by Luoba, Geissler, Estambale, Ouma, Magnussen, *et al*., (2004) also showed that geophagia was very common among pregnant women.

Findings of this study are in contrast with the study conducted by (Geissler *et al*., 1999) where women reported that men do eat soil but are very secretive about this practice. In the study of Zambian boys they were found eating soil although this decrease as they grew up (Geissler *et al*., 2004).

Only 3.2% of the respondents that was pregnant during the interviews. This issue opposes what usually happens with geophagy studies because the finding in Ghana was that 63% of women were pregnant during the study (Vermeer, 1971). Beside that in Kenya the majority (56%) of women eating soil were also pregnant (Geissler *et al*., 1999). Furthermore in another study of Bondo District, western Kenya, 54% were also pregnant (Luoba *et al*., 2004).

During the interview when they were asked about the reasons for eating soil, the highest percent (43%) was given to pregnancy; refer to table 4.4 and figure 4.4. In this study it was found that although geophagia was started due to pregnancy they never stopped it after delivery. One of the women was very brave in telling that she is able to stay the whole day without food as long as she can eat soil until her stomach is full then drink tea. Soil consumption sometimes serves as a meal replacement Yao,(2006).

This is also in agreement with the comment given by Reid, (1992) which says that there are similarities in terms of geophagia among blacks in Africa and blacks in the US showing that geophagia mostly occur among pregnant women. A study conducted in Ghana by Faustina *et al*. (2010) most women mentioned a number of health reasons for eating soil of which the most important one was managing nausea, which is problematic in the first trimester of pregnancy.

In contrast the majority of pregnant women in Kenya mentioned that they were eating soil because they enjoyed the smell and taste of the soil (Geissler *et al*., 1999). Furthermore, another reason that was reported by interviewee in the study conducted by Songca *et al*.,(2010) in Free State and Limpopo was craving.

According to the Mkhanyakude District Integrated Development Plan (2008/9:35), unemployment rate was estimated to be 63% and only 13% of the population was formally employed. In the study conducted at Kenya the majority (58%) of respondents were unemployed with only 9% in the labour force (Geissler *et al*., 1999) and also the study in Tanzania women who were employed were not so much involved in geophagia compared to housewives (Kawai *et al*., 2009). Summary of educational level reflected that only 6.3% had tertiary education of which the low level of education can have a negative impact on nutritional education and even employment opportunities due to lack of skills.

Although housing was dominated by concrete blocks but there was also mud-walled huts thatched with grass from which geophagists were collecting soils for consumption. This was in agreement with the study conducted by Geissler *et al*., (1998) where women reported that they were eating mud from the walls of their houses. Furthermore in Kenya coast, 72.0% of the women reported eating soil from walls of houses (Geissler *et al*., 1999). The majority (56.4%) of interviewee had no toilet facilities at all, therefore that reflected that it was possible for geophagists to consume contaminated soil.

The majority (77.7%) of the respondents were single meaning that a large number of women were without partners to assist them financially. Even the few, who had husbands, were unemployed, and therefore their economic status was not good. The statement was in agreement with Horner *et al*., (1991; Simon, (1998) who commented that geophagia usually occurred among women of poor socioeconomic background who end up geophagic because of the hunger pains. Furthermore in the study done in Korea it was found that household income affect anaemia because geophagic people had anaemia (Kim, Shin, Han, Lee *et al*., 2013). Likewise, Danford (1982) also said that geophagia is related to anaemia. Geophagia is known to be more common in lower-income people (Whitney & Rolfes, 1993).

5.2 Prevalence of Geophagia

The majority (83.3%) of the respondents reported that they were consuming soil from 4 - 10 times a day, only few were taking it once a day and 39.6% have been eating soil for more than 10 years, showing that this belief is deeply rooted and not just practiced for a short period of time during pregnancy. The amount of soil taken per day by respondents varied widely ranging from 57g to 884g per day depending on how much is taken at a time and how many times per day. Other studies conducted in sub-Saharan Africa reported that pregnant women were consuming an average of 30 to 50g daily (Geissler *et al*., 1998; Luoba *et al*., 2004). The amount of soil that was consumed by Kenyan school children as reported by Geissler *et al*., (1977) was ranging from 8g to 108g per day.

In this study 60.9% subjects reported that the practice of soil consumption is also practiced by other family members. In one of the household visited during the interviews, a bulk of soil collected for consumption was scattered over the bag for sun drying. After probing further it was discovered that almost the whole family was geophagic but only one was interviewed.

