UNIVERSITY OF VENDA

SCHOOL OF ENVIRONMENTAL SCIENCES

DEPARTMENT OF HYDROLOGY AND WATER RESOURCES

Effects of open defecation on geophagic soils and water resources: A case study of Siloam village in Limpopo Province, South Africa

BY

RAVULUVULU FUNANANI RACHEL (11572148)

A research submitted to the Department of Hydrology and Water Resources in fulfilment of master's Degree of Hydrology and water Resources.

SUPERVISOR: SENIOR PROF. G.E. EKOSSE

CO-SUPERVISOR: PROF. J.O. ODIYO

FEBRUARY 2018

DECLARATION

I, Ravuluvulu Funanani Rachel, student number 11572148, hereby declare that this master's dissertation proposal is my own work and is submitted in fulfilment of a master's Degree of Earth Science in Hydrology and Water Resources. This is my own work and it has not been submitted to this or any other university for any degree. All the reference materials contained herein have been fully acknowledged. This research project was conducted at the University of Venda, Limpopo Province, under the supervision of Senior Prof G.E. Ekosse and co-supervision of Prof J.O. Odiyo.

Student:	**Miss F. R. RAVULUVULU**
	Signature …………………………. Date………………….
Supervisor:	**Senior Prof. G.E. EKOSSE**
	Signature…………………………. Date…………………
Co-supervisor:	**Prof. J.O. ODIYO**
	Signature………………………… Date…………………

DEDICATION

I dedicate this work to my lovely family, especially my daughter Uhone Tshikunde and my mother Nethwadzi Mutshinyalo.

ACKNOWLEDGEMENT

Above all, I want to thank God for giving me the strength, determination and wisdom to complete this research. Most importantly I would like to thank my supervisor Senior Prof G. E Ekosse and my co-supervisor Prof J. O Odiyo, for dedicating their time to this research and helping me to work hard, giving me the courage to proceed with the study and the guidance required in making the study a success.

I would also like to thank the following people:

To all the participants from Siloam village who agreed to participate in the study and dedicated their time for the study to be a success, including fieldworker Ramaita Slim for continuous assistance in field work.

Ms. F.I Mathivha, for her mentorship role. All the guidance, assistance as well as valuable advice and ideas during the study is highly appreciated and not forgetting Dr. N. Bukalo for her guidance, her time of assistance, patience and advice during the study especially towards the end of my project.

Mr. G. K Pindihama, for statistical analysis.

Agriculture Research Commission (ARC), for Water and Soil analysis.

The University of Venda, CHETL, Research and Publication Committee (RPC) and the National Research Foundation (NRF) for funding the project.

ABSTRACT

Communities in South Africa have been noted to consume earthy materials such a soil among others. Geophagy is largely practised in the rural areas as opposed to urban places, and in these places the level of sanitation is low and people usual practice open defecation. The practice of Geophagia has been associated with cultural, medicinal, psychological, religious and nutritional deficiency among others. The aim of the study was to investigate the effects of open defecation on geophagic soils and water resources in Siloam village. The study also aimed to understand the reasons why people practice geophagia in Siloam village and the health effect associated with consumption of geophagic soils.

To carry out the aim of the study, a questionnaire survey was conducted among women who practice geophagia between the ages of 18 and above in Siloam village. Two hundred and eighty-three (283) women were selected using snowball sampling method to take part in the study. From the (283) women, (200) women represent the geophagic group and (83) women represent the control group. The existing standard questionnaire adopted to generate data on human geophagia included aspects on demography, socio-economic, cultural, ecological, physicochemical aspects, indigenous knowledge and health effects of geophagic consumers. Participants were asked basic questions on why they practice geophagy, their geophagic material preferences, where they collect the geophagic material and other related questions.

A total of twelve soil samples were collected from Siloam village, from the twelve soil samples collected eight were collected from sites known for geophagic practice and another four soil samples were collected from sites where geophagia is not practiced and the samples were used as control soil samples. All the twelve soil samples were analysed for the presence of geohelminths ova using Ammonium Bicarbonate Protocol (AMBIC protocol). The AMBIC protocol consists of four analytical procedures, namely, sample preparation, sample washing with AMBIC solution, geohelminths ova recovery through a modified zinc flotation method and microscopic analysis.

Furthermore, a total of twelve water samples were collected from Nzhelele River and ponds water in Siloam village. From the twelve water samples, eight samples were collected close to where geophagic materials were collected and where open defecation is reported to be taking place and the remaining four water samples were collected randomly from Nzhelele river and water ponds in Siloam village and was recorded as a control group. A total of 12 water samples were analysed for total coliform and faecal coliform Escherichia Coli (*E.coli)* indicator using the membrane filter technique.

The results from the administration of the questionnaire revealed there was prevalence in the practice of geophagia in the area. The study found that most of the villagers in Siloam consumed soil nearly on daily basis. According to the results, only women were involved in the geophagic practices in the area. Additionally, the study revealed that geophagic consumers were mainly in the age of child bearing age group and reddish and yellowish soils were the most preferred. Furthermore, the results showed that geophagic consumers in the area generally consumed soil commonly because of cravings and pregnancy, however, those who were not pregnant also consumed soil.

The respondents reported that they mostly consumed clay and this material was consumed in its dry state and mostly unprocessed, if processed, it would be baked. This geophagic material was mainly found in the wild (riverbed, valley etc.); it was also found that most of the soil consumers did not know that the substances they consumed could be harmful to them. Among those who knew the consequences of consuming the material stated that soil consumption causes constipation, tooth decay, body poisoning, and abdominal pains.

The results from the control group, 83 women who do not practice geophagia, aged between 18 and above, analysed using chi-square revealed a significant association of age with consuming soils ($p<0.05$), while there was no association of income source ($p>0.05$) and educational level ($p>0.05$) with consuming soils. Chi-square ($\chi 2$) analyses further revealed that there was no association of knowledge on the harmful nature of the substance ($p>0.05$), frequency of getting infections ($p>0.05$) and experiencing chronic illnesses ($p>0.05$) with frequency of consuming soils.

The results of geophagic soils revealed the absence of geohelminths ova in the entire geophagic sample. Meaning geophagic consumers in Siloam village are not at risk of acquiring geohelminths infection which may be of potential risk to human health. However, geophagic consumers may be exposed to various other potentially hazardous biological and non-biological soil contents. The results of the water samples revealed that most of the water samples in the areas where open defection is reported to be practised had higher composition of faecal and total coliform bacteria. The composition was above the South African recommended standard for negligible risk of microbial infection. This has caused a great threat to those who consume soil collected near water resources, especially from riverbed and those who also use these water sources on their daily basis.

The study recommends that geophagic consumers should continue to bake their materials before consumption as it might reduce the bacteria and toxic substances found in soils. The study also recommends that the residents of Siloam be made aware of the potential health hazards that might be posed to soil consumers and the effects of practicing open defecation near community water resources as high level of faecal coliform (*E. coli)* were found in the water.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS AND UNITS

AMBIC	Ammonium Bicarbonate
Ca	Calcium
CEC	Cation Exchange Capacities
Cu	Copper
CFU	Colony Forming Units
DF	Degrees of Freedom
DWAF	Department of Water Affairs and Forestry
E. coli	Escherichia Coli
Fe	Iron
GI	Gastrointeintestinal tract
GPS	Global Positioning System
KH_2PO_4	Potassium Dihydrogen Phosphate
LT	Lauryl Tryptose
M-FC	Membrane Faecal Coliform
Mg	Magnesium
NaOH	Sodium hydroxide
ND	Not Detected
SACS	South African Committee for Stratigraphy
SS	Single Strength
STH	Soil Transmitted Helminth
SPSS	Statistical Package for the Social Sciences
TNTC	Too Numerous to Count
TFC	Too Few to Count
USA	United States of America

UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development
USA	United States of America
WRC	Water Research Commission
WHO	World Health Organisation
Zn	Zinc
°C	Degrees Celsius

LIST OF APPENDICES

CHAPTER 1
INTRODUCTION

1.1 Background of the Study

Geophagia, practiced by both humans and animals, is defined as the deliberate and compulsive consumption of earthy material or substances such as red, white or grey clay soils (Ekosse and Jumbam, 2010; Norman *et al*., 2015). This habit has been in existence from historical times and is widely practiced across the globe (Abrahams, 2005). It is practiced in Africa (Mahaney *et al*., 2000; Macheka *et al*., 2016), United states of America (USA) (Boyle and Mackay, 1999; Hunter, 1973; Vermeer and Frate, 1979; Casavale, *et al*., 2017), Asia including India and China (Hunter, 1973; Utara, 2002; Majorin *et al.*, 2017), Australia (Reilly and Henry, 2000), and Europe (Woywodt and Kiss, 2002; Ziegler, 1997). Geophagia has been reported in South Africa (Ekosse and Jumbam, 2010; Mathee, *et al*., 2014; Van Onselen *et al.*, 2015).

Geophagia has been described as a medical condition (Diko and Diko, 2014) and has been justified by several explanations which could be classified as cultural, psychological, medical, physiological and nutritional (Callahan, 2003; Geissiler *et al*., 1998; Harvey *et al*., 2000; Abrahams *et al.*, 2013; Santos, *et al*., 2016). Geissiler *et al*., (1998) as well as Odongo *et al*., (2016) identified geophagia as a possible risk factor in the transmission of various geohelminths parasitic infections and that it could be implicated in the development of iron depletion and anaemia.

Geohelminths (soil-transmitted helminths, STHs) are a group of intestinal parasites that causes human infection through contact with parasite eggs or larvae that thrive in warm and moist soil (Gawor and Boreka, 2017). These belong to the class called “nematode” and they are transmitted primarily through contaminated soil, which includes roundworms (*Ascarislumbricoides*), whipworms (*Trichuristrichiura*), and two hookworms (Ancylostomaduodenale and *Necatoramericanus*) (Blaszkowska, *et al*., 2013). They are called nematode because they have a dirt life cycle which does not need intermediate hosts or vectors, and the parasitic infection occurs through faecal contamination of soil, foodstuffs and water supplies (Epstein, 2015). According to Sumbele *et al*., (2011), the occurrence of geohelminth in soil is normally linked to the sanitary conditions and habits of the people in the environment in which soils are found.

Infection by Soil Transmitted Helminths (STHs) has been increasingly recognized as an important public health concern, particularly in developing countries (Farghly, *et al*., 2016). There have been regular endeavours to determine and present figures for STHs infections in Nigeria (Nock *et al*., 2003). Worm transmission is enhanced by poor socio-economic conditions, deficiencies in sanitary facilities, improper disposal of human faeces, insufficient supplies of potable water, poor personal hygiene, substandard housing and lack of education (WHO, 1996; Assefa, *et al*., 2014).

Safe drinking water for human consumption should be free from pathogens such as bacteria, protozoan parasites and viruses and meet the standard guidelines (WHO, 2004; Allende and Monaghan, 2015). However, lack of access to safe drinking water, together with inadequate sanitation and hygiene are implicated in 88% of diarrhoea diseases in both developed and developing countries and 2.2 million people die annually of diarrhoea in developing countries (WHO, 2004; Tumwine, 2005; Prüss-Ustün, *et al*., 2014). Furthermore, it is estimated that more than a billion people in the world do not have access to safe water, and approximately 2.5 billion people do not have access to adequate sanitation facilities (WHO, 2010).

Lack of adequate sanitation such as toilets results in the pollution of drinking water sources in the rural areas and this is the case due to open defecation and has serious health impact on the public (McClain and Paye, 2017). Faecal pollution of water leads to introduction of a variety of intestinal pathogens that cause water borne diseases (Jacobson and Ian, 1988; Soller, *et al*., 2014). The greatest microbial risks are associated with ingestion of water that is contaminated with human or animal faeces (Pandey, *et al*., 2014). Since the geophagic materials are found mainly near the rivers and along the river banks, the materials can easily be contaminated by polluted waters.

Open defecation is considered to be one of the risk factors that causes geohelminths infection (Worrell, *et al.,* 2016). Geohelminth is the second leading cause of mortality in children less than 6 years of age in Africa (Ogbe *et al*., 2002; Platts-Mills, *et al*., 2015). These infections are a result of poor hygienic habits such as indiscriminate disposal of human and animal faeces. These habits permit contact of faeces and its accompanying microbial load including geohelminths ova with soil (Phiri *et al*., 2002). Geophagic materials could contain geohelminths which pose a health threat to individuals who practice geophagic activities.

1.2 Statement of the problem

In Siloam village due to lack of adequate sanitation, people resort to open defecation. This practice is widely practiced openly as a way of addressing the improper sanitation challenges. Consequently, this poses a health hazard to the community in general and those who practice geophagia in particular. Though geophagia is widely practiced in South Africa (Woywodt and Kiss, 2002; Mathee, *et al.,* 2014; Macheka *et al*., 2016), little is known about the geophagia activities in the rural areas particularly in Siloam village. Maybe due to insufficient information or limited studies, people continue to consume earthy materials without being aware of their composition. In Siloam, the consumption of geophagic materials is often observed on daily basis especially among females of all ages (Figure 1.1). Most of the sources of the geophagic materials are located close to water bodies such as rivers and ponds.

The area is also affected by lack of clean water supply and scarcity; as an alternative people in this community use untreated river water for domestic purposes. The untreated river water being used by the community is classified as unsafe as a result of open defecation done near water sources among other human activities that contaminate water. This open defecation near water sources introduces harmful bacteria in water (Soller, *et al*., 2014). The South African constitution states that every person has a right to have access to an environment that is not harmful to their health and well-being (DWAF, 2005). In South Africa, nearly 21 million (about 54% of the population) lack basic sanitation (DWAF, 1996). Therefore, it is because of this backdrop that the study seeks to unpack the effects of open defecation on geophagic soils and water resources.

Figure 1.1: A woman consuming geophagic material near dirty water in Siloam village, Nzhelele area.

1.3 Motivation

Having access to clean water, improved hygiene and better sanitation reduces transmission of water borne and other diseases (Karsils, 2004). Thus, it is therefore important to understand and investigate if open defecation impacts on water sources and geophagic areas. Moreover, it is of importance to understand the health hazards posed by the consumption of water and geophagic materials that are exposed to the open defecation. The study has contributed to the understanding of the effects of open defecation on geophagic soils and water resources and contribute to the body of knowledge.

1.4 Objectives

1.4.1 Main objective

The main objective of this research was to investigate the extent of geophagic practice and effects of open defecation on geophagic soils and water resources.

1.4.2 Specific objectives

- To determine the reasons for geophagic practice in Siloam village.
- To identify and characterise geohelminths ova in geophagic soils.
- To investigate the effects of open defecation on water resources.
- To investigate possible health effects associated with open defecation and geophagic practice.

1.5 Research Questions

These research questions have been formulated to help achieve the objectives of the study:

- How prevalent is geophagic practice among communities of Nzhelele area?
- What are characteristics of geohelminths ova identified in geophagic soils?
- Does open defecation have effects on water resources?
- What are the possible health effects associated with geophagic practice in areas where open defecation is practiced?

1.6 Description of the Study Area

1.6.1 Location of the study area

Siloam village falls under Makhado Local Municipality in Vhembe District, Limpopo Province, South Africa. Siloam village is conveniently situated along the major tarred road (R523) from Sibasa to Wyllisport and it is 60km North East of Makhado (Louis Trichardt) and is approximately 45 km West of Thohoyandou. Its geographic grid is located between22°53´46.80˝ S latitude and 30°11´ 33.22˝ E longitude (Figure 1.2).

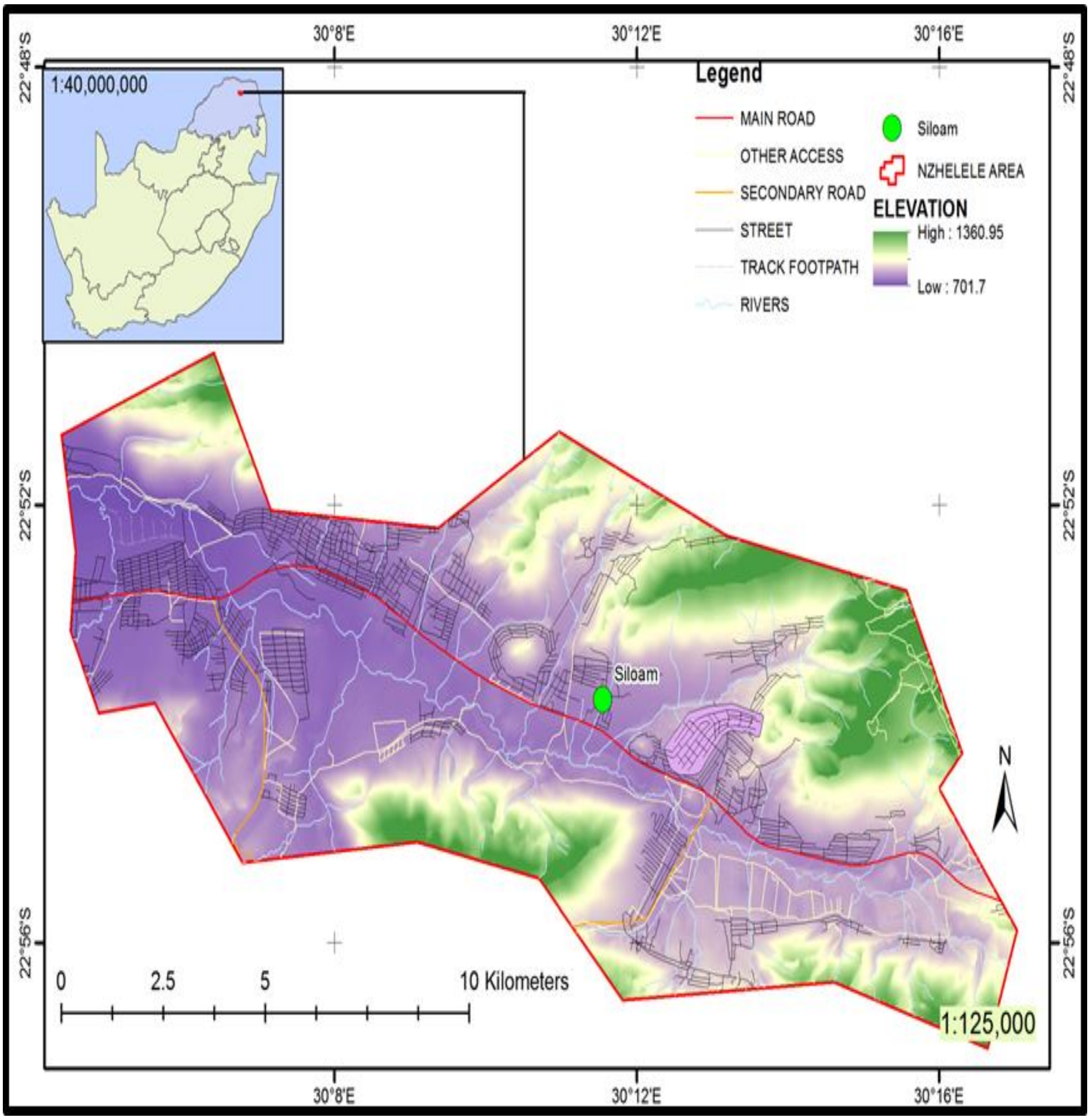

Figure: 1.2: Location and hydrogeology of the study area

1.6.2 Geology of the study area

The study area falls within the youngest formation of the Soutpansberg Group, the Nzhelele Formation (Table 1). Locally, it is dominated by basalt, which originated from the lava at the base of the formation. There are dark-red shale and thinly bedded sandstone. Also, there are interlayers of tuff, ignimbrite, chert, and in place tuffaceous shale (Mundalamo, 2003).

Table 1.1: Lithostratigraphy of the Soutpansberg group as compiled by the South African Committee for Stratigraphy. Slight modifications have been made to the

Formation	Member	Lithology	Thickness (m)
Nzhelele	Lukin Quartzite Mutale Tuff Musekwa Basalt	Predominantly white or light-coloured, brown-weathering, laminated quartzitic sandstone with interbedded shale and sandy shale. Lukin Member: white quartzite Alternating reddish, brownish or variegated shale, shaly sandstone, sandstone, and quartzitic sandstone with clay pellets and pellet conglomerate. Locally there are intercalations of tuff (Mutale Tuff Member) or basaltic lavas with interbedded tuff, ignimbrite, sandstone, shale and chert (Musekwa Member)	1 000–2 000
Wyllies Poort Quartzite	Bluebell Conglomerate Devils Gully Basalt	White, pink and light-coloured, medium-grained quartzitic sandstone and purple, brown or reddish coarse-grained sandstone, locally with interbedded pebble washes, grit, conglomerate, shale, mudstone, siltstone and lava Bluebell Conglomerate Member: boulder conglomerate Devils Gully Member: lava, mudstone and siltstone Calcareous rocks at base in one locality	1 000–4 000
Fundudzi		Light-coloured quartzitic sandstone and quartzite and purple, brown or reddish sandstone, locally gritty or conglomeratic with interbedded lava, tuff, agglomerate, shale, sandy shale, and siltstone	0–2 800
Sibasa Basalt		Predominantly basaltic lavas, with interbedded tuff, agglomerate, ignimbrite, quartzite, quartzitic sandstone, grit, conglomerate, shale, mudstone and siltstone	0–3 300
Tshifhefhe		Medium-grained partly feldspathic, quartzitic sandstone with interbedded shale, siltstone and mudstone; or shale with interbedded sandstone or feldspathic quartzitic sandstone, grit and graywacke, arkose, conglomerate, and shale	0–9

Lithostratigraphy as presented by SACS (Adapted from Bristow, 1986).

Younger consolidated and silicified sedimentary strata, predominantly sandstone and quartzite of the Soutpansberg Group have intruded these to form the spectacular, steep sided hills, and mountains of the eastern limb of the Soutpansberg Mountain (Mundalamo, 2003). Quartzite mountain range is predominant hence the area is dominated by granite. Groundwater is controlled by the prevailing lithology of the given area (Malaza, 2014).