This is in agreement with the study conducted by Mortazavi & Mohammandi, (2010) in Zahedan, where 20.7% of respondents mentioned that the practice is also common among other family members. The study done with the school children in Lusaka revealed that 79.5% had relatives in their households that were also eating soil.

5.3 Practices for Geophagia amongst participants

Ways of collecting soil for consumption varied according to individuals such that more than half (52.4%) of respondents preferred digging with a knife, followed by handhoe, buying from street vendors, digging, purchasing from street vendors, using bush knife, spade, walls from houses and selective picking by hand as showed in chapter 4, Fig 4.3.

In contrast the traditional soil collecting methods that were used in South Africa (Limpopo and Free State) were only digging, scrapping and hand grapping (Ekosse *et al*, 2010).

The local names of earth consumed at Mkhanyakude District include umcaka which is a white, fine soil found in powdery form and is purchased from street vendors; isiduli which is a termite mould, where most termites are found and is brownish to dark in colour, ibomvu, is red in colour in a ball form and is purchased from street vendors as already processed soil; isibomvu, is red clay soil which is usually in lumpy form; isidaka, is a loamy soil which is brown to black in colour; ihlabathi, is a fine sandy soil; umgabadi: is brown to dark virgin soil found in the form of lumps and inkwali, is the earth that has been removed where road construction has been taking place.

In contrast local names of soil consumed by Pemba in Zanzibar, Tanzania were udongo, ufue, vitango pepeta and mchanga (Young *et al*., 2007). Another local name of earth consumed in Ghana and Togo-West Africa was ayelo. It is mentioned that soil was moulded into lumps of 20g to over 200g a piece and was oven baked and sold for ingestion (Tayie, Koduah & Mork, 2013). In Kenya's Bondo District the local name of earth, in the form of soft stones that was consumed was odowa, and it was eaten by 54.2% of the women (Luoba *et al*., 2004). In Nigeria, there were people of a certain tribe that were eating soil called kanwa which was also given to infants and nursing mothers (Hunter, 2004).

The majority (79.8%) of respondents mentioned that they were not processing earth before consumption, with only a few of them placing soil next to fire to attain the smoked taste and smell. In contrast to that the Pembas in Tanzania who were eating earth were aware that soil could be dirty and were processing it using (pan heating, sun drying and brushing off loose material on exterior in an effort of trying to reduce the likelihood of microbial infection (Young *et al*., 2007). Furthermore during the study conducted by Brand *et al*., (2009) where they were investigating about the possible effects associated with human geophagic practice, soil was collected from the specific sites, shaped and oven dried before consumption. (Reilly & Henry, 2000)

Besides soil, there was other non-food items like ash, chalk, toilet pepper, coal and goat dung that were eaten by 10.6% of the respondents. In contrast the commonly used non-food items in Mexico were dirt, bean stones, and magnesium carbonate (Simpson *et al.,* 2000).

5.4 Knowledge of geophagia by participants

A total of 87.2% of the respondents admitted that eating soil was not helpful because it resulted in many health problems. The majority of 60.6% respondents agreed on the following side effects caused by geophagia namely acute stomach pains, worm infections, cancer, constipation, diarrhea, blood stools, womb blockage, fibroids, painful defecation, appendicitis, gallstones, acute bladder pains, heavy bleeding and pains during menstruation.

Other side effects for soil consumption indicated by literature were nutritional deficiency of either iron or zinc (Kondo & Sokol, 2006), tooth wear as indicated in the literature review, chapter 2 (Ngole *et al*., 2010). Consumption of toxic substances like cadmium found in the soil can cause kidney damage together with poisoning caused by consuming soil contaminated by herbicides and pesticides which in turn cause maternal death (Abraham, 2005). Geophagia is also associated with microbial infections (geohelminth infections) that affect 3.8 million people worldwide, and cause 125,000 estimated deaths each year (WHO, 2002).

The majority (75.0%) of respondents reported that they were obtaining soil for consumption from termite moulds while 10.6% respondents were purchasing from street vendors. Other sites were areas where soil erosion occurred, river banks, mud wall of houses, fire place and area of construction. This is in agreement with the study conducted in Lusaka where the specific sites for geophagic soils as mentioned by Zambian school children were plaster of houses, street vendors, earth deposite by termites on the barks and poles (Nchito, Geissler, Mubila, Friis & Olsen, 2004). This is also almost the same with what Reilly & Henry, (2000) explained, that the sites where clay soils were collected were river banks, pits and termite moulds and geophagists had different preferences over them.

When geophagists were asked whether they are free to send somebody to collect geophagic soils, half of them (50.0%) were free and another half was not free. The reason for not being free was due to the sensitivity they have on the knowhow and where clay is collected. Another thing was that soil consumption was a copied behavior especially to children. In agreement with the above it is emphasized that geophagists are choosy when collecting soil such that they consider the place where it is obtained, colour, texture, smell and even its physical state (Abraham & Parsons, 1997; Reilly & Henry, 2000; Nchito *et al*., 2004).The practice of soil consumption was a copied behavior especially to children in countries like Zambia (Lusaka) where it was freely practiced (Hunter, 1993). That is why some soil consumers denied sending children to collect soil for consumption.

5.5 Colour for analyzed geophagic soil samples

The majority 33.0% of respondents reported that they prefer red geophagic soil followed by black and brown colour. This is in agreement with the study conducted in Limpopo and Free State by Songca *et al*., (2010) where most people preferred red soils. Other colours that were used were white, grey and yellowish referred to in Figure 4.3, chapter 4. Colour selection for geophagic soils vary with individuals although red was most popular. This might be the reflection of the amount of iron in their diets because red soils are normally known to have iron (Halstead 1968). Futhermore during the study conducted in Tanzania Junta, Jumpei, Hidekazu, Sol, Kilasara & Takashi, (2009) reported that the colour of the soil reveal the mineral constituency of the soil. Black soils have got organic matter which is usually high in microorganisms (Ekosse, 2010). Therefore all people interested in black coloured soils should be discouraged to use it in its natural form. Processing especially baking might be the better option because processing can destroy harmful bacteria.

In agreement with this, the study conducted by Ngole *et al*., (2010) revealed that the colours used for consumption were reddish in Swaziland and yellowish and greyish in South Africa. Again according to Diamond, (1999) geophagists are selective to certain types of soils and these soils include red, white, yellow and brown clay types. In contrast, in Ghana and Togo-West Africa, the colour of soil that was normally ingested was creamy-white loamy clay (Tayie, Koduah & Mork, 2013). Reddish and yellowish coloured clay are used as sun screens in the Eastern Cape Province (Hoang-Minh *et al*., 2010).

According to Matike, Ekosse & Ngole, (2011) the cosmetic soils used for cleansing had hue of 5Y meaning that all samples collected for this study were not suitable for cleansing because according to (Table 4.5 chapter 4) there is no hue resembling 5Y. In the study that was conducted at Oliver Tambo District (Eastern Cape) the soils suitable for sunscreen function were identified by having hue 2.5YR. All samples collected from Hlabisa local municipality (Makhowe, Gabadela, Mpembeni and Mquthungo) had hue of 2.5YR (dark reddish brown colour of the soil) meaning that it could be used as a sunscreen cream.

5.6 Composition of sampled soils used for geophagia

5.6.1 Nutritional composition

According to Mahan, (2008) the recommended daily intake of phosphorus for adult females, pregnant and lactating women is 1250 mg/day. In table 4.6 it is reflected that, the mean phosphorus for Hlabisa is (7.26 mg kg^{-1} soil), Mtubatuba (9.21 mg kg^{-1} soil), Big 5 (8.97 mg kg^{-1}

soil), Mhlabuyalingana (6.14 mg kg^{-1} soil) and Jozini (6.87 mg kg^{-1} soil) meaning that phosphorus identified in the soil samples was far below the human body requirements.

According to Mahan, (2008) the recommended daily intake of potassium for adult female vary from 4.5 mg/day to 4.7 mg/day, pregnant women (4.7 mg/day) and lactating women is 5.1 mg/day. The mean potassium for Hlabisa was (38.54 mg kg^{-1} soil), Mtubatuba (72.17 mg kg^{-1} soil), Big 5 (243. 89 mg kg^{-1} soil), Mhlabuyalingana (66.84 mg kg^{-1} soil) and Jozini (294.44 mg kg^{-1} soil). That means that potassium was available in abundance in all samples when compared to recommended daily intake. When there is too much potassium in the body kidneys have to work very hard otherwise they are overloaded.

The recommended daily intake of calcium for adult females, pregnant and lactating women is 1300 mg/day according to Mahan, (2008). Only one municipality reaches the recommended daily intake that is Mtubatuba with the mean calcium of 1666.32 mg kg^{-1} soil.