According to Nyabeze *et al*., (2010), the study area is further characterised by a number of dykes and faults including the Siloam fault which contains a hot spring. The dykes create impermeable barriers to the aquifer. The hot spring is located on a really conductive zone that is 150 m wide (Nyabeze *et al*., 2010; Tshibalo, *et al*., 2015). The depth and condition of the thermal water may have an unhealthy impact on both the community and the surrounding environment (Nyabeze *et al*., 2010).

1.6.3 Topography

Topography plays a major role in recharge as some of the water bearing formations are recharged via topographical section or topographical high spot (Ayer, *et al*., 2016). The study area is located within the Soutpansberg mountain range which stretches from the tropic of Capricorn District up to the Beit bridge border post to the majestic Blouberg to the west and flanking the Kruger National Park to the east. The mountain terrain has an altitude ranging from 800m to 1300m above mean sea level (Kabana, 2004; Durowoju *et al*., 2016).

1.6.4 Soils

Soil is the mixture that consists of rock particles, air, water, organic matter and living soil organisms (Asafp-Adjei *et al*., 2013). 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 a 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, acts as engineering medium and it also acts as water reservoir because when it is rains the soil stores 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 microorganisms' activities or chemical reactions (Buol, 1995).

The study area consists of medium loamy or coarse sand to sandy clay loam with clay content and ranging from 4-40% (Institute of Soil, Water and Climate, 1994). There are two types of soil which include sandy and loamy soil (Rashid *et al*., 2005). The weathering of igneous and sedimentary is the origin of the soil in the study area

(Kabanda, 2004). Reddish soil which covers the area is attributed to the results of weathering of iron-bearing basalt.

1.6.5 Climate

1.6.5.1 Temperature

Siloam village is characterised by high temperature variations depending on the different seasons. The seasons are summer (September to early April) and winter (May to July). The summer temperatures range from 22°C to 40° C and winter temperatures from 16°C to 22°C (Makungo, 2008). Just after the winter season, the area is windy with a regular wind speed of about 3.6 m/s (Mundalamo, 2003).

1.6.5.2 Rainfall

The mean annual rainfall of Nzhelele ranges from 350-400 mm per annum (Makungo *et al.,* 2010). The rainfall is seasonal and occurs during summer months from October to March (Makungo *et al.*, 2010). More than 80% of the rainfall occurs in the summer months and only about 20% occurs in the winter months (DWAF, 2001). The rainfall is largely influenced by the Soutpansberg Mountains and moist air approaches the Soutpansberg Mountain from the south-east (i.e. Thohoyandou) and consequently the highest rainfall occurs on the southern and eastern slopes of the Soutpansberg (Department of Water Affairs and Forestry, 2001).

1.7 Land use

The study area consists of small scale subsistence agriculture and rural settlements. The agricultural practices mainly include farming such as of cattle, goats, pigs, crops (maize, vegetables, sugarcanes, etc.).

CHAPTER 2
LITERATURE REVIEW

This chapter reviews the literature on geophagic practice, characterisation of geophagic materials, Health effects of geophagic material, open defecation and its possible effects on water resources and potential threats to public health.

2.1 Distribution of Geophagic Practice

Geophagic behaviour has been widely reported in parts of South Africa, namely; Thabo Mofutsanyane District, Free State, Eastern Cape Province; QwaQwa, Vhembe district and Mangaung area in central South Africa (Ekosse and de Jager, 2011; Sumbele *et al*., 2011; Momoh, 2011; Mathee, *et al*., 2014; Mathee, 2014; Van Onselen *et al*., 2015; de Smidt *et al*., 2015; Momoh *et al*., 2015). Although this ageless habit has been proven archaeologically to be as old as Homo sapiens, it has nonetheless persisted over the centuries. Cultural and psychological reasons as well as medicinal, physiological and nutritional needs have been advanced to justify the practice (Callahan 2003; Geissler *et al*., 1998; Harvey *et al*., 2000; Hunter and de Kleine, 1984; Vermeer, 1966; Van Wyk, 2013; Jyothi, 2015; Nnorom, 2016).

Though formerly previously believed to be common among communities of low social status (Halsted, 1968), recent studies have indicated that pregnant females in affluent societies indulge in geophagic practice (Odongo *et al*., 2016; Diko and Diko, 2014). It is most common in many indigenous communities especially in developing countries (Ngozi, 2008; Castiano and Mkabela, 2013); and has also been linked to superstition (Halsted, 1968; Junmbam, 2013). In Southern Africa, women and children in both urban and rural settings are engaged in geophagia (Macheka *et al*., 2016; Momoh, *et al*., 2015). South African urban women believe that the consumption of earthy material including soils and clays enhances their looks (Woywodt and Kiss, 2002). Most of the earthy materials consumed contain clay minerals. The consumption of earth-like substances, such as clayey soils by women is closely related with pregnancy, especially in Africa, as this practice has proven to alleviate nausea and promotes healthy fatal development (Knishinsky, 1998; Hunter, 2003; Luoba *et al*., 2004; Kawai *et al*., 2009; Bisi-Johnson *et al*., 2010; Mathee, *et al*., 2014; Hunter-Adams, 2016). In addition, urban-dwelling South African women believe that earth-eating to be somatologically advantageous in the development of a fair or lighter complexion (Woywodt and Kiss, 2002). Often mothers, who practice geophagia due to cultural and familial aspects, will impart their habit to their children (Vermeer and Frate, 1979; Nchito, *et al*., 2004; Ellis and Schnoes, 2006; Jain, 2015).

2.1.1 Distribution of geophagia in the world

Geophagy has been around and practiced by many people from different parts of 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 and Kiss, 2002); North American, (Grisby *et al*., 1999); Central America (Hunter and Klein, 1984); South America, (Abraham and Parsons, 1996); Asia (Aufreiter *et al*., 1997). 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).

The practice and the reasons of geophagia may differ from country to country. The study conducted in 16 villages in the Marika protected area of Madagascar found the prevalence of geophagia to be 53.4% in a sample of 760 individuals (Golden *et al*, 2012). According to the results of the study conducted in Panama the prevalence of geophagia was 22.5% in a sample of 41 women (Lachlan and Bodkin, 2011). In rural South America the practice of geophagia is reported to be more common among the black women. It is believed that the spread of geophagia has been introduced by slaves in South America (Anitei, 2008). In Bangladesh the practice of geophagia is noticed among pregnant women. Women in Bangladesh believed that consuming soil boosts their appetite and health which they believe will result into the delivery of healthy babies. Poor and unemployed individuals in Bangladesh collect burnt mud and sell it as a way of generating income (Anitei, 2008).

A study undertaken in villages around Shiraz city in the Fars province of Iran showed that children and pregnant women were more likely to practice geophagia than other members of the community (Karimi *et al*., 2002). The Aboriginal people in Australia also eat white clay for medicinal reasons (Bateson and Lebroy, 1978). In Mexico, eating deep red dirt of Chimayo, "an old adobe-brick and stucco structure", is practiced daily since it is believed that the clay is sacred (Callahan, 2003). In the United States of America, a significant percentage of pregnant women (31.1% of 225) in Southern California practiced geophagia (Simpson *et al*., 2000), while 23% - 44% of the Latin-American population also practice geophagia (López *et al*., 2004). The percentage of women in urban areas of Washington DC that practiced geophagia was found to be low (8%) (Edwards *et al*., 1994), while women in Texas reported a high incidence (76%) of consuming clay (Rainville, 1998).

It was also reported that in urban and rural areas of Augusta, Georgia, 32.5% of postnatal inpatients practiced geophagia (Sage, 1962) and in women (n=211) attending antenatal clinics in Georgia, 21% consumed soil during pregnancy (Edwards *et al*., 1954). Pregnant and lactating women (n=204) attending two health facilities in Dar es Salaam, Tanzania, showed a 60% incidence of eating soil (Nyaruhucha, 2009). According to Shivoga and Moturi (2009) in a Jamaican study, children who practiced geophagia were more prone to malnutrition. Several studies have also reported that children of school-going age practice geophagia. These include children from Lusaka, Zambia (74.4%) (Nchito *et al*., 2004), Senegal (58.7%) (Diouf *et al*., 2000) and Mississippi in the USA (26%) (Ferguson & Keton, 1950).

2.1.2 Distribution of geophagia in Africa

Geophagia is mostly common in women of child bearing age, in developing countries including those in Africa (Brand *et al*., 2010.). The highest incidences of geophagia have been reported in African countries (Ngozi, 2008). It has been reported in Nigeria, Kenya, Botswana, Cameroon, Ghana, Guinea, Ivory Coast, Malawi, Senegal, Sierra Leone, Tanzania, Uganda, Swaziland and South Africa 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 reason for engaging in geophagia. Geophagia has also been reported to be high amongst scholars in Nigeria where hookworm infection was identified in 58% of primary schoolchildren in Anambra State (Chumkwuma *et al*., 2009).

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 geophagia (Geissler *et al*., 1997). According to the study that was conducted in Kenya in Likuyani District of Kakamega County the prevalence of geophagia was 45%. Also, in Malawi, pregnant women commonly practice geophagia, but women who are not pregnant do not practice geophagia because they believe that consumption of geophagic material is a sign of pregnancy (Hunter, 1993).

During the study in Zambia for detecting helminths ova in soil, it was found that out of 85 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 and Mwikuna, 2009). The prevalence of geophagia among Zambian girls was 74.4% (Nchito *et al.*, 2004).

The study conducted in Tanzania showed that the prevalence of geophagia was 64% (Nyaruhucha, 2009). The Chagga women of Tanzania believe that geophagia is sacred to women and defines their femininity (Knudsen, 2004). The prevalence of geophagia according to the results of a study conducted in Tanzania in a sample of 971 HIV positive pregnant women was 29% (Kawai *et al*., 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.

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).

Also, 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 consuming geophagic material (Faustinah *et al*., 2010). About 30% of the indicated women practiced geophagia.

Another study conducted in Ghana showed that geophagia was practiced by both men and women. The practice of geophagia was not limited to pregnant and lactating women, and it was found to be common in both rural and urban communities (Norman *et al*., 2015). Another study conducted in Ghana in rural and urban areas of Kumas showed that the prevalence of geophagia was 47% in a study of 400 pregnant women (Faustina, *et al*., 2010). Women (n=171) attending antenatal clinics in the eastern Caprivi region of Namibia also consumed soil and 41.5% of the women were found to be anaemic (haemoglobin <11 g/dl) (Thomson, 1997).

Geophagia has been reported in Swaziland and the study conducted involved the collection of soil samples that were analysed 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 and Ngole, 2012). It was also found that in Swaziland the majority of geophagists were women in the Hhoho and Manzini areas (Peter, 2011).

In South Africa ingestion of clay is mainly practiced by pregnant women. The practice of geophagia is also noticed in different provinces in South Africa. According to the study conducted by George and Ndip (2011) in the Eastern Cape uMthathta the prevalence of geophagia was reported to be 75% and to be very high among girls, pregnant and non- pregnant woman. Various reasons for the practice of geophagia were mentioned ranging from craving, due to smell and texture, belief of reducing morning sickness, hunger pangs and providing essential nutrients (George and Ndip, 2011).

In a study undertaken by Walker *et al*. (1997) amongst South African women, the prevalence of geophagia was found to be 38.3% in urban women and 44.0% in rural women Studies undertaken in the rural area of QwaQwa in the Free State region (Mogongoa *et al*., 2011) and in Limpopo region (Songca *et al*., 2010) have shown that the practice of geophagia is still prevalent under persons from rural areas in Southern Africa.

The study conducted in Johannesburg revealed that a large number of women practiced geophagia especially the migrant women. The prevalence of geophagia in pregnant women was reported to be 20% and was at risk of anemia. The study conducted by Mathee (2014) in Johannesburg consisted of women born in South Africa and those not born in South Africa (Mathee, 2014).

2.1.3 Distribution of Geophagia in Women

In different countries pregnant women have been identified as a group in which geophagia is more common. Women in both urban and rural areas practice geophagia (Ekosse *et al*., 2010), and especially those who are pregnant (Mogongoa et al., 2011). Pregnant women in Africa believe that geophagic material is good for fetal development. Women seek for traditional doctors to administer geophagic material to them during pregnancy. Recent studies have indicated that pregnant women in affluent societies engage also in geophagic practice (Ekosse *et al*., 2010). Ngozi (2008), found it is common in developing countries, especially African indigenous communities, and it has been linked to superstition (Halsted, 1968). In urban South Africa, young women believe the consumption of earthly material enhances their beauty and gives them a lighter colour (Woywodt and Kiss, 2002; Ekosse *et al*., 2010). Eventually, mothers who practice geophagia end up transferring the habit to their children and future generations (Vermeer and Frate, 1979; Ellis and Schnoes, 2006).

2.1.4 Distribution of Geophagia in Children

Geophagia is a natural habit among infants (especially toddlers 18 to 24 months of age) and young children (2 to 6 years) (Ellis and Schnoes, 2006; Bisi-Johnson *et al*., 2010). Children ingest significant quantities of soil due to their tendency to play on the floor either indoors or on the ground outdoors. Children may ingest soil and dust through deliberate hand-to-mouth movements, or unintentionally by eating food that has fallen on the floor (Nwafor, 2008).

Geophagic practice is commonly found in metabolically unbalanced, malnourished and inadequately supervised children (Garcia *et al*., 1987), but it may also occur at all levels of society (Kolandaivelu and Balan, 1979). There is little literature documented in teenage children who are involved in the practice even in developed countries (Geissler, 1997; Ellis and Schnoes, 2006). Young children are curious and explore their environment by putting their hands, objects and other materials in their mouths. Most of them try eating dirt, and only some persist with the behaviour. Saathoff *et al*., (2004) also reported the prevalence of consumption of soil in rural schoolchildren from the Northern parts of KwaZulu-Natal.

2.2 Characterisation of Geophagic material

2.2.1 Physicochemical

Types of clay or soils consumed vary widely depending on several soil inherent properties. Preference for a particular soil has often been linked to properties like soil colour, its fineness or coarseness, and in some instances its organoleptic properties, all of which are influenced by the soil physico-chemical properties including pH, and minerals content. Wilson (2003) and Young *et al*., (2008) indicated that physico-chemical properties may aid in the interpretation of physiological and nutritional reasons for geophagic practice but according to Mahaney and Krishnamani (2003), most geophagic materials are not properly characterized in terms of their pH, electrical conductivity (EC), CEC and texture. Studies of physicochemical properties of geophagic soil revealed variations in their color (Mahaney *et al*. 2000; Abraham (1997) and clay content (Abraham and Parsons 1997; Aufreiter *et al*. 1997). The physico-chemical properties of the soils ingested may therefore play a significant role in the accessibility of nutrients contained in the ingested soils. Studies by Slamova *et al*. (2011), Ekosse *et al*., (2010), and Dominy *et al*., (2004) have indicated that kaolin group of minerals are the most dominant clay minerals in geophagic soils. Some of these soils could contain high concentrations of major and trace elements which could be associated with health complications (Kutalek *et al*., 2010).

2.2.2 Mineralogy of Geophagic Materials

Geophagic clayey soil properties such as colour, texture, smell and taste all play a role in the type of clay that geophagists choose to consume (Reilly and Henry, 2000; Wilson, 2003; Nchito *et al*., 2004; Young *et al*., 2007; Ekosse and Jumbam, 2010; Ngole *et al*., 2010; Young *et al*., 2010). Bentonite clay is available worldwide as a digestive aid, while kaolin is also widely used as a digestive aid and as the base for some medicines. Attapulgite is an active ingredient in many anti-diarrheal medicines (Ziegler, 1997).

Geophagic materials consumed contain clay minerals, which are secondary minerals derived from chemical alterations of mostly feldspars and micas (Ekosse *et al*., 2010). White/khaki soft geophagic clays preferred by most of the respondents of the study done in the Limpopo and Free State, South Africa are dominated by kaolinite and/or smectite (Ekosse *et al*., 2010). Moreover, yellowish and reddish clays contain Fe, which might be the reason for their consumption. Kaolinite has the ability to change iron to a state which the body cannot utilize, at the same time absorbing the iron in the duodenum. This deprives the body of iron, thus leading to iron deficiency anaemia (Kikouama *et al*., 2009).

Clay is largely made up of clay minerals, but quartz, feldspar, carbonates, ferruginous material and other non-clay material can also be present and are in the highest concentrations in the B horizon. Types of clay includes Ball clay, Fire clay, Flint clay and Kaolin (which largely consist of kaolinite); Bentonite and Bleaching earth (consisting mainly of montmorillonite). Common clays consist of a combination of layers of illite/smectite and montmorillonite (Bergaya and Lagaly, 2006).

In Tanzania geophagic soil samples consist of 56% sand and 33% clay. Kaolinite is the main component of the clay called pemba, with minor components of illite, goethite and hematite (Yanai *et al*., 2009). Ekosse and Jumbam (2010) have reported that clays from Swaziland used for geophagia purposes were dominantly greyish to reddish and had a pH value of 6.33. Rural women in Zambia and Zimbabwe preferred soils from large termite mounds (Diamond, 1998), while pregnant and lactating women in western Kenya prefer to ingest soft stone known as "odowa" and earth from termite mounds (Luoba *et al*., 2004).

South African geophagists usually prefer clayey soils consisting of clay and sand (Ekosse and Jumbam, 2010). Clayey soil from the Free State Province is silky, whilst those from Limpopo Province are gritty and powdery (Ekosse and Jumbam, 2010). The geophagic clays in QwaQwa contain mostly quartz and kaolinite (Ekosse *et al*., 2008). A study undertaken among rural black women in QwaQwa showed that these women preferred white clay, while some ate yellowish geophagic clays (Ekosse and Jumbam, 2010). This is also seen in other provinces such as the Limpopo Province (Ekosse and Jumbam, 2010).

2.2.3 Chemical Composition of Geophagic Material

Red soil is ingested in many communities to prevent or alleviate symptoms of iron (Fe) deficiency anemia because of its inferred high Fe content (Harvey *et al*., 2000; Dreyer *et al*., 2004). Though soil has been ingested to alleviate symptoms of Fe, deficiency anemia, Severance *et al*., (1988) have shown that geophagia has in some cases caused Fe deficiency. This was attributed to the CEC of the ingested soils (Brouillard and Rateau, 1989). According to Ngole *et al*., (2010) the colour of the soils infers the presence of iron (Fe) and other related cations, which may not be bioavailable in the gastrointestinal (GI) tract. Kikouama *et al*., (2009) stated that white clays contain kaolin and smectite, with yellowish clays containing goethite.

2.3 Reasons for human beings indulging in Geophagic Practice

Human beings indulge in geophagic practice for wide varieties of reasons. Some of the reasons given for people's crave for earthy materials are the following: acting as an agent to counteract diarrhoea (Krishnamani and Mahaney, 2000; Prasad, 2014); to supplement intake of available Cu, Ca, Zn and Mg by rural communities (Mills, 1996; Davies, 2008; Momoh, *et al*., 2013); to reduce abdominal pain caused by heart burn and nausea (Hunters and de Klein, 1984; Ekosse *et al*., 2011; Riang'a *et al*., 2017); in the treatment of dysentery, cholera and in the definition of feminists amongst women (Knudsen, 2002; Ngole *et al*., 2010; Otto, 2014). According to Wilson (2003), three main reasons were advanced to explain geophagic practice; these are, hunger, micronutrient deficiency and protection from toxins and pathogens. The practice of geophagia is regarded as a complex behaviour with etiology including psychological, cultural, physiological, medicinal reasons, traditional and religious beliefs.

2.3.1 Cultural Reasons

Soil consumption is a traditional cultural practice which is used as remedy or treatment for illnesses (Dominy *et al*., 2004; Vermeer and 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). The reference to soil as dirt makes geophagia unacceptable in some cultures (Nchito, 2004; Ghorbani, 2008). Whereas, some cultures believed that soil consumption is the link between good health, fertility and ancestor's blessings (Njiru *et al*., 2011). On the contrary some look at it as a gift from the ancestors and consumption is seen as a sign of fertility (Ghorbani, 2008). It is suggested that the origin of geophagy may be based on the fertility of the earth, thus women eat soil before, during and after pregnancy (Abrahams et al., 1995). In Malawi, geophagic practice is seen as a sign of pregnancy in women (Ghorbani, 2008). In the study that was conducted in Kenya 32% of women said that the reason for eating soil is pregnancy (Geissler, Prince and Levene, 1999). In Africa, geophagia is practiced mostly in pregnant women (Hunter, 1973). According to Bisi-Johnson *et al*. (2010) geophagia is a traditional cultural or religious activity which has been observed especially during pregnancy. According to Ghorbani (2008) geophagia is a cultural practice done at religious ceremonies. The practice of geophagia is a traditional cultural practice which is used as a remedy or treatment for illnesses (Vermeer and Frate, 1979; Dominy *et al*., 2004).

2.3.2 Religious Reasons

Geophagia is an ancient behaviour practiced because of the belief in its religious and magical powers. Geophagia is a cultural practice passed from generation to generation because of its religious beliefs and because is considered as a spiritual, ceremonial and traditional practice (Van-Wyk, 2013). Geophagia is a common practice in black women in the southern parts of the United States. Geophagia is commercially exploited in United States-Mexican border towns, where cakes of clay imprinted with impressions of Christ are sold for children to suck on (Bick *et al*., 1993). In Guatemala clay briquettes with cathedral designs on them are sold to pregnant mothers (Bartas and Ekman, 2001).

In the Middle East for spiritual reasons, Christians take soft whitish stones from Bethlehem grotto and rub them in water for nursing mothers to drink and also in Pakistan where Muslims eat grey flat oblong cakes made from dust of the Prophet Mohammed’s tomb as a cure for all diseases (Hunter,1993). African-American women consume holy clay tablets in order to derive psychological comfort and allay anxieties associated with ill-health or pregnancy (Hunter *et al*., 1989; Geissler, 2000; Days, 2017). Women of reproductive age from Kenya consume soils from termite mounts that have symbolic significance because of their red colour (i.e. the colour of blood), intense taste, fertility, the use of their material for building dwellings and their location may be coincident with sites of burials or former habitation (Hunter and de Kleine, 1984; Geissler, 2000; Abrahams, 2005).