According to Mahan, (2008) the recommended daily intake of magnesium for adult females was 240 mg/day, for pregnant women (400 mg/day) and for lactating women (360 mg/day). The mean magnesium for Hlabisa (509.66 mg kg^{-1} soil$^{)}$, Mtubatuba (795.09 mg kg^{-1} soil), Mhlabuyalinga (165.29 mg kg^{-1} soil) Big 5 (370.30 mg kg^{-1} soil) and for Jozini (407.86 mg kg^{-1} soil). That means that Mhlabuyalinga was the only municipality with less magnesium.

According to Mahan, (2008) the recommended daily intake of zinc for adult female, pregnant and lactating women ranges from 8-12 mg/day but all municipalities had far less zinc.

According to Mahan, (2008) the recommended daily intake of manganese for adult female, pregnant and lactating women ranges from 1.6 mg/day to 2.6 mg/day. Hlabisa had (5.19 mg kg^{-1} soil), Mtubatuba (7.73 mg kg^{-1} soil), Big 5 (10.31 mg kg^{-1} soil), Mhlabuyalingana (3.15 mg kg^{-1} soil) and Jozini (35.07 mg kg^{-1} soil), meaning that manganese identified can be more than required depending on the amount of soil consumed per day.

According to Mahan, (2008) the recommended daily intake of copper for adult females ranges from700 mcg/day to 900 mcg/day, pregnant women (1000 mcg/day) and lactating women is 1300 mcg/day. Hlabisa had (20.89 mg kg^{-1} soil), Mtubatuba (10.68 mg kg^{-1} soil), Big 5 (8.89 mg kg^{-1} soil), Mhlabuyalingana (0.83 mg kg^{-1} soil) and Jozini (1.22 mg kg^{-1} soil). That means that all samples were far below the recommended daily intake of human being.

4.6.2 The pH of the soil

The pH of the sampled soils as indicated in chapter 4 ranged from 4.75 to 6.06, meaning that soils were acidic. During the process of absorption, enzymes in the small intestines absorb the nutrients when they are at neutral pH (Lowe, 2002). Whatever reaches the small intestines (lumen) in an acid form, the enzyme (gastrin) responsible for nutrient absorption is not released (Wank, 1998).

5.6.3 Absorption of the mineral nutrients of geophagic clays

The study conducted in Turkey on the effect of iron absorption by (Minnich, Okcuoglu, Tarcon, Arcasoy, Cin, Yorukoglu, Renda & Demirag, 1968) proved that clay properties block iron absorption.

The study conducted by (Hooda *et al*., 2004) where soil consumption simulation was designed to represent the condition of the gastro- intestinal tract in order to determine the absorption of mineral nutrients from ingested soil, the result reflected that beside that soil contain number of mineral nutrients geophagia reduce the absorption of already food-born nutrients in the human body.

The study for investigating the iron status of women consuming soil comparing with those not consuming soil showed that iron deficiency anaemia was not in the control group but only the geophagic women had iron deficiency anaemia (Mogongoa, Brand, der Jager & Ekosse, 2011).

The study conducted in Wilmington, North Carolina by (Gonzalez, Owens, Ungaro, Werk, & Wents, 1982) reflected that clay properties are capable of binding almost 30% of potassium, so beside binding iron, zinc and calcium, geophagic soils also causes hypokalemia -low potassium (Gonzalez *et al*.,1982; Dreyer, Chaushev & Gledhill, 2004).

Although mineral nutrients like iron are available in geophagic soils, but are not absorbed by the body, because mineral nutrients especially iron become insoluble in the small intestines where absorption take place due to neutral pH of intestines, while minerals such as iron are in acidic form (Young, 2011).

Food security of human beings and animals is ensured by soil by providing mineral nutrients through soil-plant-human being and soil-plant-animal food chain (Hooda *et al*., 2004). Although it appears that soil is rich in minerals, absorption of nutrients from soil by plants is different from that of humans (Stokes, 2006).

5.7 Microbial content of sampled soils

One of the objectives for conducting this study was to identify the presence and the abundance of microorganisms. The findings of the study conducted at Mkhanyakude District were nearly the same as the study by Ekosse, (2010) because all sampled soils in Table 4.7 had microorganisms, but the content varied with different soils refer to Table 4.8 in chapter 4. That agrees with the statements that says that soil constitute a variety of microorganisms such as algae, fungi, bacteria and virus, and they are responsible for decomposition of organic matter and mineral transformation (Doran, 1982; Roper, 1983; Sikora & Coy, 1990). Therefore that indicated that regardless of colour and type of soil, microbes are always available in the soil in different quantities.

Table 4.8 showed that soils with high clay content were having the least microbial numbers and also showing that soils with the lowest clay content had high microbial content. Generally dark soil have high microbial activity, however in this case colour showed no influence in microbial load, but according to (Ekosse, 2010), dark coloured soils indicated the presence of organic matter which harbour a lot of microbes. Therefore people eating soil from the areas like (Somkhele, Mduku, Mbhodla and Makwakwa) should be aware of high content of microorganisms.

The presence of microorganisms depends on the physical and chemical properties of soil (Alexander, 1977). Other organisms cannot tolerate acidic conditions e.g. fungi can be found in acidic conditions as opposed to bacteria (Alexander, 1977; Doran, 1980). Most microorganisms survive better in the near-neutral pH that ranges from 6-7 because the availability of soil nutrients is best in this pH range (David, Sylvia, Peter, Hartel; Jeffrj, Fuhrmann, David & Zuberer, 2005). Therefore microbial content showed that it varies with different areas because microorganisms prefer certain soils. Other microorganisms are adapted to extreme or stressful soil conditions such as acidic soils (David et al., 2005). So, microbe's native to another environment will be not native to another environment and other microbes prefer other soils because of their nutritional content.

5.8. Limitations

One of the objectives for conducting this study was to identify the presence and the abundance of microorganisms particularly those that are pathogenic to human health. Due to financial constraints the pathogenic microorganisms could not be analysed; only the presence and amount of microorganisms were determined. The laboratory used could not analyse the iron content in the geophagic soil samples. The researcher was only informed after the soil was already collected and taken for analysis to the lab.

CHAPTER 6
CONCLUSIONS AND RECOMMENDATIONS

6.1. Conclusions

The study findings indicate that there is a high prevalence of geophagia in Mkhanyakude District of KwaZulu-Natal province, South Africa. It appears that geophagia has been for many years a normal daily practice in the community studied. Beside the interviewees, other family members in some households were reported to be consuming soil. Furthermore, individuals could eat soil several times a day. The colour of the mostly consumed soil was red; the local names of soil commonly ingested were *ibomvu, isiduli and isibomvu* collected by digging with knife and hand hoe. The mostly mentioned site from where the soil was collected was termite. Some of the respondents reported that when their financial position was good (after having received grants) *umcaka* (geophagic soil) was purchased from street vendors.

Interview discussions with the female respondents suggested that females were largely geophagic. The motivational factor for soil consumption mostly mentioned was pregnancy, but the practice continued even after delivery. Furthermore, it seemed that poor finance also contributed to *geophagia*, especially among the big families headed by unemployed females. The study findings also revealed that there were beliefs and perceptions, both negative and positive, associated with eating soil. Some positive beliefs are that soil consumption acts as a remedy for stomach pains and diarrhoea, prevent morning sickness and also act as a binding agent of toxins and bacteria in the intestines, similar to the perceptions of other soil eaters as documented in the literature. The negative beliefs include that geophagia results in appendicitis, gallstones, pains and heavy bleeding during menstruation, cancer and painful defecation. However, the majority of respondents admitted that eating soil was not helpful as it contributed to a lot of health problems as indicated above. Yet, some of the respondents proudly mentioned that they were addicted to soil eating and would stop only if assisted to.

It was found that the soils eaten contained different levels of mineral nutrients, including calcium, zinc, potassium, phosphorus, magnesium, manganese and copper. These mineral nutrients varied with soil types (magnesium content in samples from Ntandabantu was 1244.63 mg/kg while Othangwini had 32.32 mg/kg). Although the absorption of nutrients was not investigated in this study, the pH of the samples was acidic (pH varied from 4.75 to 6.06) indicating that, malabsorption of nutrients is possible in the gut because the enzyme responsible for absorption cannot be secreted in the acid condition. However, if a significant proportion of the mineral nutrients found in the studied soils are bioavailable after consumption of the soils, they will contribute to mineral nutrition and alleviation of mineral deficiencies, such as iodine and zinc, prevalent in South Africa.

All geophagic soils had microorganisms, of which quantities depend on the area where soil samples were collected. Soils with high clay content had the least microbial population because of small soil particles that are closely packed, whilst soils with the lowest clay content had high microbial count. The high microbial load of some of the soils studied suggests that there is a potential health hazard for the soil eaters, particularly in the light of the fact that the respondents indicated that, generally (confirmed by 79.8% respondents), the soils were not processed in any manner, e.g. heating, that would reduce their microbial load.