2.3.3 Psychological Reasons

The practice of geophagia is regarded as a psycho-behavioural disorder (Hunter 2003). Psychological upset can motivate the practice of geophagia and geophagia is linked to a number of psychological abnormalities (Callahan, 2003). According to Songca *et al*., (2010) young geophagic women in South Africa believed that soil consumption improves their natural beauty and (Ngozi, 2008) has reported that pregnant women in Nairobi, Kenya, choose soft stone because they believe it is safer and makes the baby and mother stronger during labour.

2.3.4 Physiological needs for micronutrients

Geophagia is reported to be a reaction to a physiological need and is associated by some with growth periods such as pregnancy and childhood (Cavdar *et al*., 1983). According to Zedlitz (2010), the craving for clay usually occurs when the demand for nutrients is higher, such as during pregnancy and childhood. During pregnancy, the requirements for nutrients are very high such that expecting women with nutrient deficiencies develop cravings for earthy materials, as the way of supplementing deficient nutrients like iron, zinc and calcium (Young *et al*., 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).

Geophagia is considered an attempt to obtain the required minerals. In most cases human eats clay or soil when the nutritional demand is high. It is more common for children to eat more soil during their period of greatest growth, when their bodies require more nutrients (Abrahams, 2005). Young *et al*., (2008) illustrated that people consume soil to increase micronutrient intake and to supplement iron, zinc calcium and other micronutrient deficiencies. According to Abrahams (2002) the shortage of calcium and iron may cause a craving for chalky substances. It is also believed that soil have the ability to increase calcium levels (Van Wyk, 2013).

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 the bioavailability of potassium, zinc and iron by means of clay binding with nutrients and eventually leads to the lack of micronutrients in the human body (Young *et al*., 2010).

However, Lanzkowsky (1959) suggested that iron deficiency causes geophagia, but the evidence is not conclusive. Danford (1982) found that Iron deficiency is common among people who practice geophagia and that leads to the idea that iron deficiency causes geophagia. 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 *et al*., 2000). 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 and de Kleine, 1984).

2.3.5 Medical Reasons

Among the different reasons people give for practising geophagia, the health reason is very prominent. The main reasons for human geophagic behaviour are: the detoxification of noxious substances, alleviation of gastrointestinal upset, such as diarrhoea, supplementation of mineral nutrients and the alleviation of excessive acidity in the digestive tract (Tateo *et al*., 2006). Most people that practise geophagia claim that it is because earthy materials or clay gives them the minerals that they need (Abrahams, 2005). Minerals claimed to be found in soil are calcium, iron and magnesium (Abrahams, 2005). This is the reason why most people who consume earthy materials or clay are females, especially during child bearing age, pregnancy and lactating women. In general, females during the child bearing years are often diagnosed with iron deficiency anaemia.

According to the study by (Carretero, 2002; Tateo *et al*., 2001) soil is used to heal common illnesses of gastro intestinal tract (GIT) because they possess medicinal properties. Kaolin and smectite are officially used in modern pharmaceuticals to prevent nausea, vomiting and gastrointestinal disorders (Young *et al*., 2007). However, most of the people who eat earthy materials present with the 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 eating earthy materials is a remedy for intestinal parasites and diarrhoea also promotes the practice of geophagia (Vermeer and 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). In Uganda soils are ingested for medical purposes to absorb harmful substances such as tannin and to reduce the bitterness of certain foods (Abrahams, 1997). According to Gumbo *et al*., (2010) a reason for consuming clay is due to the understanding that certain bacteria that are contained in it will help the digestive system function properly by reducing the growth of harmful bacteria, assist in lactose digestion, and improve the general health of the geophagist.

Another reason for indulging in geophagic practice was boosting of the immune system. If the immune system of pregnant women declines, that 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 microorganisms that they have been exposed to (Abrahams, 2005; Young *et al*., 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.

2.3.6 Hunger and poverty

Geophagia is commonly practiced in societies where poverty and famine in present (Ghorbani, 2008). Soil consumption is usually practiced by women and children to relieve hunger (Brand *et al*., 2009). The hunger reason holds that people consume earthy materials because they do not have anything else to eat (Laufer, 1930; Raphuthing, 2015). In 2002, food shortages were reported to be causing geophagia in Malawi (Norman *et al*., 2015). Many plants containing toxins were consumed during the period of food shortage, for example, the African famine food called the wild yam, *Discoreadumentorumpax* (Abrahams, 2005). Mud cookies baked in the sun by Haitians in Port-au-Prince is one way that poor people reduce hunger as food prices soar (Wiley *et al*., 2008).

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 and Kiss, 2002). In times of famine and poverty, geophagia serve as an appetite suppressant and is common in people suffering from anorexia nervosa (Vermeer and Frate, 1979). 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).

2.3.7 Pregnancy

According to Bisi-Johnson *et al*., (2010) pregnant and lactating women believe that the consumption of soil satisfies all the cravings associated with pregnancy. According to Reilly and Henry (2000) in Malawi geophagia is considered as a sign of pregnancy and not consuming soil during pregnancy is regarded as an unusual behaviour. Some women consume soil during pregnancy because they believe that soil consumption will cure oedema of legs and believe that it will make their babies beautiful. Van Wyk (2013) also noted that physiological changes during pregnancy can be the reason for geophagia. Geophagia is observed in pregnant women as a feature of iron deficiency (Woywodt and Kiss, 2002).

2.4 Types of clay or soils consumed

Geophagic materials are found in all sorts of shapes and sizes, and these differ from region to region and from country to country. Geophagia is practiced for different reasons by different people. People who consume clay have different choices, when it comes to selection of the clay they consume. The Geophagia materials are picked or mined from different selected areas. Some prefer termite, moulds, pits, riverbanks whereas others even prefer house walls (Reilly and Henry, 2000). Ekosse *et al*., (2010) noted that the preference of choice on clay or soil to be consumed include colour, taste and texture. The preference of texture and taste also differ from person to person, some prefer the clay or soil a bit powdery whereas others prefer the clay in a rock form, some prefer tasteless and some prefer clay with sour taste (Reilly and Henry, 2000).

2.5 Health Effects of Geophagia Practice

According to Brand *et al*., (2009) geophagia is the practice that is more common in women and children as a folk medicine. According to Simon (1998) geophagia is associated with positive health effects. Geophagia may supplement mineral nutrients. According to Lambert *et al*., (2013) clay or soil substances that is consumed by people interacts with the food bolus and the digestive mucosa. Geophagia may have harmful or beneficial effects on human health. Geophagia may strengthen digestive barriers against alkaloids and toxins, whereas on the other hand complex interactions of clay with metals and ions may generate low-level poisoning and deficiencies damaging the health and nutritious status of individuals practicing geophagia (Lambert *et al*., 2013).

Hooda *et al*., (2002) noted that geophagia has numerous health and medical problems. According to Van Wyk (2013) geophagia is associated with medicinal treatment and a remedy for certain diseases. Geophagia has various health implications in the human body which includes constipation, cramping, pain perforation from sharp objects like rocks or gravel contamination (Hooda *et al*., 2004). Geophagic soil may expose humans to parasitic infestations (George and Ndip, 2011). Most human illnesses that are associated with geophagia are caused by concentrations of the following elements in food or water that are either lacking or toxic, these elements include copper, fluorine, iodine, lead, selenium aluminium, arsenic, cadmium and thallium (Oliver, 1997). Soil ingestion also causes microbiological infections like helminthiasis (Kawai *et al*., 2009).

2.5.1 Positive Health Effect of Geophagia Practice

Geophagia may play a positive role in the health of individuals indulging in this practice in that it may correct bodily homeostasis by adjusting an imbalance in or a deficiency of minerals (Prasad, 2014). In addition, it could supplement elemental nutrients, adjust the pH in the digestive system, and serve as a treatment for some ailments (Aufreiter *et al*., 1997; Diko and Ekosse, 2014). According to Mpuchane *et al.,* (2008), indigenous communities in Africa, the Americans, the Caribbeans and Asias use clays as the active ingredient in the treatment of several ailments. Earlier on, Thompson (1913) as well as Black (1956) also reported the use of clay against poisons. Detoxification of food, the alleviation of gastrointestinal disorders such as diarrhoea (Oliver, 1997; Johns and Duquette 1991; Wilson, 2003; Pandey *et al*., 2014; Arhin and Zango, 2017), and the supplementation of mineral nutrients including calcium, copper, iron, manganese iron, manganese and zinc (Johns and Duquette 1991; WHO, 1996; Van Onselen *et al*., 2015) have also been reported as emerging factors in support of human geophagic practice.

According to University of Chicago (2011) there are several benefits of eating soil and clay. It is believed that Earth soil consumption protects the stomach against toxins, parasites, and pathogens. Different researcher's ague about the benefits of geophagia some believe that geophagia provides nutrients such as iron, zinc, or calcium, whereas others believe that earth has a protective effect, or is working as a shield against ingested parasites, pathogens and plant toxins. Geophagia is believed to delay and ease the hunger pangs (University of Chicago, 2011). Clay may benefit calcium absorption. Clay retards the motility of the gastrointestinal tract and increase the time for calcium absorption from foods to take place by binding with secondary compounds in plant foods. Clay may release bound minerals that make them available for absorption (Hunter, 2004). The mineral content of soils from different regions varies, some contain the following minerals which are very important during pregnancy, iron, calcium, magnesium and copper (Anitei, 2008). Soil lowers morning sickness in pregnant women. Kaolin in the soil also helps to prevent diarrhoea. Geophagia also act as a mineral supplement for pregnant women as the nutrients requirements increase (Anitei, 2008).

Though there is insufficient information on the practice of geophagia, some beneficial effects have been established over the years largely by trial and error (Mahaney *et al.,* 2000) and more recently using clinical-biological methods (Droy-Lefaix and Tateo, 2006). Clays are used as indigenous active ingredients for the treatment of a wide range of ailments and diseases in Africa, the Americas, Caribbean and Asia (Mpuchane *et al.,* 2008; Van Onselen *et al*., 2015). The Pomo Indians of California and even Sardinians treated corns with clay to make them more palatable (Oliver, 1997; Johns and Duquette, 1991). Red soil, because of its iron (Fe) content is believed to be able to prevent Fe deficiency anaemia, although the bioavailability of the Fe has been put into question (Harvey, *et al.,* 2000; Dreyer, *et al.,* 2004). They are report of pregnant women in Africa eating soil to facilitate smooth delivery, and dark skin for the child (Ekosse *et al*., 2017).

2.5.2 Negative Health Effects of Geophagia Practice

Though geophagia may have several positive attributes, the Committee on Research Priorities for Earth Science and Public Health, National Research Council (2007) has cited it as a potential health threat to several communities (Mathee, *et al*., 2014). According to Oliver (1997), soil ingestion could lead to a specific disease or general ill-health. Health issues that have been linked to geophagia include iron deficiency anaemia, hypocalcaemia, parasitic infections, mechanical bowel disorder and perforation of the sigmoid colon (Key *et al*., 1982; Ekosse *et al*., 2013). Reid (1992) and (Matangila, *et al*., 2014) showed an increased level of anaemia following prolonged soil ingestion. Hooda (2003) reported that ingestion of clayey soil could also result in deficiencies of certain elements in the human system because soils with high CEC would absorb elements that are already in solution, thereby reducing their availability for absorption in the gastrointestinal tract (GI). Soils, especially those rich in clay and organic matter, are biological sinks for many microorganisms, some of which are pathogenic (Esmaeilzadeh and Ahangar, 2014).

According to Magongoa *et al*., (2011) it is believed that soil eating inhibits the absorption of iron from the gut into the blood stream. Anitei (2008) mentioned the following effects of eating soil: constipation caused by clay, geophagia affects the ability of the body to absorb nutrients which may lead to nutrient deficiency, and soil may cause a person to crave for other non-food substances (Anitei, 2008). According to Abrahams (2005) consuming contaminated soil is dangerous in a way that it may cause maternal death. Course particles found in the geophagic soil can affect the dental enamel and can also cause the rupturing of the sigmoid colon (Ngole *et al*., 2010). Consuming various minerals found in the soil can cause different types of complications to human health. Consuming soil with too much cadmium can cause kidney damage (Young, 2007).

In Nigeria and the United States of America (USA), ascariasis in children and toxocariasis are commonly associated with geophagia (Callahan, 2003). Perforation of the sigmoid colon has been reported in geophagic individuals (Woywodt and Kiss 1999). Negative effects of geophagia on human health are influenced by factors that may include the properties of the clayey soils ingested, their genesis, mining environments, and other possible anthropogenic activities. Brouillard and Rateau (1989) have attributed deficiency of some cations in geophagic individuals to the CEC of the soil ingested. Prolonged ingestion of soils with high concentrations of heavy metals could result in metal toxicity. Whereas some individuals practising geophagia are aware of the health implications of the practice, others are not.

2.6 Open Defecation

Open defecation is the practice of defecating in the fields, bushes, and bodies of water or other open spaces (Okullo *et al*., 2017). The practice of Open Defecation is much more common in rural areas of sub-Saharan Africa an estimated 35% of rural households, in contrast to 8% of urban households, reported to practice Open Defecation (WHO, 2012). The factors contributing to open defecation especially in rural villages have been reported. These factors include habit, nomadic cultural lifestyles, and poor design of public toilets (Moruff, 2012); absence and non-functionality of latrines (Bartlett, 2003); available open space; and poor understanding of health and hygiene factors. According to Geetha and Kumar (2014) in another study, outdoor defecation has been explained as an everyday habit formed during childhood and that it is very common among people living in rural areas.

In Nigeria, a considerable amount of human and animal waste is discharged into the soil daily leading to the seeding of the soil with pathogenic organisms including geohelminths eggs and larvae (Nock *et al*., 2003). Observations in Zaria Northern Nigeria showed that 70% of the soil samples collected in a school compound was contaminated with geohelminths eggs showing the level to which the soil can be contaminated with faeces (Nock *et al*., 2003).

2.7 Open Defecation associated with Water Bodies

South Africa's water resources are in global terms, scarce and limited in extent (Moriarity, 2001; Shen, *et al*., 2014). More than 1.2 billion people in the world currently lack access to a safe water supply, and two in five have no access to improved sanitation (USAID, 2003). There is virtually no access to safe drinking water among the poorest 40 per cent of people in Africa (WHO/UNICEF Joint Water Supply, and Sanitation Monito, 2014). In most parts of South Africa water resources are already fully utilized or overdrawn (Kanyoka *et al*., 2008). Domestic water uses in South Africa are characterised by significant inequities in terms of access to the resource and quality of services (Kanyoka *et al.,* 2008). When people are not supplied with adequate amount of water, they turn to other alternative sources of water which may cause diseases (Dungumaro, 2007; De Silva *et al*., 2014).

In many developing countries, people living in rural areas collect water from communal sources which are either exposed (e.g. unprotected wells, unprotected springs, and rivers) or improved (e.g. protected wells, boreholes and public standpipes) (WHO/UNICEF, 2000; Sobsey, 2002). Furthermore, people in rural communities generally lack knowledge on route of waterborne diseases which increases the risk.

Many people lack knowledge about potential risks of uncovered and inappropriately stored water, hand washing with soap before eating, preparing food and after defecation (Rana, 2009). According to WHO, about 600 million episodes of diarrhoea and 40, 00,000 childhood deaths are reported per year due to contaminated water and lack of sanitation.

Defecation on boundaries of water bodies results in bacteriological contamination of water (Water Aid, 2011). Open defecation remains the predominant norm and poses one of the biggest threats to the health of the people in India. Estimates suggest that nearly 65 percent of India's population still defecate in the open. This results in a faecal load of 2, 000,000 metric tons per day, which finds its way into soil and water bodies, contaminating them with pathogens (Rajgire, 2013). Defecating in the open can also contaminate water resources through runoff, where the faeces get to be washed away into the rivers during rainfall.

2.8 Geohelminths

Nematodes commonly parasitic to humans and capable to induce disease upon entering the human host are sometimes found in soils and directly transmitted to humans in the absence of an intermediate host (Peters and Gilles, 1989; Hotez, 2000; Winn, *et al*., 2006). The most frequently encountered pathogenic nematodes associated with human geophagia, are the geohelminths, T. *trichiura*, A. *lumbricoides*, and the *hookworms*, N. *americanus* and A. *duodenale* (Hotez, 2000; Bethony, *et al*., 2006). T. *trichiura* is classified under the superfamily *Trichuroidea*, A. *lumbricoides* under the family *Ascarididae* and the *hookworms* under the superfamily *Strongyloidea* (Schistosomiasis Research Group, 2009).

Geohelminths are responsible for the most prevalent human infections globally, having a significant effect on the poor in developing countries (Hotez, 2000; Holland and Kennedy, 2002; De Silva *et al*., 2003; Hotez *et al*., 2006; WHO, 2008; Rajagopal *et al*., 2014; Traversa, *et al*., 2014). Especially the African continent seems to be heavily burdened with geohelminths infection (De Silva, *et al*., 2003; Karagiannis-Voules, *et al*., 2015).

2.8.1 Life Cycle of Geohelminths

The life cycles of geohelminths necessitates dispersion of fertilized ova within soil through faecal contamination. Favourable soil conditions (warm and humid) allow these ova to develop into an infective stage (Maier *et al*., 2000; Winn *et al*., 2006, Murray *et al*., 2009).

Adult geohelminths reside primarily in the intestinal lumen of their host where copulation and ova-production take place; *T. trichiura* in the large intestine, and *A. lumbricoides* and the hookworms in the small intestine (Winn *et al*., 2006; Ash and Orihel, 2007; Murray *et al*., 2009). However, the pathway of these parasitic geohelminths to the intestinal lumen, differ notably. After ingestion, *T. trichiura*, hatches in the small intestine and the hatched larvae migrate to the large intestine (Winn *et al*., 2006; Ash and Orihel, 2007; Murray *et al*., 2009).

A. lumbricoides also hatches in the small intestine and undergoes obligatory migration through the liver and lungs, after which larvae migrate to the small intestine via the respiratory tract, coughing and swallowing (Winn *et al*., 2006; Ash and Orihel, 2007; Murray *et al*., 2009). In contrast, *hookworm* filariform larvae enter through the skin, migrate via the circulation to the lungs, after which larvae also migrate to the small intestine via the respiratory tract, coughing and swallowing (Winn *et al*., 2006; Ash and Orihel, 2007; Murray *et al*., 2009).

Trichuris and *Ascaris* ova are well-protected and able to survive extreme environmental temperatures (Murray *et al*., 2009). Both *T. trichiura* and *A. lumbricoides* enter the host through oral ingestion of infective ova from contaminated soil (Figures 2.1a, 2.1b). In contrast, the *hookworms* (*A. duodenale* and *N. americanus*) mature into infective filariform larvae within the soil and commonly enter the host through larval penetration of the skin, although oral ingestion of *A. duodenale* filariform larvae may also initiate infection (Figure 2.1c) (Winn *et al*., 2006; Ash and Orihel, 2007; Murray *et al*., 2009).

In the final stages of the life cycles in human hosts, ova are passed into the faeces and thereafter the degree of sanitation and hygiene practiced by the community determine how ova are spread and deposited into the environment (Peters and Gilles, 1989). More common vectors of geohelminths ova dispersement throughout the environment include indiscriminate defecation by humans and animals, the use of raw human faecal matter as crop fertilizer and unrefined human habits (Peters and Gilles, 1989).

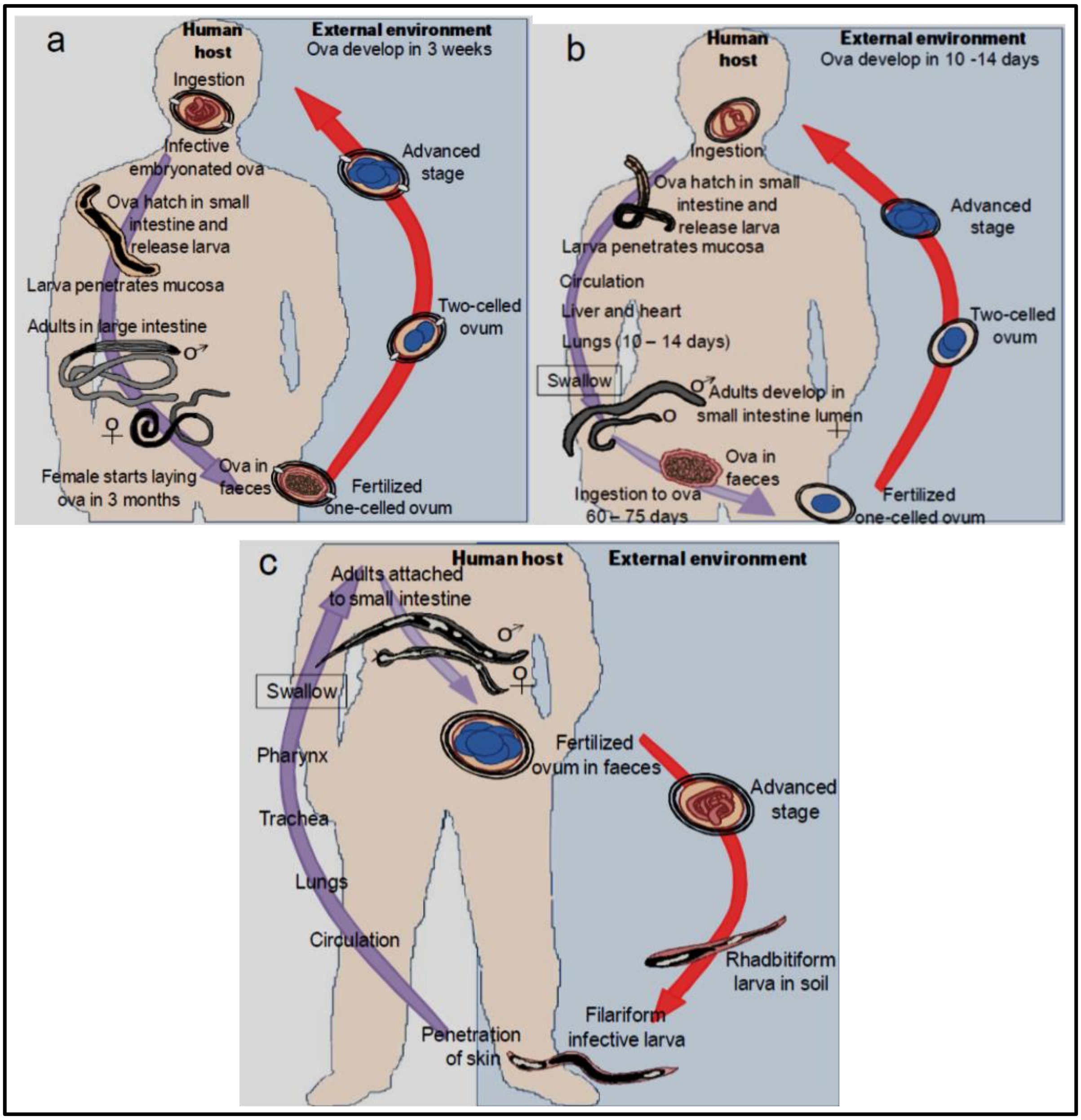

Figure 2.1: *Life cycles of pathogenic nematodes (geohelminths): a. T. trichiura; b. A. lumbricoides; and c. A. duodenale and N. americanus (hookworms)* (After Perridge, 2010).

2.9 Summary of the chapter

This chapter summarises reviewed literature on the Distribution of geophagic practice, Characteristics of geophagic materials, reasons for human beings indulging in geophagic practice, types of clay or soils consumed, health effect of geophagia practice, Open defecation, open defecation associated with water bodies and geohelminths including the life cycle of geohelminths.

CHAPTER 3
MATERIALS AND METHODS

3.1. Preamble

This chapter discusses the methods and procedures that were used during this project. The chapter further explains the research procedure, population, and sampling technique, Geophagic soils sampling site, water sampling sites, sources of data and data collection methods and instruments that were used in this study. Lastly, the data analysis is further explained.

3.2 Research Design

The research was designed to utilise both qualitative and quantitative methods of data collection and analysis and it adopted a case study approach.

3.2.1 Ethical Considerations

Ethical considerations were duly followed and permission were sought and obtained before visiting the field (Appendix 2). Lupele (2002) emphasised the need to ask for permission from the traditional leadership or authorities before any research can be conducted in their rural set up. In this regard, permission was obtained from tribal leadership or authorities. The purpose of the study was fully explained to the leadership and authorities who helped to publicise the study among the residents and encourage them to give their full cooperation. Consent forms were administered and fully explained to the participants. The participants were free to withdraw from participation when they feel the need to do so (Appendix 3).

3.2.2 Study population and Sample size

Residents of Siloam village participated in this study. A snowball sampling was used to select a sample size to participate in the study. Siloam is a rural village with 439 households and a population of about 2023.

According to Onabanjo, (2010) a sample size is a representative group or subset of all the members of a population of interest, while sampling is a process of obtaining information from a subset of a large group. A sampling frame is a list of study cases in a population, or the best estimation of them. White (2000) offers the following table as an indication of what the size of a sample ought to be for any scientific social research (table 3.1).

Table 3.1: Statistical rules used for indicating the sample size of the study

Population size	Percentage suggested	Number of respondents
20	100%	20
30	80%	24
50	64%	32
100	45%	45
200	32%	64
500	20%	100
1000	14%	140
10 000	4.5%	450
100 000	2%	2000
200 000	1%	2000

Source: (White, 2000)

Table 3.2: The study population and sample size

Village	Population size	% of Population sampled	Sample size
Siloam	2023	14%	283

A total of two hundred and eighty-three (283) participants were sampled. This number was calculated as the 14% of the population, and hence, a reasonable representation of the total of 2023 population in the community following (white, 2003) as illustrated in table 3.1. Only women aged between 18 and above were selected to participate in the study because geophagia is more prevalent among women. In total, 283 participants were sampled from Siloam village.

3.3 Sampling sites

3.3.1 Geophagic soil sampling sites

Geophagic sites were located with the help of the consumers and interpreters from Siloam village. The soil consumers were able to supply information on different locations and the type of soils preferred and consumed according to their own individual preferences. Generally, all the geophagic mining sites were well known and some of them had been extensively mined by consumers.

Geophagic soils from Siloam Village were collected from quite several different geophagic sites and the areas were easily accessible. Some of the geophagic materials were collected from the valley (Figure 3.1) whereas some collected their soils from the tree and the most popular one is the mango tree as illustrated in (Figure 3.2). The public gravel road contains munyaka clay (Figure 3.3) which is easily assessable, does not require digging as it is loose and preferred by young school girls. Whereas some young girls preferred gravel road, older women preferred soil near the riverbed of Nzhelele river and ponds where the soil is wet and moist (Figure 3.4) and (Figure 3.6). Other older women prefer the soil from their yard as its always available (Figure 3.5). Some geophagic sites preferred by soil consumers in Siloam Village was soil from the termitaria (Figure 3.7). Control soils samples were also collected from Siloam village where there is no history of open defecation and geophagic practice (Figure 3.8).

Figure 3.1: Geophagic soil collected from the valley at Siloam Village.

Figure 3.2: Geophagic soil collected from Munngo tree at Siloam Village.

Figure 3.3: Geophagic soil collected from the public road side at Siloam Village.

Figure 3.4: Geophagic soil collected from riverbed at Siloam Village.

Figure 3.5: Geophagic soil collected inside the Yard at Siloam Village.

Figure 3.6: Geophagic soil collected near the pond at Siloam Village.

Figure 3.7: Geophagic soil collected from termitaria at Siloam Village.

Figure 3.8: Geophagic soil collected from control site at Siloam Village.

3.3.2 Water sampling sites

Water samples from Siloam Village were collected from quite a number of different sites near geophagic mines. Water sample sites were located with the help of the participants who practice geophagia and also use river water for domestic purposes. The water sample were collected from Nzhelele River near the River bank were older woman prefer to take the geophagic soil from and also were open defecation take place (Figure 3.9a, 3.9b 3.9c).

Figure 3.9a: young children doing laundry near sampling site at Siloam Village, Nzhelele River**.**

Figure 3.9b: A women doing laundry near sampling site at Siloam Village, Nzhelele River**.**

Figure 3.9c: Young children swimming near water sampling site at Siloam Village, Nzhelele River**.**

Some of the water samples were collected from the water pond protected by arcacia trees which is also near the geophagic site (figure 3.10). However, some of the water samples were collected from Nzhelele River near where cows were graving (Figure 3.13). Control water samples were also collected from Nzhelele River from the upstream and downstream of the river where water is not being used for domestic purpose and there is no history of open defecation and geophagic practice. (Figure 3.11) and (Figure 3.12).

Figure 3.10: pond water protected by arcacia tree were water samples were collected at Siloam Village, Nzhelele River.

Figure 3.11: Upstream water sampling site at Siloam Village, Nzhelele River**.**

Figure 3.12: Downstream water sampling site at Siloam Village, Nzhelele River**.**

Figure 3.13: Cattles grazing near sampling site Nzhelele river.

3.4 Data collection procedures

The purpose of data collection is to obtain information that will aid in making decisions and achieving the objectives of the study. In this study, the data collection process was gathering of primary data. The primary data collection was achieved through the use of questionnaires, soil sampling and water sampling.

3.4.1 Questionnaire survey

A standardised questionnaire developed in 2007 by Senior Professor Georges Ekosse to characterise human geophagic habits and geophagic clayey soils, previously used by the geophagia working group in other parts of South Africa, Botswana and Swaziland was used in this study. The questionnaires were used to collect data of geophagic practice in Siloam village.

A snowball sampling method was used to obtain the population size to which questionnaires was administrated. The questionnaire survey was conducted among women who practice geophagia between the ages of 18 and above. Two hundred and eighty-three (283) women were selected to form part of the study sample.

3.4.2 Soil sampling

A convenience sampling method was applied during soil sample collection in Siloam village. This method entails the collection of samples at the convenience of the researcher and is an economical estimation of the truth (Keyton, 2006). The indigenous knowledge obtained from the practitioners was employed to decide on mining sites to be included in the study. Thus, the practitioners provided valuable information regarding potential collection sites. The soil samples were then collected in areas known for human geophagic practices within the rural settlements of Nzhelele area, Siloam village and kept cool in cooler boxes whilst collection was taking place and during transport to the laboratory, where they were refrigerated until analysed (Sandor and Estrada, 2008).

Collection of the soil samples was done on October 2017. However, during the collection of the soil samples, hands and utensils were used that were cleaned using 70% alcohol while sampling. Approximately 200 g of each soil sample collected was then placed inside appropriate re-sealable plastic bags. From each identified site a soil sample was collected, usually more than 20 cm from the surface, as suggested by Hunter (2003), who discovered that individuals plagued by geophagic cravings tend to obtain deeper embedded soil. These soil samples were then labelled and documented using a data collection sheet.

The control soil sample group was collected from sites not used by geophagic consumers located within the rural settlements of Siloam area. The collection of the control soil samples took place in October 2017. The collection methodology for the control soil sample group was also similar to that described for the geophagic sample group, but the control soil samples were named sample C for control. In total, soil samples for laboratory analyses were collected from 12 sites for Geohelminths ova analysis.

The coordinates of each geophagic site were noted with a Garmin GPS (Global Positioning System) device. GPS is a satellite-based navigation and surveying system used for determination of precise position and time, using radio signals from the satellites, in real-time or in post-processing mode. It is being used all over the world for numerous navigational and positioning applications, including navigation on land, in air and on sea. It determines the precise coordinates of important geographical features as an essential input to mapping. The device offers very high accuracy coordinates in most surveying and navigational applications at very low cost and with high efficiency (Anderle, 1988; Colombo and Watkins, 1991).

3.4.3 Water sampling

Water samples were collected from Nzhelele River and ponds close to where geophagic materials are being collected. Samples were collected using 500ml plastics bottles. Samples were taken in accordance with the DWAF sampling guide (DWAF, 2000). The sampling bottles were not filled up to the brim; 25 mm space was left for shaking of the bottle before analysing.

3.5 Data analysis methods

3.5.1 Questionnaire Analysis

In this study, the data from the administered questionnaires was analysed and simplified using Microsoft Excel 2013 and statistical procedures of Statistical package for Social Sciences (SPSS Version 24.0). The data was first coded, defined and labelled and fed in Microsoft Excel and then imported into SPSS program to generate descriptive and inferential statistics. Descriptive statistics and graphical analysis of the data were captured and explained. Statistical methods, namely frequencies and percentages, were calculated for categorical data. Means and standard deviations, medians and percentiles were calculated for numerical data. Analytical statistics, namely the Chi-Square statistic for differences between categorical data, was used to calculate significant differences amongst the different geophagic soil samples and the control groups. A significance level of 0.05 was used throughout the study. Data was presented in a form of tables and graphs. If p-value was >0.05, it indicated that there was no significant difference between the mean or median values of the control group and the geophagic group. In addition, if the p-value was <0.05, then there was a significant difference between the mean or median values of the control group and the geophagic group existed.

3.5.2 Detection of the presence of Geohelminths ova

No standard method exists for the detection of nematode ova, including geohelminths ova, in soil-based samples (Buckley *et al*., 2008; Fard *et al*., 2016). However, a wide variety of recovery methods for nematode ova from soil-based samples have been used over the years (Buckley *et al*., 2008; Krause, *et al*., 2015). For example, geohelminths ova identification from Pemban geophagic soils were conducted using a basic technique, which involved sieving and the microscopic examination of the resultant sediment (Young *et al*., 2007; Ghidiu *et al*., 2014). However, flotation techniques have shown several advantages during soil sample analysis, including cost-effectiveness and time-efficiency (Kuczynska and Shelton, 1999; Deb and Majumdar, 2013). Generally, poor geohelminths ova recovery occurs with flotation techniques, as ova inherently adhere to clay and silt soil particles (Kuczynska and Shelton, 1999; Deb & Majumdar, 2013).

For this study, the recommended Ammonium Bicarbonate (AMBIC) protocol was used for geohelminths ova recovery, as the method entails disruption of ova-soil particle bonds and consequently, a higher ova yield (Buckley *et al*., 2008).Soil samples were analysed for the presence of potentially pathogenic geohelminths ova, using the AMBIC protocol, which incorporates a modified zinc sulphate flotation method, described by the Water Research Commission (WRC) of South Africa (Buckley *et al*., 2008; Amoah *et al*., 2017).The AMBIC protocol consists of four analytical procedures, namely, sample preparation, sample washing with AMBIC solution, nematode ova recovery through a modified zinc flotation method and microscopic analysis (Buckley *et al*., 2008). The volume was adjusted according to the amount of soil sample analysed. All soil samples were analysed in duplicate. Below are the procedures that were followed to detect the geohelminths ova using Ammonium Bicarbonate (AMBIC) protocol.

Procedure 1: Sample preparation comprises of the following:

1. One gram of the soil sample was placed into a 50 ml Falcon conical test tube.

Procedure 2: Sample washing with AMBIC solution comprises of the following:

2. The sample was washed through addition of saturated AMBIC solution up to the 15 ml mark on the tube and vortexed (Vortex mixer-300) for 3 min.

3. During mixing, larger particles were freed from the bottom of the tube using applicator sticks if necessary.

4. Tubes were then capped and left to stand for one hour.

5. Thirty minutes into the standing period, tubes were vortexed for 3 minutes and then shaken (Labcon shaker) for an additional 2 min.

6. After an hour, samples were centrifuged (HeraeusBiofuge Primo centrifuge) at 940 g for 3 min.

7. The supernatant was then discarded into waste buckets.

8. Deionised water (about 15 ml) was added to the sediment and vortexed for 2 min.

9. The samples were again centrifuged at 940 g for 3 min, and the 47-supernatant discarded.

Procedure 3: Modified zinc flotation method for Geohelminths ova recovery comprised of the following:

1. About 12 ml of zinc sulphate solution was added to the tube and vortexed for 2 min.

2. Tubes were then centrifuged at 600 g for 3 min.

3. The supernatant was poured into a clean 50 ml conical test tube and thereafter each tube was filled with deionised water to decrease the specific gravity.

4. Tubes were centrifuged at 1850 g for 3 min.

5. Wet preparations was prepared from the pellet of each tube and then examined under ×10 and ×40 objectives of a light microscope.

Procedure 4: Microscopic analysis comprises of the following:

1. Pellet examination of each tube were conducted in duplicate and visualization under the light microscope aided through the addition of Lugol's iodine to accentuate any ova present in the wet preparations.

3.5.3 Detection of the presence of Geohelminths ova of Control Soil Samples

Ammonium Bicarbonate (AMBIC) protocol was also used to detect the presence of Geohelminths ova in the control soil samples.

3.5.4 Determination of water quality

Procedure

1. Isolation and enumeration of total coliform by membrane filtration technique

Water samples from Nzhelele River and ponds from Siloam village were analysed using Membrane Filtration Techniques. Membrane Endo Agar LES (m-Endo agar LES) was used to confirm presence of total coliform. LES Endo agar was prepared and heated to boiling until all media completely dissolved, allowed to cool and stored at 4°C in the dark before use. Membrane filtration technique (Membrane filter size of

0.45 micron) was used to isolate and enumerate total coliforms. Water samples volume of 1 or 5 mL (diluted to a volume of 10 mL) was filtered through the membrane filters. Dilution was done with sterile solution of potassium dihydrogen phosphate (KH_2PO_4) buffered dilution water (0.625 mM, pH 7.2, adjusted with 1 mol/L NaOH solution). The plates and the control were incubated for 24 ± 2 hours, at 35°C. A golden-green metallic sheen is a characteristic feature of colonies grown in this particular medium (Figure 3.14); and were counted under a dissection microscope. Colonies exhibiting alternate colours (negative) were not counted (Figure 3.15).

Figure 3.14: Positive for total coliforms on m-Endo agar

Figure 3.15: Negative for total coliforms on m-Endo agar

2. Isolation and enumeration of faecal coliform by membrane filtration technique

Water samples from Nzhelele River and ponds from Siloam village were analysed using membrane filtration techniques. Faecal Coliform (m-FC) agar was used to confirm presence of faecal/thermo tolerant coliform. The medium was suspended in 1 L of sterile purified water and the pH was adjusted to 7.4. The medium was heated with constant agitation to boiling until complete dissolution, this was allowed to cool and stored at 4°C in the dark before use. A volume of 10 mL of 1% rosolic acid in 0.2N NaOH was added, boiled for one minute and allowed to cool prior to pouring into sterile plates. The membrane filtration technique (Membrane filter with 0.45 micron) was then used to isolate and enumerate faecal coliform. Water sample volumes of 5, 10 or 50 mL were filtered through the membrane filters. Sample volumes less than 10 mL were diluted to a final volume of 10 ml with sterile solution of potassium dihydrogen phosphate (KH_2PO_4) buffered dilution water (0.625 mM, pH 7.2, adjusted with 1 mol/L NaOH solution). The plates and control were incubated for 24 ± 2 hours at 44.5 °C. Colonies with a characteristic blue colour were indicative of faecal coliforms (Figure 3.16) and counted under a dissection microscope. Colonies exhibiting alternate colours were not counted (Figure3.17).

Figure 3.16: Positive for faecal coliform on m-FC agar

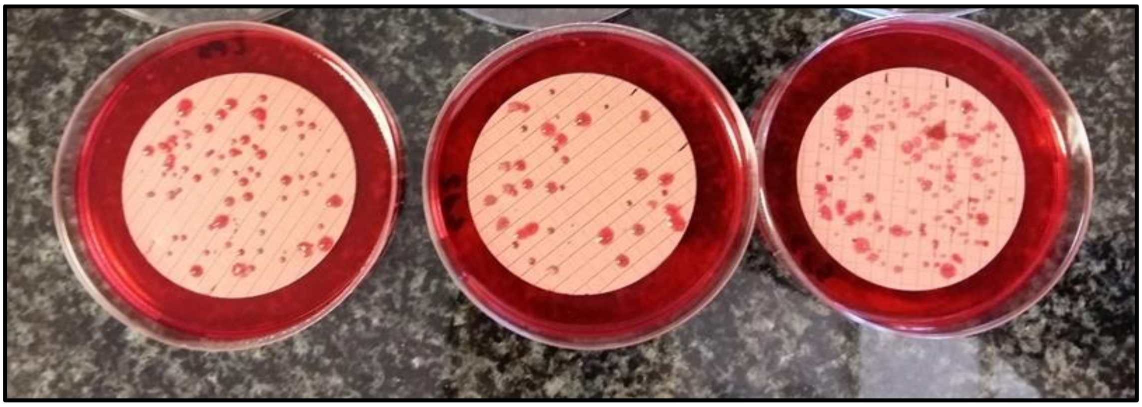

Figure 3.17: Negative for faecal coliform on m-FC agar

3.5.5 Confirmatory tests

To confirm the membrane results for total coliforms, each colony (3 representative numbers of colonies from each plate) was sub-cultured to tubes of Lauryl Tryptose (LT) single-strength (SS) broth and incubated at 35°C for 24 hours. Gas production within this period confirmed the presence of total coliform. Tubes with no gas production after 24 hours were incubated for an additional 24-hour period.

3.5.6 Determination of water quality control

Control water samples from Nzhelele River, and ponds water were analysed using membrane filter technique. Both total coliform bacteria and faecal coliform bacteria were enumerated on Lauryl sulphate broth medium prepared according to the manufacturer’s instructions (Merck, Darmstadt, Germany). Control Water samples were analysed for the presence of total coliform and faecal coliform using the membrane filtration technique. The raw water was diluted up to 10^{-3}, and then a 250 ml of water sample were filtered through a sterile 47-mm- diameter membrane filter inserted in a filtration unit.

The membrane filters were then be placed right side up on the Petri Dish containing an absorbent pad soaked in the culture medium. Plates for enumeration of total coliform bacteria was inverted and incubated at $37^{o}C$ for 24 hours. Metallic green colonies were counted as positive colonies for total coliform bacteria. Faecal coliform bacteria were inverted and incubated aerobically at $44.5^{o}C$ for 24 hours. Dark blue or violet colonies were considered positive colonies for faecal coliform.

3.6 Summary of the chapter

The chapter summarises the materials and methods used in collection and analyses of data for the study. The field work comprised of field survey, questionnaire distribution, soil and water sampling. soil samples were collected from different sites identified by women who practice geophagia. The data for questionnaire analysis included aspects of demographic information, socio-economic and cultural aspects, indigenous knowledge, physico-chemical, mineralogical, geological and chemical aspects, ecological aspects and human health elements associated with geophagic practices have been described in full. The soil samples analysis procedure for detection of presence of geohelminths ova in all 12 soil samples using AMBIC Protocol solution was followed and explained in full. water samples analysis for faecal and total coliform from river water and ponds from Siloam village using membrane filter technique was also explained in full.

CHAPTER 4
RESULTS AND DISCUSSION

Geophagia, practiced by both humans and animals, is defined as the deliberate and compulsive consumption of earthy material or substances such as red, white or grey clay soils (Ekosse and Jumbam, 2010; Norman *et al*., 2015). This habit has been in existence from historical times and is widely practiced across the globe (Abrahams, 2005). Geophagia is being practiced in the united states of America (Boyle and Mackay, 1999; Hunter, 1973; Vermeer and Frate, 1979; Casavale, et al., 2017), Asia including India and China (Hunter, 1973; Utara, 2002; Majorin *et al*., 2017), Australia (Reilly and Henry, 2000), and Europe (Woywodt and Kiss, 2002; Ziegler, 1997). In Africa, geophagia is more common among communities with poor socio-economic status particularly in the sub-Saharan Africa (Abrahams, 2002; 2005; Wilson, 2003). Previous studies revealed that certain communities in South Africa are known to be practicing geophagia (Ekosse *et al*., 2010; Ngole *et al*., 2010) and the soils they consume are different. Among those communities, the rural settlement of Siloam area, Limpopo province is the subject of the study.