6.2 Recommendations

Health education is required to raise the awareness about disadvantages of consuming soil (such as tooth decay, rupturing of the intestines and cancer), and to improve the health of geophagists by educating people with regard to healthy eating practices and to improve the quality of soil they consume by processing (baking) soil before eating. Early identification of this practice of geophagia during pregnancy is also important to prevent iron-deficiency anaemia in pregnant women and these women should be advised not practise geophagia during pregnancy but antenatal nursing clinic should be visited in order to obtain safe supplements. The communities could be educated to consume soils moderately. Microbial safety may be achieved by advising the communities to heat the soils, e.g. smoking and baking.

Having found that all geophagic soils at Mkhanyakude had microorganisms with varying microbial content or total count of organisms, other studies should be conducted to identify the actual species especially those that are pathogenic to human health. When the types of species are known, it will be much easier to predict the type of infection that might attack geophagists.

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ANNEXURE A

Letter of ethics approval from the humanities and social sciences ethics committee, University of KwaZulu-Natal

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

10 October 2012

Mrs AT Msibi 212561498
School of Agricultural, Earth and Environmental Sciences
Pietermaritzburg Campus

Dear Mrs Msibi

Protocol reference number: HSS/1040/012M
Project title: Prevalence and practice of geophagia Umkhanyakude District (DM27) Northern KwaZulu-Natal

EXPEDITED APPROVAL

I wish to inform you that your application has been granted Full Approval through an expedited review process.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the school/department for a period of 5 years.

I take this opportunity of wishing you everything of the best with your study.

Yours faithfully

Professor Steven Collings (Chair)

/pm

Supervisor: Dr M Siwela
Academic Leader: Professor D Jaganyi
cc School Admin: Ms Michelle Francis

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COLLEGE OF AGRICULTURE ENGINEERING AND SCIENC
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INSPIRING GREATNESS

ANNEXURE B

Consent document for participants

Consent to participate in research

You have been asked to participate in a research study. Ethics approval has been received from the University of Natal.

- ❖ The objective of research has been described to me orally. I understand what my involvement in the study means and I voluntarily agree to participate.
- ❖ I m aware that the results of the study, including personal details will be anonymously processed into a study report and will remain confidential.
- ❖ I understand that I may, at any stage without prejudice, withdraw my consent and participation in the study.

I declare myself prepared to participate in the study.

…………………………………………… ……………………………

Printed name of participant Contact Number

……………………………………………

Signature of participant

……………………………………………

Date

ANNEXURE C

SURVEY IN UMKHANYAKUDE

GEOPHAGIA
SOCIO-DEMOGRAPHIC INFORMATION

Respondent Number: 1-2

Interviewer: 3-4

Municipality: 5

Ward: 6

Age: 7-8

Sex: 9
1.Female 2. Male

Household compositiom

A1. How many persons live in the house permanently (5-7 days per week) 10-11
1. 1-3 2. 4-7 3. 8-10 3. >10

A2. How many children do you have (nucleur family)? 12
1. One children 2. Two children 3. Other, specify

A3. Number of extended family children staying with you? 13
1. One children 2. Two children 3. Other, specify

A4. Number of extended family members staying with you? 14
1. One 2. Two 3. Other, specify

A5. Number of the household children attending school? 15
1. One 2. Two 3. Other, specify

A6. Number of the household members attending tertial education? 16

1. One 2. Two 3. Other, specify

A7. Number of the household members attended tertial education? 17
1. One 2. Two 3. Other, specify

A8. Number of the household members that are working? 18
1. One 2. Two 3. Other, specify

A9. What is your marital status? 19
1. Unmarried
2. Married
3. Divorce
4. Widowed
5. Living together
6. Separated
8. Other, specify………………………………………………………………….

A10. What type of water source is used? 20 21
1. Piped (yard / internal)
2. Piped (public tap free / paid)
3. Bore hole
4. River / Stream / Dam / Well
5. Protected spring
6. Other, specify………………………………………………………………….

A11. What type of housing is used? 22 23
1. Concrete blocks
2.Concrete bricks
3. Mud blocks
4. Tin
5. Plank wood
6. Mud wood
7. Stones and cement
8. Stones and mud

ANNEXURE C

A12. What type of toilets are used? 24 25

1. Flushed
2. Improved pit lactrines (VIP / chemicals)
3. Other unimproved lactrines
4. No facility

A13. To what faith / religion do you subscribe? 26-27

1. Zion christian Church (ZCC)
2. Roman Catholic Church
3. Shembe
4. Presbyterian of SA
5. Apostolic faith mission
6. Lutheran Church
7.Pentecost
8. Assembly of God
9. Uncertain / Do not know
10. Traditional African Belief
11. Other, specify
12. None

A14. Does your faith have any influence towards your soil eating? 28

1.Yes 2. No

3. Other, specify ……………………………………………………………………….

A15. If yes explain how? ……………………………………………………………….