4.1 Data from questionnaire: Human geophagia

Data regarding human geophagia was obtained through completion of 283 questionnaires by geophagic participants at Siloam village. The questionnaire was set on the aspects of demographic information, socio-economic and cultural aspects, indigenous knowledge, physico-chemical, mineralogical, geological and chemical aspects, ecological aspects and human health aspects associated with geophagic practices (Appendix 1).

4.1.1 Demographic information of participants from Siloam Village

The study respondents consisted of 283 female villagers drawn from Siloam village. All the 283 (100.0%) respondents were rural dwellers. The majority (68.3%) of the respondents were single, 13.7% were married, 13.3% were living together and 4.7% were divorced. Findings of the survey indicated that 198 (81.5%) of the respondents were not formally employed, hence relied on non-wage earnings and 41 (16.9%) were formally employed.

Table 4.1: Demographic information of the respondents from Siloam Village (n=283)

Location	**Rural**	**Suburban**	**urban**	
N=283	100%	0%	0%	
Sex	Male	Female		
N=283	0%	100%		
Age (years)	18-30	31-40	41-50	More than 50
N=281	74.0%	16.0%	5.7%	3.6%
Marital status	Married	Divorced	Single	Living together
N=278	13.7%	4.7%	68.3%	13.3%
Income Wage	Wage employment	Non-wage employment	other	
N=243	16.9%	81.5%	0.8%	
Occupation	Students	Teacher	Nurse	Other professions
N=96	66.7%	8.3%	6.3%	8.6%

The respondents' age ranged from eighteen (18) years to sixty-five (65) years with a mean age of the sample being twenty-six (26) (Table 4.2). The respondents were mainly drawn from the 18-30 years' age group (74%), with the above 50 years' age group contributing the least proportion (3.6%).

Table 4.2: Descriptive statistics of the respondents' age

N	Minimum	Maximum	Mean	Std. Deviation
281	18.00	65.00	26.12	9.96

Figure 4.1 illustrates the respondents age. As shown the majority of the respondents fell between 18-30 years of age (74.0%). Other studies have indicated that Geophagia is more prevalent among child bearing women which are mostly found between this age group. The figure further shows that the least number of people who participated in the study were 50 years and above.

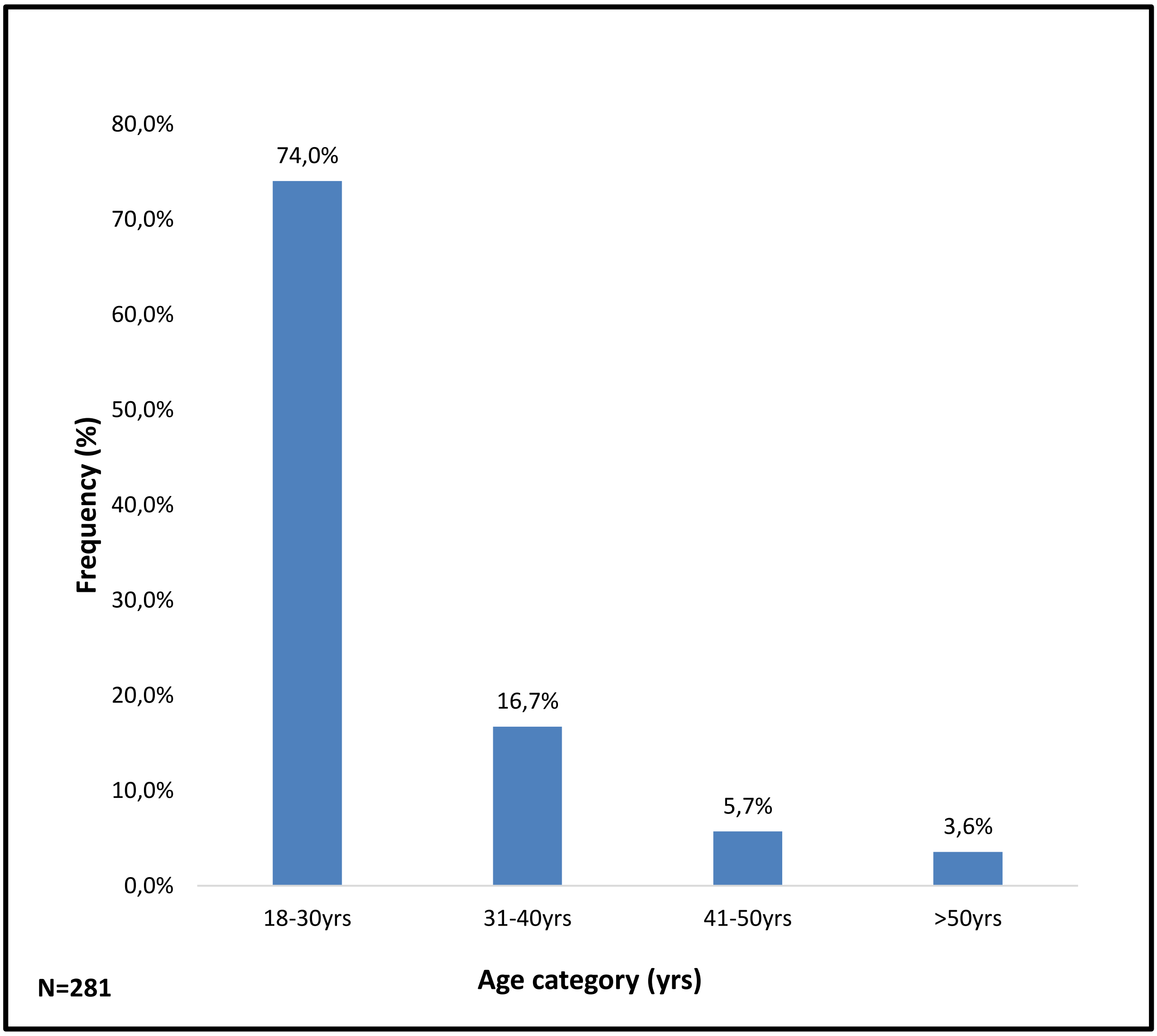

Figure 4.1: Age categories of the respondent

Figure 4.2 shows that the majority of the study respondents, 124 (45.6%) had a secondary level qualification. Also, a significant proportion, 34 (12.5%) had technical qualifications, similar to those who had higher education qualification. The result from this study is in agreement to another study done by Halsted (1968). A study by Peter (2011) also produced similar results where the majority of the participants that consumed soil were in possession of only secondary education (60.38%), primary education (22.68%), tertiary (7.55%) education and followed by those who did not have any formal education (6.60%). In the analysis of these previous studies and this study, it can be seen that the majority of the people who are involved in geophagic practices have at most secondary education or lower. However, it is also important to note that those with higher qualifications are also involved in this practice but to a lesser extent as confirmed by various studies (Peter, 2011 and Msibi *et al*., 2014) including this present study. Thus, as the education level increases, the chance of geophagic practice decreases. Given these results, one can conclude that indeed level of education has a significant impact on the geophagic practices. As the majority of the consumers of soil had secondary qualification, it can be inferred that geophagic consumers in Siloam Villages are sufficiently literate to understand the consequences of geophagic practices.

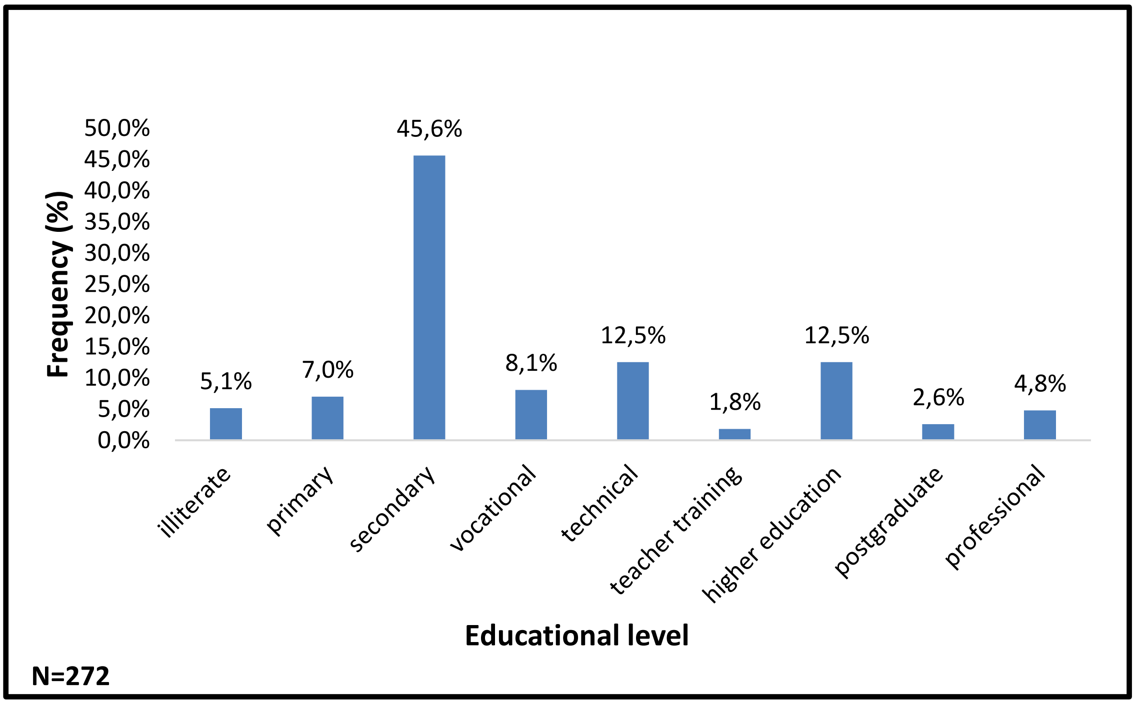

Figure 4.2: Educational level of the respondent

4.1.2 Socio-economic and cultural aspects of geophagia.

The findings of the study revealed that of the 283 respondents, 70.6% practiced geophagia, and 28.0% had never consumed earthy material and 1.4% used to consume earthy material as illustrated in Table 4.3. Of those who indicated that they had consumed soils, the majority (45.2%) indicated that they consumed once a day and 36.7% indicated that they consumed at least more than once per day. Among the respondents 11.7% indicated that they consumed once a week and 6.4% indicated that they consume at least once a month. Consumers of soils in this study have been in the practice for a maximum of 31 years and a minimum of 1 year and the average years of consuming of the respondents was 7.1 years.

One thing that emerged clearly from this study was that most of the respondents had been consuming soils for a lengthy period (at least 31 years), with only 25.9% indicating that they had been consuming soils for 1-2 years. It is clear from the responses that soil consumers crave to eat soil daily (75.3%), even when pregnant (81.8%) (Table 4.3).

Besides soils, most of the participants (85.8%) do not consume any other non-food substances. The few who indicated that they consume non-food substances, 12 (60.0%) said they consume chalk and 8 (40.0%) said they consume ice (Table 4.3). The consumption of ice and chalk is not as regular as that of soils, with half of the respondents (50%) indicating that they consume these non-food substances weekly and approximately one in three (36.4%) saying they consume monthly and approximately one in ten (13.6%) saying they consume daily.

It is also clear from the findings in Table 4.3 that perceptions about the soil-consuming habits differ, with one in four (24.6%) of the respondents indicating that the habit is positively perceived, one in three (32.4%) indicating that it is negatively perceived, and two in five (39.7%) saying they do not know how the behaviour is perceived. More than half of the respondents (52.5%) indicated that the practice of consuming soils is common among community members, whereas (29.5%) are family members who practice geophagia, (39.8%) being their neighbour and (30.7%) is among the friends.

Table 4.3: Socio-economic and cultural aspects of geophagia from Siloam village

Are you presently consuming soil?	yes	no	used to	
N=283	70.7%	27.9%	1.4%	
If yes how often do you consume the soil?	once a month	once a week	once a day	more than once a day
N=188	6.4%	11.7%	45.2%	36.7%
If yes, for how long have you been consuming soil?	1-2yrs	3-5yrs	6-10yrs	>10yrs
N=112	25.9%	34.8%	18.8%	20.5%
Do you crave to eat soil?	once a month	weekly	daily	only when pregnant
N=186	5.9%	9.1%	75.3%	9.7%
When pregnant how often do you consume the soil?	monthly	weekly	daily	
N=77	3.9%	14.3%	81.8%	
Do you consume other none food substances?	yes	no		
N=155	14.2%	85.8%		
If yes name the substance	chalk	ice		
N=20	60.0%	40.0%		
How often do you consume this substance?	daily	weekly	monthly	
N=22	13.6%	50.0%	36.4%	
How much of the substance (handfuls) do you consume	daily	weekly	monthly	
N=20	15.0%	45.0%	40.0%	
Do other people know that you consume clay?	yes	no	don't know	
N=184	63.0%	15.2%	21.7%	
If yes who are aware?	family members	extended family	friends	other
N=127	55.9%	7.1%	35.4%	1.6%
How do people perceive this habit of eating non-food substances	positive	negative	indifferent	don't know
N=179	24.6%	32.4%	3.4%	39.7%
Is this practice common among certain members of the community?	yes	no	don't know	
N=179	52.5%	3.4%	44.1%	
If yes, specify	family member	friends	neighbours	
N=88	29.5%	39.8%	30.7%	

Figure 4.3 shows the reasons mentioned by participants for consuming soil. As indicated in Figure 4.3, the major contributing factor for consuming soil was revealed to be cravings (58.1%). Thus, the majority of geophagic consumers in Sialom village consume soils because of the burning or insatiable desire for it. Phakoago (2017) also found simialr results that the majority of the participants said that the main reason for consuming soil was cravings in Ha-Nchabeleng village. The second most reason for consuming soil was found to be pregnancy (20.5%) and some reasons are unknown. Contrary to this, Msibi *et al*. (2014) findings showed that pregnancy was the major reason for consuming soil. There is also a significant number (14.9%) of people who does not know why they consume soil. Given these findings, one might assume that perhaps pregnancy stimulates the cravings or desire to consume soil. Figure 4.3 further shows that a very low number of geophagic consumsers in this village attach this practice to rituals (0.5%), medical value (0.5%) and or dietary (0.5%) purposes, this is similar to other studies elswhere such as those of Perridge *et al*., 2010; and Peter, 2011).

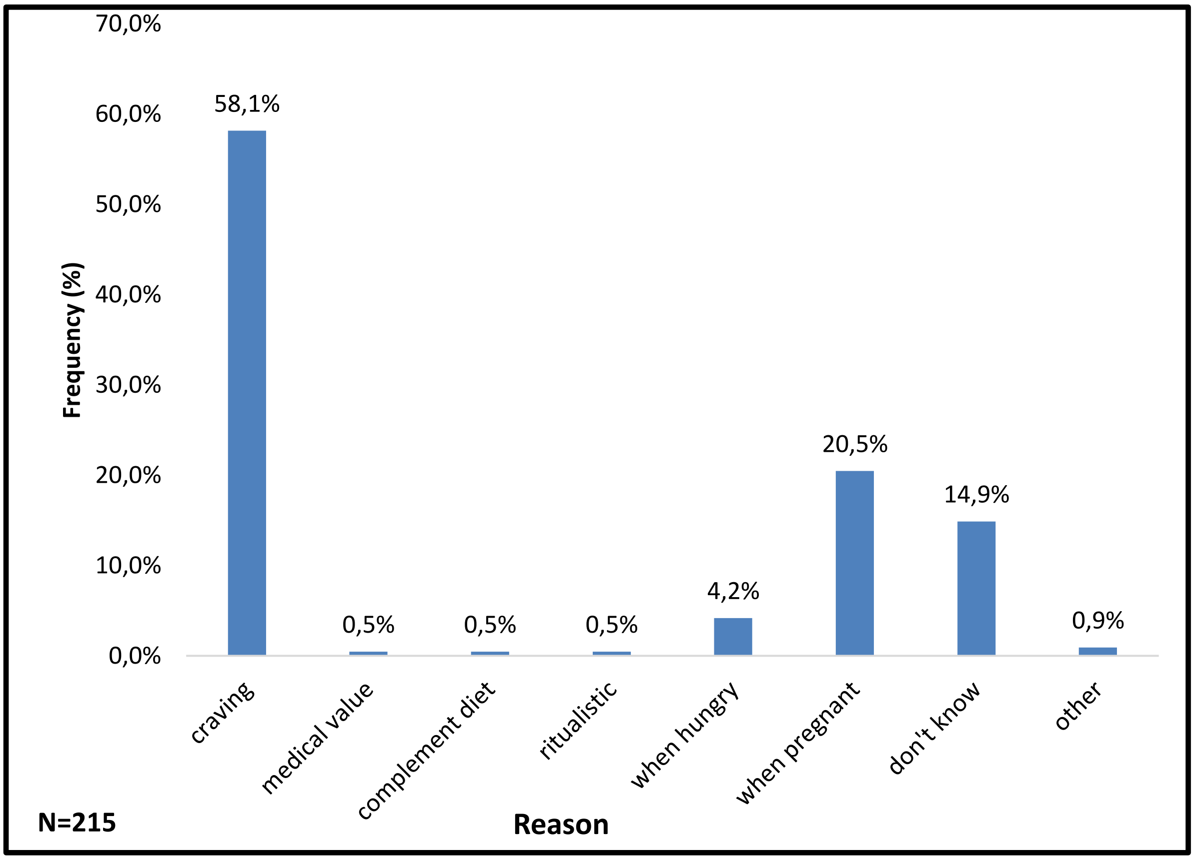

Figure 4.3: Reasons for consuming soils

Moreover, in this study, the reasons for craving soils were tested and the results were depicted in Figure 4.4. Pregnancy (46.0%) and experimenting (44.7%) were found to be the major reasons why people in Siloam village crave and consume soils. Among the other reason for craving soils, nausea and constipation were found to be the least reason why people in Siloam village consume and crave soils as shown in Figure 4.4. Craving is common among pregnant woman where they crave non-food subsistence. This study showed that indeed pregnancy was making women crave for soil. However, this was in a way similar to a study conducted by Msibi et al., (2014) that revealed consumers ingested soil because of pregnancy. Additionally, craving was also reported by interviewees in the study conducted by Songca et al., (2010) in Free State and Limpopo.

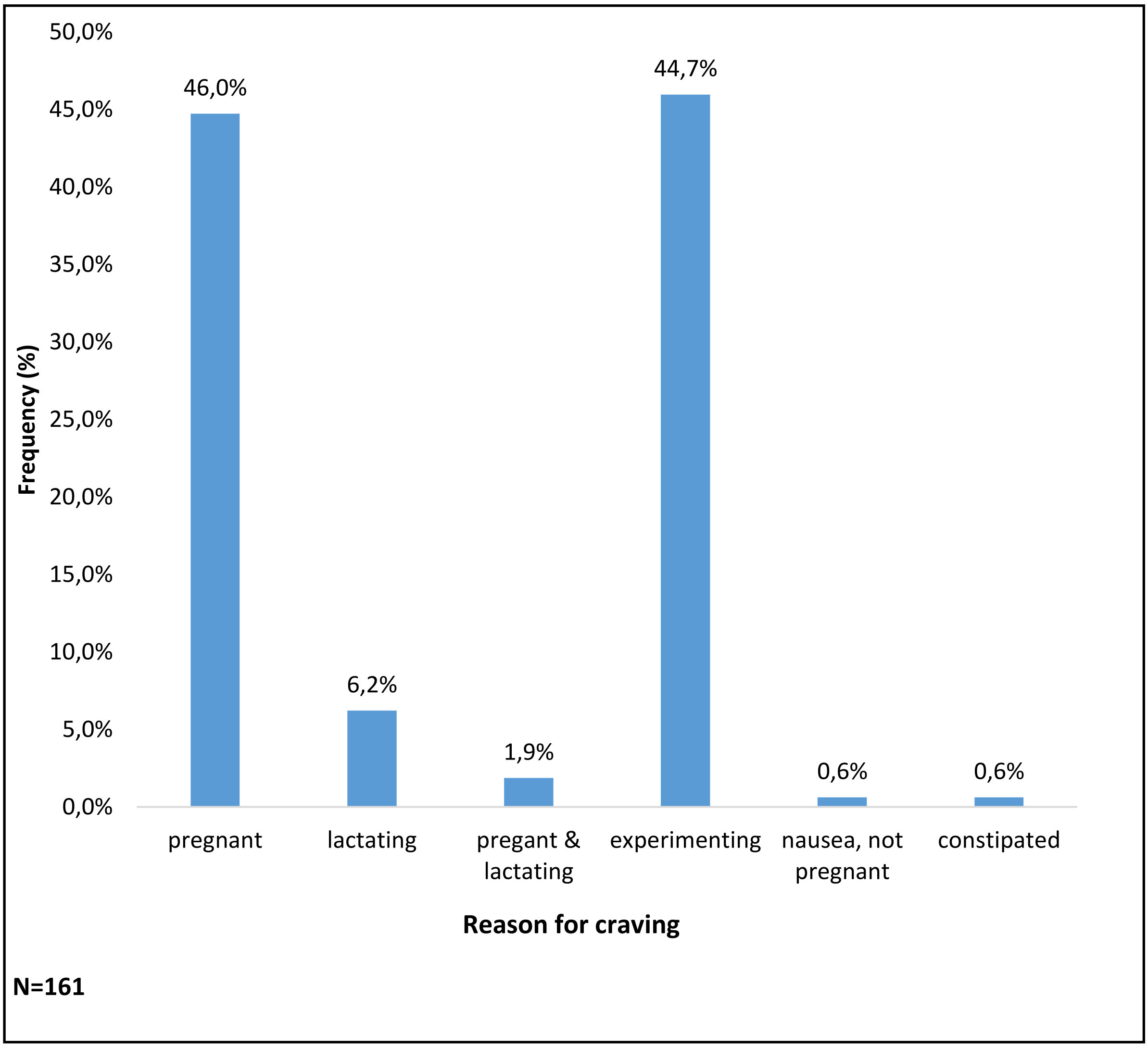

Figure 4.4: Reasons for craving soils

4.1.3 Indigenous knowledge

It is clear from the respondents that clay (74.5%) is the most commonly consumed substance, with almost all (97.2%) of the respondents indicating that they consumed the material dry. Phakoago (2017) found contradictory results, that soil was most preferred to clay. The traditional names given to consumed substances are; *mavu a yellow substance*, *munyaka*, *mutshenzhe*, *mutwa* and *vumba*. *Munyaka* with almost two in five (38.0%) respondents, is the most popular substance, followed by *mutwa* with one in four consumers (25.0%), then *vumba* (18.0%), *mutshenzhe* (13.0%) and *mavu a yellow* (6.0%) as depicted in Table 4.4.

Furthermore, the results of this study, like the ones found by Ekosse *et al.,* (2008) shows that the majority of the respondents obtain these substances mainly from the wild (64.1%), followed by the roadside (12.0%), purchasing (11.4%), yard (6.5%), pond-bed (3.8%), tree (1.6%) and given to (0.5%) (Table 4.4).

The most commonly bought consumed substance is *mavu a yellow*, as indicated by almost half the respondents (50%). The findings indicated that the price range for these soils range from R5 to R10 of the South African Rand, with almost two in five saying they buy for R5 and R10 per handful (Table 4.4).

The respondents were further asked to state the reasons for choosing a specific colour for their geophagic practices and the results were illustrated in Table 4.4. Taste (73.8%) was the major influencing factor to choosing a specific colour, followed by easiness of accessibility (20.1%). Similar, to a study by Perridge (2010), where Geophagist from the investigated district of Thabo Mofutsanyane generally consume clayey soil because of its taste.

Results, in Table 4.4 further show that this material is normally stored in plastic bags. Three in four (76.9%) of the respondents indicated that length of storage differs, but the results showed that most geophagic consumers normally kept this material for less than thirty days (92% of the respondents). Contrary to a study by Perridge (2010) where respondents (vendors) stored their clayey soils in plastic containers for two to fourteen days before it was purchased by geophagic customers.

Table 4.4: Indigenous knowledge

What substances are consumed?	soil	clay	soil from termites				
N=192	20.8%	74.5%	4.7%				
How are substances consumed?	wet	dry					
N=107	2.8%	97.2%					
What are the traditional names of substances consumed	mavu (a yellow)	munyaka	mutshenzhe	mutwa	vumba		
N=100	6.0%	38.0%	13.0%	25.0%	18.0%		
Where do you obtain the substance	from the wild	buy	given	pond bed	road	tree	yard
N=184	64.1%	11.4%	0.5%	3.8%	12.0%	1.6%	6.5%
If you buy, give the brand name	mavua yellow	munyaka	yellow clay	Yellowsoil			
N=6	50.0%	16.7%	16.7%	16.7%			
If you buy indicate the price per handful	R2	R4	R5	R5-R10	R10		
N=14	7.1%	7.1%	35.7%	7.1%	42.9%		
What is the colour of substance consumed	reddish	whitish	yellowish	brownish	khaki	purplish	
N=188	38.8%	1.1%	31.4%	8.0%	1.6%	19.1%	
Why do you prefer to consume the specific colour type	taste	easily accessible	smell				
N=149	73.8%	20.1%	6.0%				
Method of storage of substance	container	plastic bag					
N=39	23.1%	76.9%					
Length of storage	2-7 days	8-14 days	15-30 days	>30 days			
N=25	40.0%	4.0%	48.0%	8.0%			

In a number of studies, the soil colour preference demonstrated by geophagist when they select clayey soils for consumption, was recorded (Nchito, *et al*., 2004; Ekosse, *et al*., 2010; Ngole, *et al*., 2010). Colour selection for geophagic soils vary with individuals. Figure 4.5 shows the colour of the soil preferred by the geophagic consumers of Siloam village. As shown, the majority of the respondents preferred reddish (38.8%) and yellowish (31.4%) soils. Interestingly, these results are in agreement with the study conducted in Limpopo and Free State by Songca *et al*., (2010) where most people preferred red soils. It is also in agreement with Ekosse *et al*., (2010) findings, where it was found that yellowish colour was among the most preffered. The results further revealed that one in five (19.1%) preferred purplish soils, with a very small proportion saying brownish (8.0%), khaki (1.6%) or whitish (1.1%).

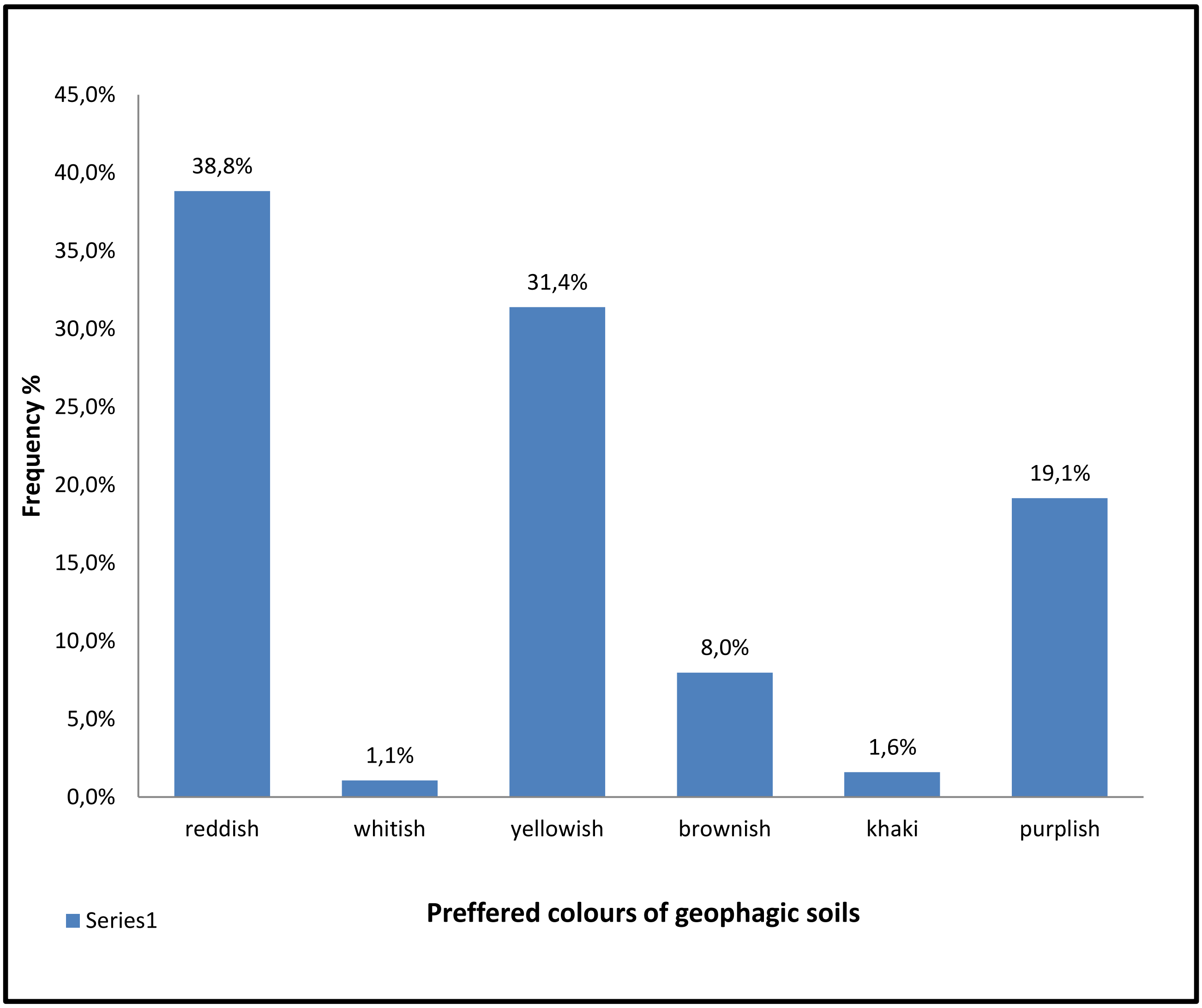

Figure 4.5: Preferred colour of geophagic soil consumed by respondents.

4.1.4 Physico-chemical, mineralogical, geological and chemical aspects

The consumed material by the respondents in Siloam village is mainly obtained from the riverbed (35.5%), termitaria (32.7%) and valley (23.6%) as illustrated in Table 4.5 and Figure 4.6. Buying, from the roadside, hill/mountain and trees were other sources where geophagic material were obtained with less than one in ten (<10%) popularity amongst these (Table 4.5). Of the geophagic substances collected were from a mound, two in five (43.8%) indicated that they collect it from the surface of the mound, one in three (31.3%) said it did not matter, about one in five (18.8%) said they collect from inside the mound. These results are similar to findings conducted elsewhere (Geissler et al., 1998; Reilly and Henry, 2000; Allport, 2006; Ekosse *et al*., 2010; Msibi *et al*., 2014).

The most commonly used method for collecting the geophagic soils is digging, with three in five respondents (59.2%). Indicating as such other minor, but common collecting practices are hand-grabbing (19.1%), scrapping (11.2%) and hand-picking (10.5%). Respondents indicated that they normally dig for up to 20 to 30 cm, with three in five (63.1%) respondents indicating so (Table 4.5). The respondents further indicated that the feeling of the material when collected did not matter (83.7%) and just above half of the respondents (55.7%) said that they collected the material dry. In addition, one in three (35.0%) said it did not matter how the material feel on collection.

Geophagic soil often undergoes some degree of processing prior to consumption, which may include pounding, grinding, slurring and various heat treatments (Ekosse, *et al*., 2010). The respondents in Siloam village reported that most of these consumed geophagic substances are neither processed before consumption (96.1%) nor heat treated before consumption (73.7%) according to the responding participants as shown in Table 4.5. In cases where these substances are treated, baking is the most common form of heating with about (84.0%) of the respondents responded saying they bake, (14.0%) others saying that they burn and only (2.05%) saying that they boil.

Table 4.5: Physico-chemical, mineralogical and chemical aspects

Where does the substance you consume come from	**Hill/mountain**	**river bed**	**termitaria**	**valley**	**buy**	**road**	**tree**
N=110	1.8%	35.5%	32.7%	23.6%	1.8%	3.6%	0.9%
If from a mound, where specifically on the mound is substance collected	surface	inside mound	doesn't matter	not sure			
N=16	43.8%	18.8%	31.3%	6.3%			
Are substances obtained close to rocks	yes	no	not sure				
N=110	30.0%	59.1%	10.9%				
If yes, what is the type of rock	very hard	hard	soft				
N=35	2.9%	31.4%	65.7%				
How is the substance collected	digging	hand grabbing	scrapping	hand picking			
N=152	59.2%	19.1%	11.2%	10.5%			
If digging how deep	0-10cm	10-20cm	20-30cm				
N=65	15.4%	21.5%	63.1%				
How does the substance feel when collected?	gritty	silky	powdery	doesn't matter	don't know		
N=98	5.1%	4.1%	5.1%	83.7%	2.0%		
When are substances collected?	wet	dry	doesn't matter				
N=140	9.3%	55.7%	35.0%				
If collected wet, how does the substance feel?	very sticky	sticky	very soapy	neither			
N=9	11.1%	44.4%	33.3%	11.1%			
Are substances processed before consumption?	yes	no	sometimes				
N=154	0.6%	96.1%	3.2%				
Is there any heat treatment of substance before consumption?	yes	no	sometimes				
N=179	25.7%	73.7%	0.6%				
If yes specify type of heat treatment	baking	boiling	burning				
N=50	84.0%	2.0%	14.0%				

Respondents in Siloam Village collected geophagic soil primarily from riverbeds (35.5%). Similarly, in Kenya, soft geophagic clays ingested by school children are obtained from river beds (Geissler *et al*., 1998). Unfortunately, these clays are usually loaded with water borne bacteria and pathogens. Some respondents also indicated they obtain their geophagic soil from hill/mountains, roads, trees, valleys, termitaria and etc. (Figure 4.6). These results are similar to findings conducted elsewhere (Geissler *et al*., 1998; Reilly and Henry, 2000; Allport, 2006; Ekosse *et al*., 2010; Msibi *et al*., 2014). Only 1.8% respondents reported that they buy their soil, similar to a study by Ekosse *et al.,* 2010, where those in urban areas (38%) from Polokwane and (65%) from Mangaung obtain their geophagic materials from other sources such as purchases from vendors.

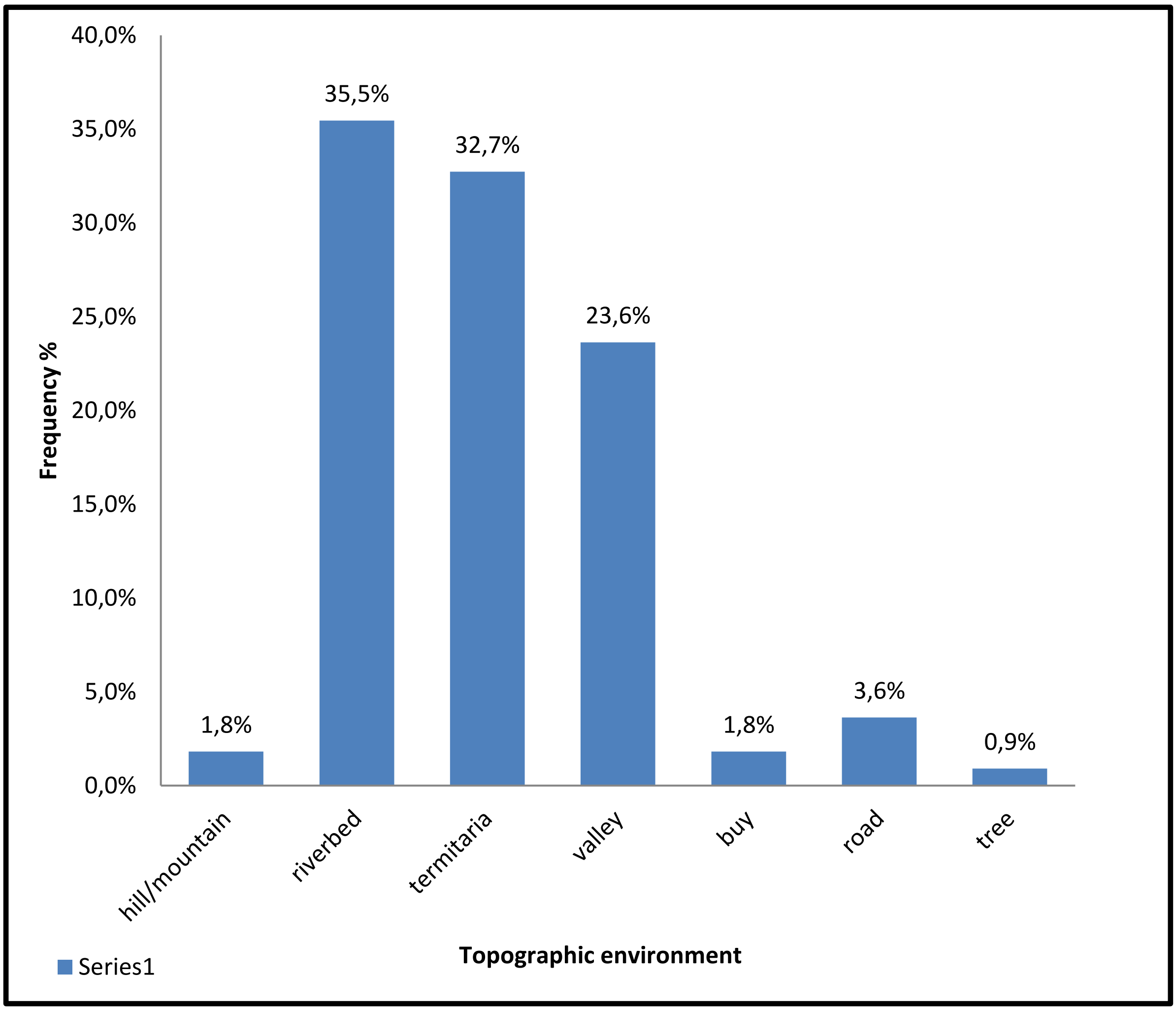

Figure 4.6: Type of geomorphological environment where geophagic soils are obtained in the study area.

4.1.5 Ecological aspects

The findings of the survey as shown in Table 4.6, shows that the respondents from Siloam Village indicated they collect soil from trees (51.5%) and mounds (48.5%) and the majority of the participants (66.7%) preferred to collect soil from flat terrain. Respondents, who collect this geophagic material from a mound, prefer to consume a newly constructed substance (77.4% of the respondents) (Table 4.6). Moreover, most of the respondents (76.5%) indicated that they have a preference for a particular tree from which they collect their geophagic material and the most preferred tree was the mango tree with (69.2%).

Table 4.6: Ecological aspects

If you consume substance from a termitaria, from which one	**mound**	**tree**		
N=33	48.5%	51.5%		
What is the shape of the mound	dome shaped	flat topped		
N=6	83.3%	16.7%		
Do you prefer to consume the substance when	newly constructed	old	doesn't matter	
N=31	77.4%	12.9%	9.7%	
What type of terrain do you normally find these mounds?	flat	hilly	valley	
N=6	66.7%	16.7%	16.7%	
Do you collect the substance from	mound	base of mound	distance from mound	
N=18	88.9%	5.6%	5.6%	
If substance is collected from a tree, do you prefer it from a particular tree	yes	no	doesn't matter	
N=17	76.5%	17.6%	5.9%	
If yes, name the preferred tree type	avocado	mufula	mugwavha	mango
N=13	7.7%	15.4%	7.7%	69.2%

Table 4.6 clearly shows that geophagic soils from a tree (51.5%) are much more popular. The respondents showed to have particular trees where soils were collected. Of the preferred trees, respondents indicated that they prefer geophagic soils from *munngo* tree (69.2%), followed by *mufula* (15.4%), *mugwavha* (7.69%) and *muafukhada* (7.69%) (Figure 4.7). Siloam village is dominated by munngo tree which might be the reason why most of the respondents prefer it.

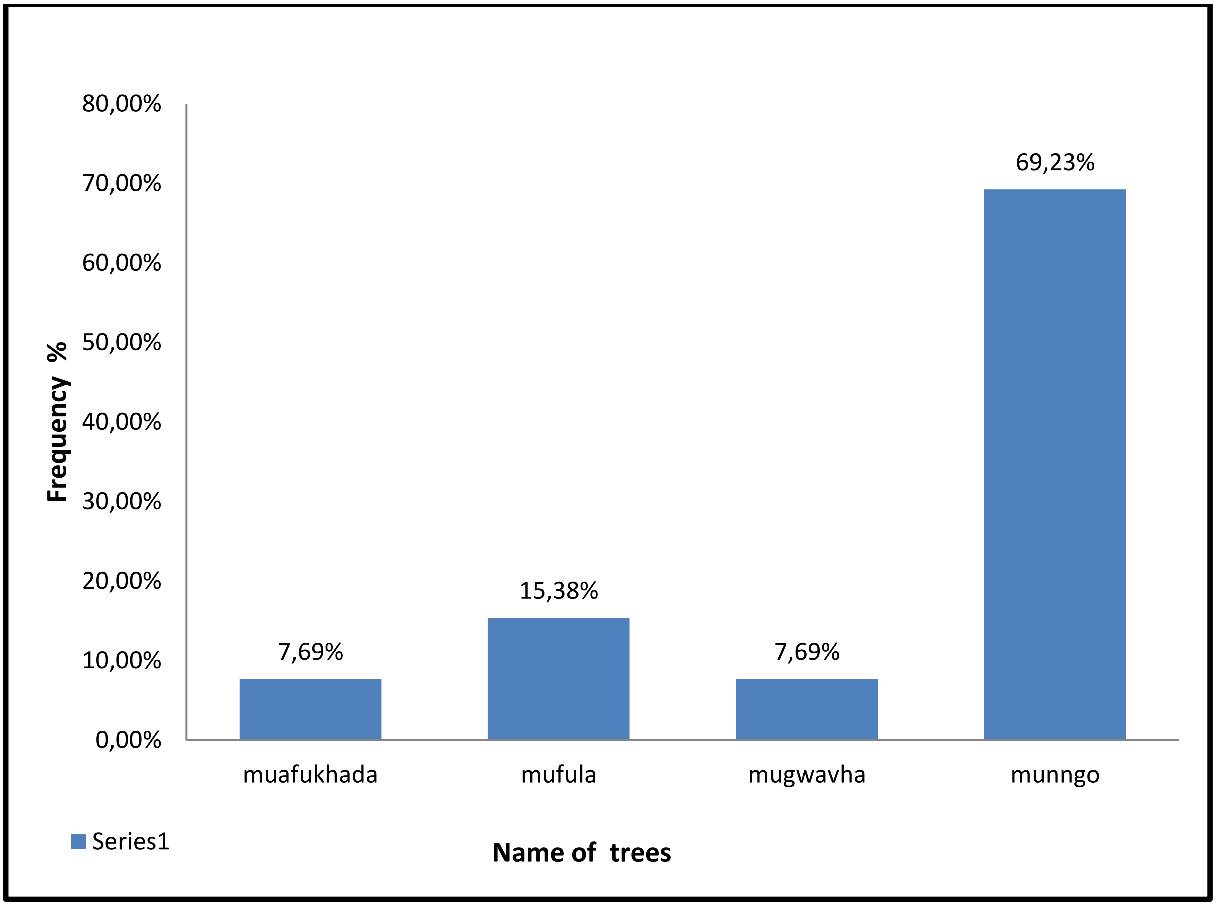

Figure 4.7: Trees preferred by geophagic consumers from the study sites.