A16. Does your home have working refrigerator or freezer? 29

1.Yes 2. No

A17. Which language do you speak? 30

1.Zulu 2. Swazi

3.Tsonga 4. English

5. Afrikaans 6. Xhosa

7. Other, specify

ANNEXURE C

A18. What is your source of income for the household per month? 31

1. Formal
2. Self employment
3. Casual / Contract
4. Social / Welfare grant
5. Pension (retirement / sick)
6. Farmer
7. Domestic worker

8.Other, specify (part-time;piece jobs etc)

A19. What is your highest level of education? 32

1. Lower Primary (Gr1-2) 2. Higher primary (Gr3-7)
3. Secondary education (Gr8-10) 3. High school (Gr 11-12)
5. Tertial education

A20. What is your primary employment status ? (tick only one) 33

1. Housewife by choice
2. Unemployed
3. Self employed
4. Full time wage earner (receive a salary)
5. Other, specify (part-time; piece job etc)
6. Don't know
7. Husband
8. Farmer
9. Schooling

A21. Husband / partner 's primary employment status (tick only one) 34

1. Retired by choice
2. Unemployment
3. Self employed
4. Full tome wage earner (receive a salary)
5. Other, specify (part time, piece job etc)
6. Without husband

A22. Who is the head of the household? 35

1. Wife
2. Husband

3.Child / ren

4. Parent
5. Grandparent

6. Friend
7. Other, specfy

A23. Who does the glossary at home? 36
1. Mother
2. Father
2. Child / ren
3. Grandmother
4. Grandather
5. Other, specify

A24. Are there any times in a month that you eat soil more than others? 37
1. Yes 2.No.

A25. If yes, Explain ………………………………………………………………….

A26. Are there any times in a year that you eat soil more than others? 38
1. Yes 2.No.

A27. If yes, Explain …………………………………………………………………. 39

A28. Do you eat soil the same way, when you pregnant than when you not? 40
1. Yes 2.No.

A29. If no, Explain ………………………………………………………………….. 41

A30. Are you breastfeeding? 42
1. Yes 2.No.

A31. If yes , how old is the baby? 43
1.Under one year 2. Under two years
3.Other, specify

ANNEXURE D

GEOPHAGIA
PREVALENCE AND PRACTICE OF GEOPHAGIA

B1. Do you consume soil? 1

1. Yes 2.No.

B2. How often do you consume soil? 2

1. Once a day 2. More than once a day
3. Once a week 4. Other, specify

B3. How much soil do you consume at a time (weighed in grams)? 3

1. 10g 2. 20g
3. 30g 4. 40g
5. 50g 6. Other, specify

B4. When did you start eating soil? 4

1. 2 years back 2. 10 years back
3. 5 years back 4. Other, specify

B5 Which colour of soil do you consume most often? 5

1. Red
2. White
3. Gray
4. Black
5. Other. Specify…………………………………………………………………….

B6. How do you mine soil for consumption? 6

1. Digging with stick
2. Purchased from vendors
3. Both of the above
4. Other, specify

ANNEXURE D

B7. What is the local name of soil consumed? 7
1. Udongo 2. Umcaka
3. Unknown 4. Other, specify

B8. Do you prepare / process soil for consumptiom? 8
1. Yes 2.No.
3. Other, specify

B9. If yes what processing method is used? 9
1. Baking 2. Other, specify

B10. Do you eat soil alone or you have a friend with whom you enjoy it with? 10
1. Yes 2. No.

B11. Is there another member at home eating soil? 11
1. Yes 2. No.

B12. What is the reason behind for processing soil? 12
1. Killing germs/ bacteria 2. Changing colour
3. Other, specify

B13. Do you ever consume any other non-food items on a regular basis e.g.
chalk, washing powder etc.? 13
1. Yes 2. No.

B14. If yes specify:

ANNEXURE D

Non food item	grams	How often consumed 1.Everyday 2. >3 times per day 3. Less than 3 times per day	[ ] 14
1……………..	………..	………………………………..	
2………………	………..	………………………………..	
3………………	…………	……………………………….	
4………………	…………	………………………………..	