4.1.6 Human health associated with geophagia

In addition, the study tested the perspectives of the geophagic consumers on their knowledge about the consequences of their geophagic practices. Results in Table 4.7 shows that the majority of the respondents (71.1%) who consume soils are not aware that the substances they consume could be harmful to their health. Table 4.7 further shows that a significant number of the participants were aware of the health hazards associated with geophagic practices such as constipation (30.0%), tooth decay

(8.3%), poisoning the body (21.7%) and abdominal pains (40.0%). Surprisingly and shockingly, almost all (99.5%) of the respondents were completely unaware of the contents of the substances they consume as depicted in Table 4.7.

Table 4.7: Human health aspects

Do you know that the substance could be harmful to your health	**yes**	**no**				
N=187	28.9%	71.1%				
If yes, in what sense	constipation	abdominal pains	poison the body	tooth decay		
N=60	30.0%	40.0%	21.7%	8.3%		
Were you ever operated upon for stomach problems?	yes	no				
N=186	0.5%	99.5%				
Are you aware of the harmful substances/ parasites that may be present in the substance?	yes	no				
N=186	26.9%	73.1%				
Do you know the content of the substance	yes	no				
N=184	0.5%	99.5%				
Why do you consume substance?	protection against infection	craving	habit	smell	other	don't know
N=109	0.9%	3.7%	1.8%	1.8%	0.9%	90.8%
Do you often get infected (common cold, flu etc)	once a month	once in 3 months	twice per year	yearly		
N=187	3.7%	18.2%	31.6%	46.5%		
Do you ingest these substances when infected	yes	no	sometimes			
N=179	16.8%	67.0%	16.2%			
Do you experience chronic illnesses	yes	no				
N=183	20.8%	79.2%				
Number of still born	none	one	two			
N=50	96.0%	2.0%	2.0%			

Reasons advanced by geophagic soil consumers to justify their belief that the soil they were ingesting could be harmful vary from one individual to another. Majority of the respondents admitted that eating soil was not helpful because it resulted in many health problems. Respondents from Siloam village (40%) indicated that abdominal pains could be the reason why soil is believed to be harmful and 30% believed that constipation could be caused by consuming the soil (Figure 4.8).

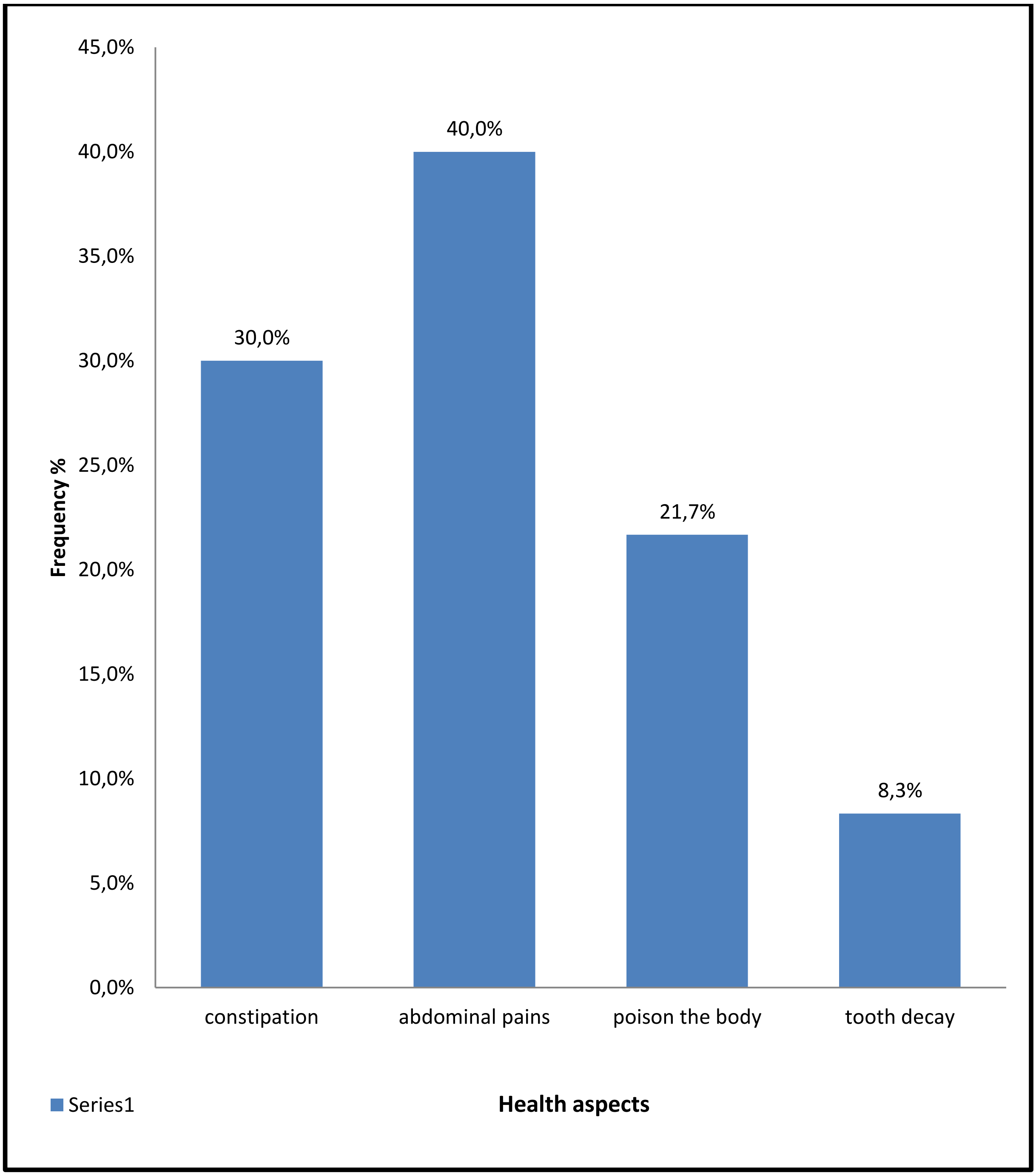

Figure 4.8*:* Health effects of soil ingestion from studied areas.

The majority of the respondents (eight in ten, 79.2%) do not experience chronic illnesses. Of those who experience chronic illnesses, Figure 4.9 shows that headaches (46.9%) are the most common illness, followed by coughs (14.3%), muscle pains (14.3%), and chest pains (12.2%). Other ailments are less common, with less than one in ten (10.0%). The results show that the respondents immune system is not compromised as consumption of the contaminated soils may impart serious health consequences on especially immune-compromised individuals in poor communities.

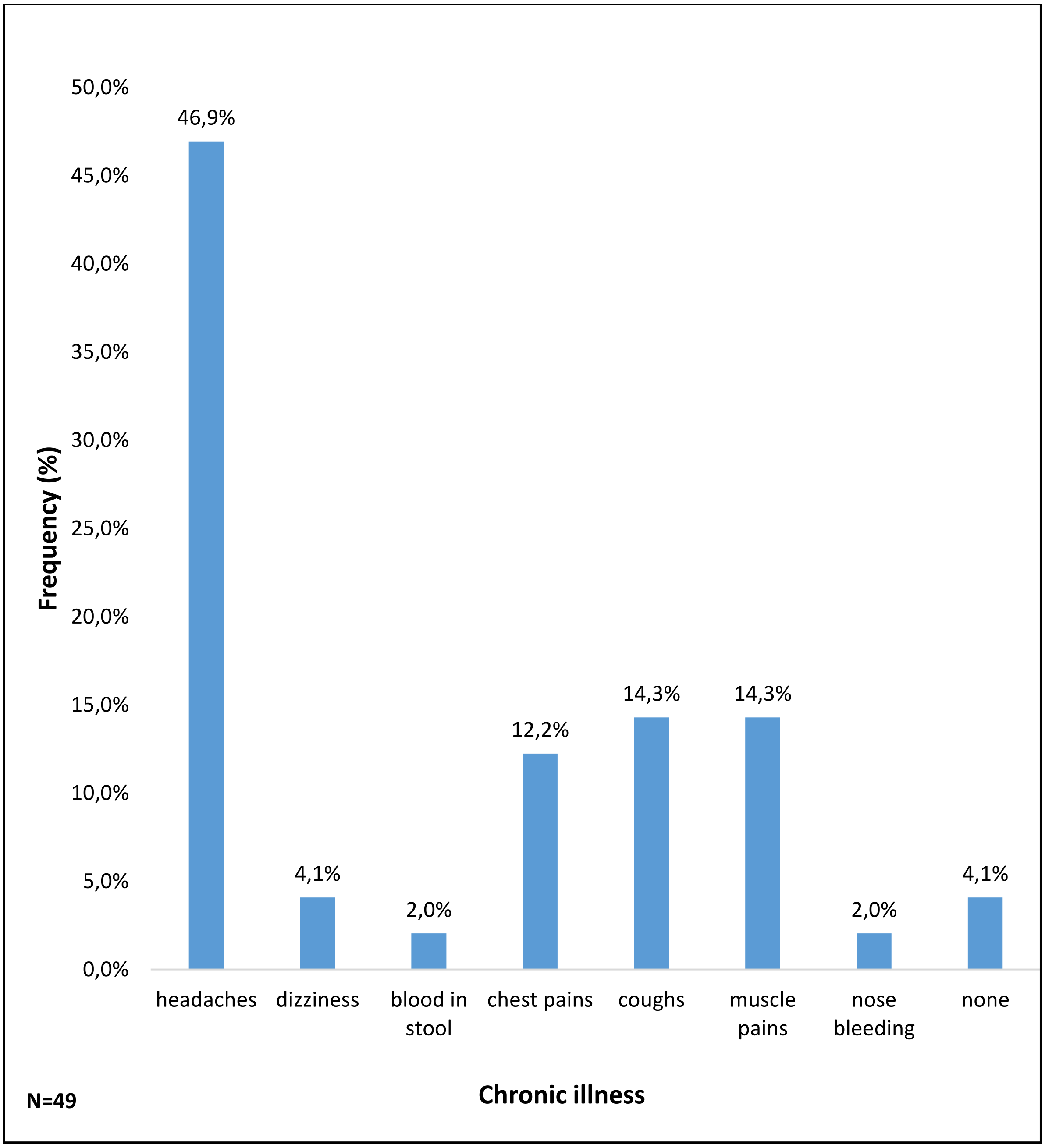

Figure 4.9: Chronic illnesses

4.1.7 Control group analyses.

The control group was drawn from 83 non-geophagic consumers and compared with geophagic consumers from the area studied (Table 4.8). The control group contained only women from the age of 18 and above, similarly to the experimental group. The control group was drawn from the rural settlement of Nzhelele area, Siloam village.

Table 4.8 Demographic, socio-economic and cultural aspects of geophagic group and control group.

Gender	**Male**	**Female**		
% geophagic group (n=186)	0%	69.1%		
% control group (n=83)	0%	30.9%		
Age (years)	18-30	31-40	41-50	> 50
% geophagic group (n=194)	67.8.0%	20.0%	5.7%	3.6%
% control group (83)	28.9%	17.8%	4%	1.6%
Marital status	Married	Divorced	Single	Living together
% geophagic group (n=194)	10.3%	9.2%	67.9%	12.6%
% control group (n=83)	29.7%	20.8%	45%	4.5%
Income Wage	Wage employment	Non-wage employment	other	
% geophagic group (n=162)	75%	25.0%	00.0%	
% control group (n=80)	40%	35.0%	25.0%	
Educational level	Illiterate	Primary	Second ary	tertiary
% geophagic group (n=127)	71.4%	81.3%	66.1%	64.7%
% control group (n=61)	28.6%	18.8%	33.9%	7.8%
Do you experience any chronic illness?	Yes	No		
% geophagic group (n=152)	27.3%	72.7%		
% control group (n=22)	6%	94%		

Chi-square (χ2) test was used to associate age, income source and educational level with the practice of consuming soils. The $p<0.05$ was considered significant. Chi-square (χ2) analyses revealed a significant association of age with consuming soils ($p<0.05$), while there was no association of income source ($p>0.05$) and educational level ($p>0.05$) with consuming soils (Table 4.9). A lower proportion of Youth (67.8%) indicated that they consume soils, compared to mature adults (85.4%) and the elderly (50yrs +) (100.0%).

Table 4.9: Factors associated with geophagia

	Chi-square	df*	p-value
Income source	3.706[a]	2	.157
Educational level	2.508[a]	2	.285
Age	8.524[a]	2	.014[†]

*df=degree of freedom, [†]statistically significant

Chi-square (χ2) test was also used to associate knowledge on the harmful nature of the substance, frequency of getting infections and experiencing chronic illnesses with frequency of consuming soils. The $p<0.05$ was considered significant. Chi-square (χ2) analyses revealed that there was no association of knowledge on the harmful nature of the substance ($p>0.05$), frequency of getting infections ($p>0.05$) and experiencing chronic illnesses ($p>0.05$) with frequency of consuming soils (Table 4.10).

Table 4.10: Health impacts of geophagia

	Chi-square	df*	p-value
Do you know that the substance could be harmful to your health	.803[a]	2	.669
Do you often get infected (common cold, flu etc)	.780[a]	4	.941
Do you experience chronic illnesses	.610[a]	4	.962

*df=degree of freedom, [†]statistically significant

4.2 Presence of geohelminths ova in geophagic soils

Geophagic consumers have different sites where they collect their soils. The study group was drawn from sites where geophagia was extensively used and very common, whereas the control site was drawn from sites where geophagia was not practiced in the study area. A total of twelve (12) geophagic soil samples including the control group collected were analysed for the presence of Geohelminths ova (Table 4.11).

Table 4.11: Geophagic Soil Samples description

Sample site number	Location Name	Geophagic Coordinates	Description colour of the soil samples
Site 1	Siloam Village	22°53´40´´S, 30°11´34´´E	Yellowish
Site 2	Siloam Village	22°53´42´´S, 30°11´30´´E	Brown
Site 3	Siloam Village	22°53´18´´S, 30°11´05´´E	Purplish
Site 4	Siloam Village	22°53´23´´S, 30°11´17´´E	Yellowish
Site 5	Siloam Village	22°53´40´´S, 30°11´34´´E	Reddish
Site 6	Siloam Village	22°53´43´´S, 30°11´24´´E	Yellowish
Site 7	Siloam Village	22°53´25´´S, 30°11´13´´E	Reddish
Site 8	Siloam Village	22°53´47´´S, 30°11´31´´E	Reddish
Site 9, (control)	Siloam Village	22°53´41´´S, 30°11´15´´E	Reddish
Site 10, (control)	Siloam Village	22°53´57´´S, 30°11´29´´E	Reddish
Site 11, (control)	Siloam Village	22°53´12´´S, 30°11´27´´E	Yellowish
Site 12, (control)	Siloam Village	22°54´42´´S, 30°12´34´´E	Reddish

Colour is the first diagnostic parameter and most important criterion used by geophagic consumers to determine suitability of soil for consumption (Ekosse and Anyangwe, 2012). Most of the respondents in this study preferred reddish (38.8%) and yellowish (31.4%) soil and the reason given was the taste. Table 4.11 shows different geophagic soil colours preferred by geophagic consumers.

Of all the twelve (12) soil samples, including the control soil samples collected in this study were analysed for the presence of Geohelminths ova using the Ammonium Bicarbonate (AMBIC) protocol, the results revealed the absence of geohelminths ova. This result is similar to a study conducted on geophagic pregnant women from Pemba, no geohelminths ova were detected in any of the geophagic materials analysed (Young, *et al*., 2007). Also, the study conducted by Perridge (2010) revealed the absence of parasitic nematode ova (geohelminths ova) from all the geophagic materials analysed.

This is surprising as there is a practice of open defecation in the study area which is usually associated with geohelminths infection. In a study conducted among primary school children in western Kenya, researchers established a significant association between geophagia and the infection intensity of *A. lumbricoides*, as well as *T. trichiura* (Geissler, *et al*., 1998). It was found that these communities would regularly defecate behind termitaria of which soil from the mound crust was then later consumed by the children, increasing the risk of ingesting faecal contaminants (Geissler, *et al*., 1998). In the present study there were also a number of pigs running around which are mostly the host of geohelminths ova. Since the adult stages of these worms reside in the intestine and pigs are known to have worms in their system, there was the expectation of them present in the environmental media.

Contrary to the findings of this study, numerous studies have indicated that geophagic soils may contain geohelminths transferred to humans through soil consumption. Due to the soil-eating habits, geophagic pregnant women from Kenya had an increased risk for geohelminth infection and especially *A. lumbricoides* infection, which may impact negatively on their health (Luoba, *et al*., 2004; Luoba, *et al*., 2005). This is corroborated by a study on Tanzanian pregnant women where an association between geophagia and A. *lumbricoides* infection was discovered (Kawai, *et al*., 2009). Furthermore, other studies found that African children are at an increased risk of acquiring geohelminths infection, commonly A. *lumbricoides* and *T. trichiura*, as a result of eating soil (Glickman, *et al*., 1999). A higher prevalence of A. *lumbricoides* infection in geophagic school children from KwaZulu-Natal (South Africa), who collect their soil from termitaria, was also reported (Saathoff, *et al*., 2002).

Another study of the Prevalence and Risk Factors of Geohelminth Infections among Primary School Children in Ebenebe Town, Anambra State, Nigeria revealed that a 53.6% geohelminths egg content from the study environment were detected and this comprised eggs of *Ascaris, hookworm* and larvae of *Strongyloides* species. Since the adult stages of these worms reside in the intestine, the presence of the eggs in soil is indicative of faecal pollution. This is proved by the fact that Umuogbuefi primary school which had the highest prevalence of geohelminths in the environment does not have toilet facilities. The pupils normally defecate in the nearby bush surrounding the school (Chukwuma, *et al*., 2009)

However, Geophagic consumers in Siloam village are not at risk of acquiring geohelminths infection. It was found no geohelminths ova, which may be of potential risk to human health, were detected in these soils. However, geophagic consumers may be exposed to various other potentially hazardous biological and non-biological soil contents. Some of these health hazards include heavy metals and also human pathogenic bacteria, viruses and other parasites which often originate from faecal contaminated water and soils.

A study by Perridge (2010) found numerous other non-ova biological materials demonstrating the rich biodiversity within all the samples. These biological materials comprised of fungal structures, mites and various nematode larvae. Geophagic consumers from Siloam village must continue with baking of their geophagic material before consumption as they reported during the study that for processed material, the preferred method was baking, as it might minimise the toxic bacteria and other harmful substance found in soil.

4.3 Microbiological assessment of river and pond water samples

The study further tested twelve (12) water samples from Nzhelele River and water ponds around Siloam village for the presence of faecal and total coliforms using the Membrane Filter Technique, the findings of the study are shown in Table 4.12. The analysis applied a triplicate approach. The microbiological parameters used to determine microbiological analysis of water are total coliforms and faecal coliforms/E.coli as depicted in Table 4.12.

Table 4.12: Microbiological analysis of Water Samples at Nzhelele River

Sample name	Faecal coliform/E.coli (cfu/ml)	Total coliform (cfu/ml)
Site 1, Pond 1, Siloam	5.88×10^3	7.24×10^3
Site 2, Pond 2, Siloam	TFC	TFC
Site 3, Nzhelele river	2.78×10^3	8.27×10^3
Site 4, Nzhelele river	1.09×10^3	6.53×10^3
Site 5, Nzhelele river	4.07×10^3	3.23×10^3
Site 6, Nzhelele river	TFC	ND
Site 7, Nzhelele river	TFC	TFC
Site 8, Nzhelele river	TFC	TFC
Site 9, Pond 3, Siloam (control)	6.07×10^3	4.53×10^3
Site 10, Nzhelele river, upstream (control)	ND	ND
Site 11, Nzhelele river, downstream (control)	ND	ND
Site 12, Nzhelele river (control)	3.45×10^3	3.53×10^3

CFU=Colony Forming Units, **TNTC**=Too Numerous to Count, **TFC**=Too Few to Count, **ND**=Not Detected.

4.3.1 Faecal coliform bacteria in River and ponds water sample

The Line graph in Figure 4.10 represent the number of faecal coliform found in different sites along the river under investigation and some ponds. As shown in Figure 4.10, these sites had varied levels of faecal coliform in all the experimental sites (sites 1, 2, 3, 4, 5, 6, 7 and 8). Site 1 and 5 had the highest levels of 5.88 x 10^3 and 4.07 x 10^3, respectively. Furthermore, site 6, 7 and 8 had faecal coliform bacteria, however, they were too few to count, thus, there was negligible risk of microbial infection for these three sites.

A study conducted by Ejechi and Ejechi (2007) found that most public water sources were generally contaminated and showed presence of faecal coliforms. These results are similar to the results of this study. However, in this study not all sites tested had the presence of faecal coliform.