ANNEXURE E

GEOPHAGIA AND THE PERCEPTION

C1. How did you learn to eat soil? ☐ 1

1. Pear group
2. Tradition
3. Started on your own
4. Saw somebody else
5. Influenced by somebody
6. Pregnancy
7. Other, specify…………………………………………………………………….

C2. Why do you think it is important or helpful to eat soil? ☐ 2

1. Healing
2. Taste, nice
3. Other, specify…………………………………………………………………….

C3. Do you eat soil for medical reasons? ☐ 3

1. Yes 2. No.

C4. If yes, explain………………………………………………………………….
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………
……………………………………………………………………………………

C5. Do you experience any constipation after eating soil? ☐ 4

1. Yes 2. No.

ANNEXURE E

C6. If yes, how often? 5

1. once a day
2. Twice a day
2. Three times a day
3. Twice a week
4. Other, specify…………………………………………………………………….

C7. Do you experience any diarrhea after eating soil? 6

1. Yes 2. No.

C8. If yes, how often? 7

1. once a day
2. Twice a day
4. Other, specify…………………………………………………………………….

C9. What other reasons that make you to eat soil? 8

2. Pregnancy
2. Other, specify…………………………………………………………………….

C10. Do you think eating soil can be helpful to other people? 9

1. Yes 2. No.

C11. If yes, how is it helpful? (Explain)………………………………………………

……………………………………………………………………………………………..

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………..

C12. If no, why not? (Explain)

……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

C12. Do you have the specific sites where that kind of soil is obtained? ☐ 10

1. River banks
2. Termites
3. Other, specify……………………………………………………………………….

C13. Can you send somebody else or a child to get it from the site? ☐ 11

1. Yes 2. No.
2. Other, specify

C14. Do you experience any other side effects after eating soil? ☐ 12

1. Yes 2. No

C15. If yes, Explain …………………………………………………………………

C16. What are the coordinates for the site, where soil sample is taken?

…………………………………………………………………………………………..

THANK YOU FOR YOUR COOPERATION.

ANNEXURE F

Most Probable Number table showing positive tube combinations after incubation

The readings had the following calculations:

	Number of tubes positive in sets of 3								Positive Tube Combinations	Table Value	MPN/g Value	log MPN/g
Soil	10^{-4}	10^{-5}	10^{-6}	10^{-7}	10^{-8}	10^{-9}	10^{-10}	10^{-11}		0.1/0.01/0.001		
A	110	000	000	000	000	000	000	000	200	9.3	9300	3.97
B	110	000	000	000	000	000	000	000	200	9.3	9300	3.97
C	111	111	000	000	000	000	000	000	330	240	240000	5.38
D	110	000	000	000	000	000	000	000	200	9.3	9300	3.97
E	111	111	000	000	000	000	000	000	330	240	240000	5.38
F	110	000	000	000	000	000	000	000	200	9.3	9300	3.97
G	111	111	111	100	000	000	000	000	331	462	4620000	6.66
H	111	111	111	111	000	000	000	000	330	240	24000000	7.38
I	111	111	000	000	000	000	000	000	330	240	240000	5.38
J	111	111	000	000	000	000	000	000	330	240	240000	5.38
K	111	111	000	000	000	000	000	000	330	240	240000	5.38
L	111	111	111	111	000	000	000	000	330	240	24000000	7.38
M	111	111	110	000	000	000	000	000	320	93	930000	5.97
N	111	111	110	000	000	000	000	000	320	93	930000	5.97
O	110	010	000	000	000	000	000	000	210	14.7	14700	4.17
P	111	111	111	000	000	000	000	000	330	240	2400000	6.38
Q	111	100	110	001	000	000	000	000	121	15.4	154000	5.19
R	111	111	000	000	000	000	000	000	330	240	240000	5.38
S	111	111	110	000	000	000	000	000	320	93	930000	5.97
T	111	111	111	000	000	000	000	000	330	240	2400000	6.38
U	111	111	000	100	000	000	000	000	301	39	390000	5.59
V	111	111	111	111	111	111	000	000	330	240	24000000000	9.38
W	111	111	111	100	000	000	000	000	310	43	4300000	6.63
X	111	111	111	111	000	000	000	000	330	240	24000000	7.38
Y	111	111	111	100	000	000	000	000	331	462	4620000	6.66
Z	111	111	111	101	000	000	000	000	320	93	9300000	6.97
a	111	111	100	000	000	000	000	000	310	43	430000	5.63
b (autoclaved control)	000	000	000	000	000	000	000	000	000	<3.0	0	0