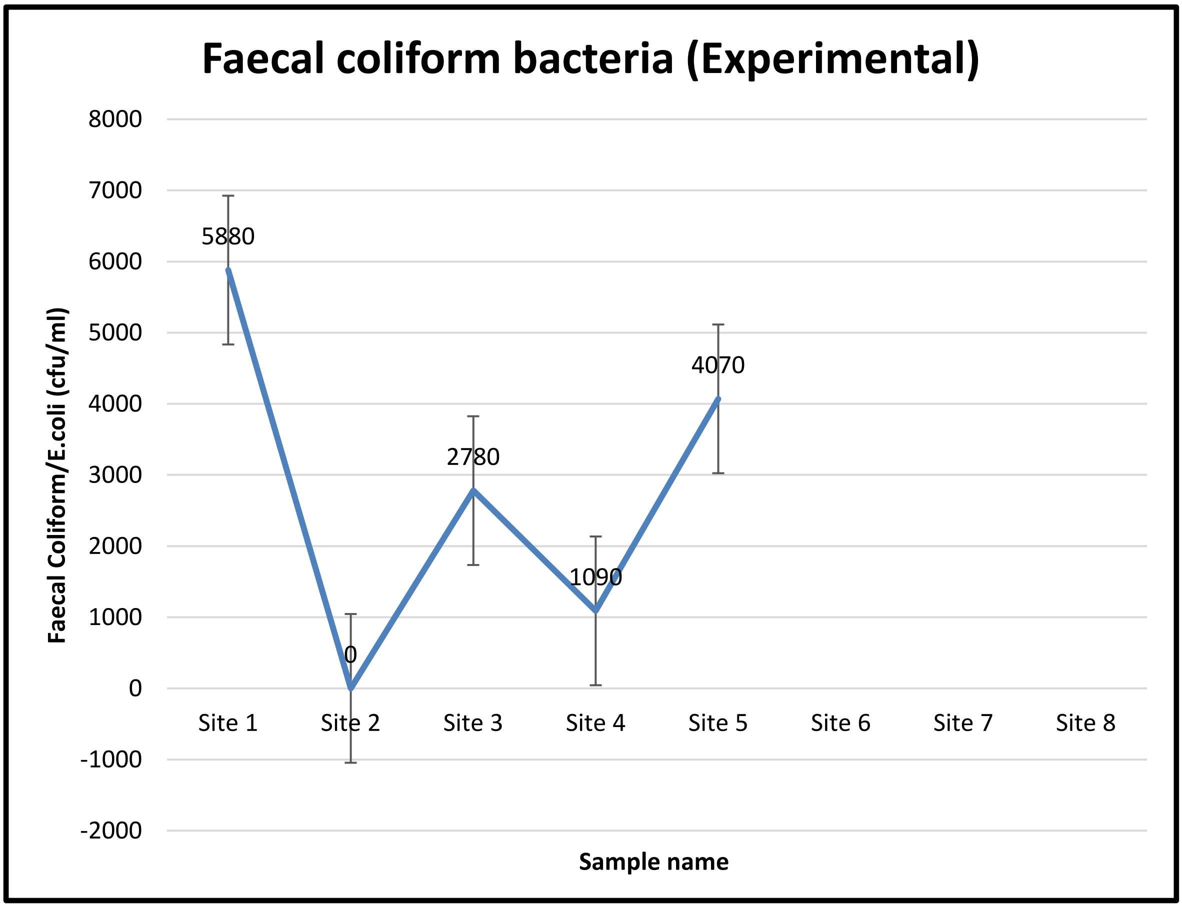

Figure 4.10: Faecal coliform bacteria in river and ponds water sample

Moreover, another study by An, *et al*., (2002) found results which had differing presence of faecal coliform count in the water depending on season and the depth where the water samples were taken. Summer was proved to be the season which had the highest level of faecal coliform. Since this study was carried out in summer, the results are similar. For future purposes there is need to test the presence of faecal coliform in other seasons. Also, Al-Harbi (2003) invested the presence of faecal coliform in pond water and results showed total viable bacterial counts in the pond water, which was similar to the pond water in Siloam village under investigation in this study.

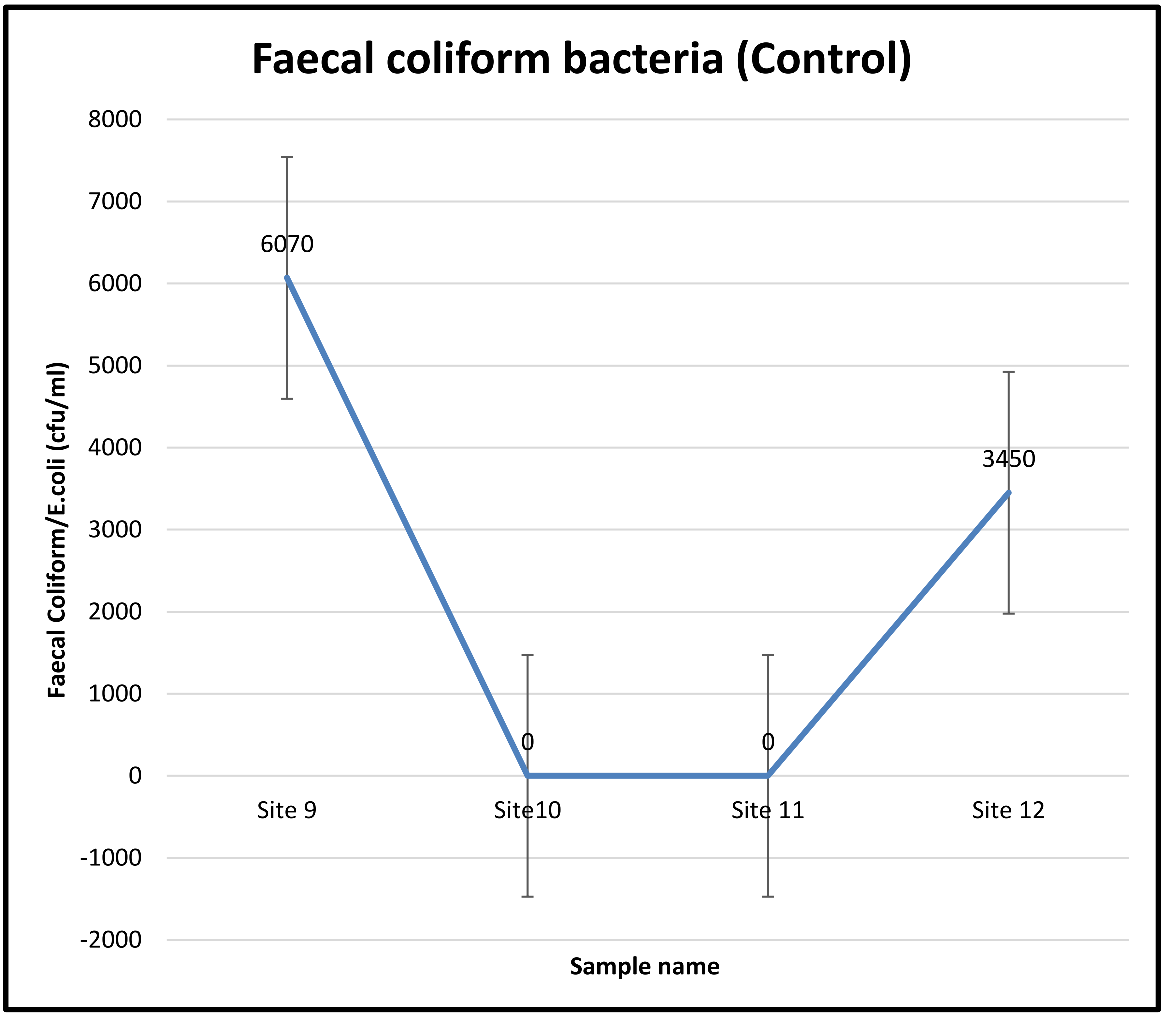

Figure 4.11: Faecal coliform bacteria in River and ponds water sample (Control)

On the other hand, control sites (sites 9 to 12) also, had varied results. Sites 9 and 12 had the highest faecal coliform bacteria detected. Interestingly, there were no bacteria detected in site 10 (downstream) and 11 (upstream) (Figure 4.11). Furthermore, the results show that the randomly picked points in the river and ponds contained bacteria.

Given these results, one can conclude that open defecation indeed contributes to the contamination of water resources with faecal coliform bacteria, as all the areas where open defection is practised were found to have these bacteria compared to upstream and downstream part of the river where open defecation is rarely practised. There is a need to educate the community of Siloam village to use water from the upstream of Nzhelele River as it was found to be clear of any faecal contaminants. Geophagic consumers must collect their material from the source close to upstream part of the Nzhelele River to minimise the exposure of being infected by water borne diseases caused by faecal contamination of water and soils.

Table 4.13 shows that the experimental sites had poor water quality as the counts in many of sites exceeded 0 cfu/100 ml-1, the maximum recommended limit for no risk set by the Department of Water Affairs (DWAF, 1996). The control sites, however, had less presence of faecal coliform bacteria and it was within the recommendable negligible risk of microbial infection. These results point out that, the water resources and areas where people practised open defection are susceptible to faecal coliform bacteria and this poses a great threat to human health. This health hazard is dangerous particularly to geophagic consumers and community members who use water from these sources.

Table 4.13: Faecal coliform bacteria in river and ponds water sample

Water Sample Sites	Minimum	Mean	Standard deviation	Maximum
Experiment Sites	0	2.76	3.41	12
Control Sites	0	2.38	1.01	0.1

4.3.2 Total coliform bacteria in River and ponds water samples

Furthermore, total coliform bacteria were analysed from the river and ponds water samples. The results and findings of this analysis are shown in Figure 4.12 and Table 4.14. The count for total coliform bacteria for the experimental sites was varied from site to site. Site 1, 3 and 4 had the highest number of total coliform bacteria of 7.24 x 10^3, 8.27 x10^3 and 6.53 x 10^3, respectively. Hong *et al*., (2010) demonstrated that total coliforms in the reservoirs were closely related with water physicochemical properties, while fecal coliforms were more associated with external input brought in by seasonal runoff.

This study proves that during the high rainfall periods, runoff picks up defacated materials and deposit them into the river during the rainy season. The findings by Hong Qui *et al*., (2010) are similar to the one by An, *et al.,* (2002) who found that public water sources had more faecal and total coliform count in summer. These studies show similarities with the current study, as this study was conducted in summer.

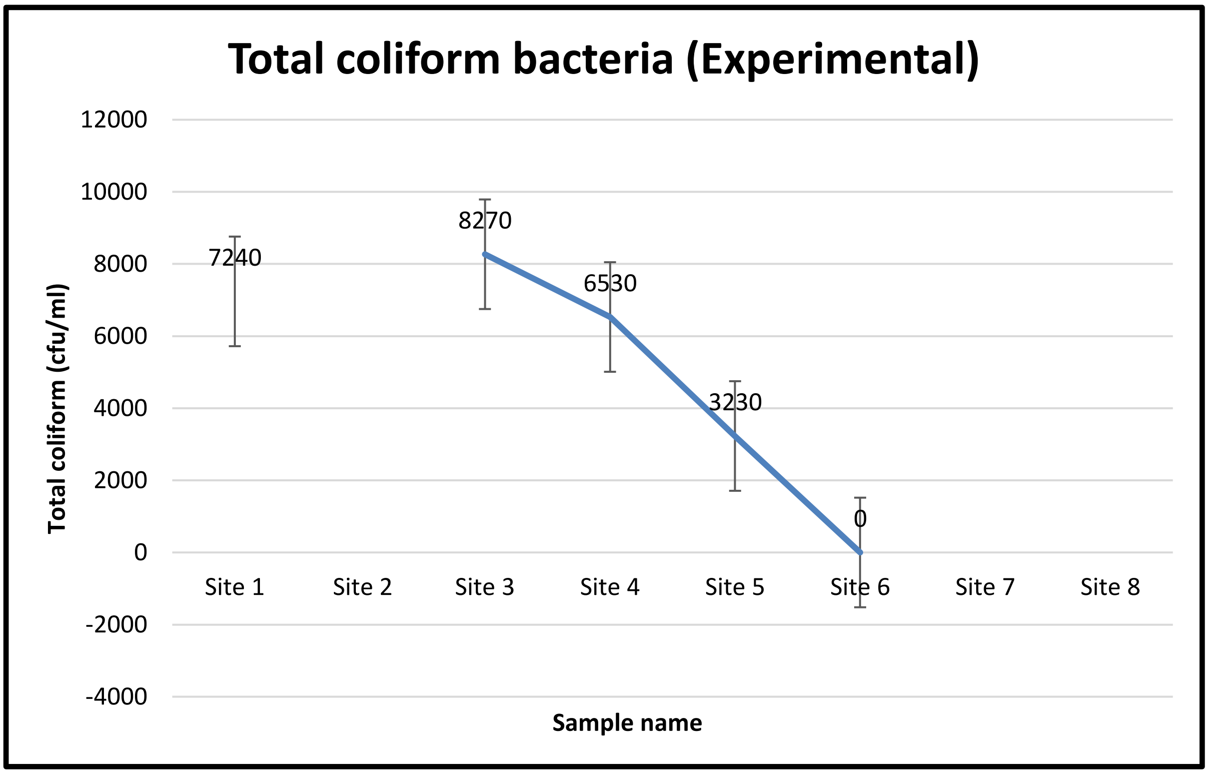

Figure 4.12: Total coliform bacteria in River and ponds water samples.

The control sites on the other hand, had the minimum and showed different results from the experimental sites. Upstream and downstream (site 10 and 11) had no detectable total coliform bacteria present at the time of the experiment while the randomly selected control sites (site 9 and 12) showed the presence of the bacteria (Figure 4.13).

Moreover, the minimum, maximum, mean and standard deviation of the control and experimental site were tested for the total coliform counts. These results were depicted in Table 4.14. The experimental sites had a minimum coliform count of 1 Cfu/100 ml, a maximum coliform count of 17 cfu/100ml and a standard deviation count of 3.96 cfu/100ml. According to the South African guidelines recommended coliform count of negligible risk of microbial infection is 0 – 5 Cfu/100 ml. Therefore, these experimental sites where people from Siloam village normally practice open defecation are above the limit and increase the risks of infection to the community members who use the water from the river and might potentially cause harm to those who collect their geophagic materials from the river beds, especially close to the point where those findings were found.

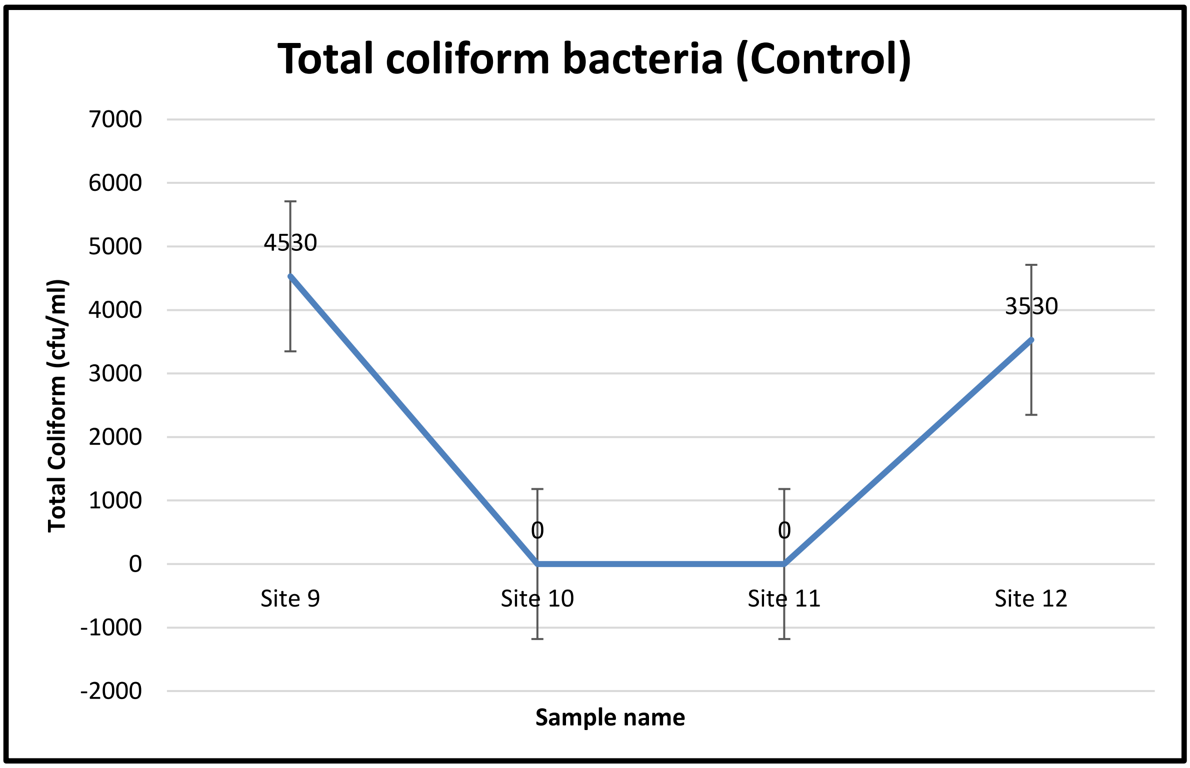

Figure 4.13: Total coliform bacteria in River and ponds water samples (Control)

On the other hand, the control sites indicated a minimum value of 0 and maximum of 3 colony forming units. The stipulated negligible risk of microbial infection for total coliform bacteria in water is 0 – 5 Cfu/100 ml, therefore, the water in these areas are safe to drink compared to the areas frequently exposed to open defecation

Table 4.14: Total coliform bacteria in River and ponds water samples

Water Sample Sites	Minimum	Mean	Standard deviation	Maximum
Experiment Sites	1	5.1	3.96	17
Control Sites	0	2.01	1.2	3

4.4 Summary of the chapter

This chapter summarises the results and discussions of the study. According to the results of questionnaire survey from Siloam village, only women were involved in the geophagic practices in the area. Furthermore, the results showed that geophagic consumers in this area generally consumed soil often because of cravings and pregnancy. However, those who were not pregnant also consumed soil. Among the many reasons for consuming soil, a significant number of people did not know why they are involved in geophagic practices.

The results from soil samples analysed for geohelminth ova using AMBIC Protocol Solution showed the absence of geohelminths ova in all 12 samples analysed. The results from water samples analysed for faecal and total coliform using membrane filter technique revealed that water resources had more faecal content above the South African recommended standard. Also, the total coliform present in the ponds and the Nzhelele River was alarming and a cause for concern especially in the areas where open defection and Geophagia is practised unlike the upstream and downstream. People of Siloam village could be at risk of being infected by various water borne diseases as the level of faecal coliform and total coliform are high near their geophagic mines, especially those who collect their materials from river beds. However people who practice geophagia are not at risk of contracting geohelminths infection as the samples analysed showed the absence of geohelminths ova.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The aim of the study was to investigate the effects of open defecation on geophagic soils and water resources in Siloam village. The study also aimed to understand the reasons why people practice geophagia in the area and the health effect associated with practicing geophagia.

The findings of this study revealed that there was prevalence in the practice of geophagia in this area. Similar, to the study by Phakoago (2017), the study found that the majority of the villagers in Siloam consumed soil nearly on daily basis. Moreover, this study found that the longest participating geophagic consumers have been involved in soil consumption for 31 years and at least a year.

According to the results, only women were involved in the geophagic practices in the area. Literature, however, shows that there is limited number of men who consume soil although the majority are women who are mainly pregnant or at child bearing age (Brand *et al*., 2009; Ekosse *et al*., 2010; Msibi *et al.,* 2014). Furthermore, the results showed that geophagic consumers in this area generally consumed soil often because of cravings and pregnancy. However, those who were not pregnant also consumed soil. Among the many reasons for consuming soil, a significant number of people did not know why they are involved in geophagic practices.

Of the soil samples collected from different sites in Siloam village were from areas commonly visited by those who practice Geophagy. These samples presented a varied wide range of colours and textures, providing for different preferences to various geophagic consumers. The colour of most consumed soil was reddish and yellowish and the commonly found soils are *mavu a yellow substance*, *munyaka*, *mutshenzhe*, *mutwa* and *vumba.* Among these types of soils, *munyaka* was the most popular followed by *mutwa.*

The study findings also revealed that there are both negative and positive perceptions over the soil consumption. However, the majority of the participants said they have no perception over the geophagic practices. The majority of the participants in this study pointed out that they mostly consumed clay and this material was consumed in its dry state and mostly unprocessed, if processed, it will be baked. This geophagic material was mainly found in the wild (riverbed, termitaria, and valley), with some also collected from the roadside, purchasing, yard, pond-bed and trees and the most used method was digging. *Muafukhada, mufula, mugwavha* and munngo were the trees from which the villagers usually collected their geophagic material. Among these trees, munngo was the most preferred for geophagic material and the least was *muafukhada* and *mugwavha.*

It was also found that the majority of the soil consumers did not know that the substances they consume could be harmful to them. Among those who knew the consequences of consuming the material stated that soil consumption causes constipation, tooth decay, body poisoning, and also abdominal pains. Although the results indicated that there were no major concerns by the geophagic consumers for practising geophagia besides the ones mentioned above. It might be of importance to inform geophagic consumers in the area with regard to possible risks associated with soil consumption.

These geophagic sites were further tested to find if they posed health hazard to the soil consumers. To do this soil samples were collected, and analysed using Ammonium Bicarbonate protocol, of these soil samples analysed in Siloam village showed that there were no geohelminths ova in the samples. The results indicated similarities with some of the studies done previously. The outcome of the study might have been influenced by the rainy season, as the samples were collected during wet season. The heavy rain could have washed away the faecal contaminants before they can penetrate the soils deeper, also most of geophagic consumers dig 10 to 20 cm deep. This therefore, calls for further investigation in another study during dry season and also collection and analysis of the top soil to establish conclusive results of the presence of geohelminths ova. The results further conclude that geophagic consumers in Siloam village are not at risk of acquiring geohelminths infection as the soil sample had no geohelminths ova.

In the present study, results revealed that water resources had more faecal content above the South African recommended standard. Also, the total coliform present in the ponds and the Nzhelele River was alarming and a cause for concern especially in the areas where open defection and Geophagia is practised unlike the upstream and downstream. This was found to be due to open defection which is generally and openly practised by the communities along the river. The level of toxicity of faecal and total coliform in the water resources is high in this area and there is therefore, a need for educating the society about the consequences of practicing open defecation and collecting geophagic materials near water sources. This also raises concerns for health effects it can pose to the community. Though geophagic consumers are not at risk of acquiring geohelminths infection they could be at risk of being infected by other water borne diseases as the level of faecal coliform and total coliform are high near their geophagic mines, especially those who collect their materials from river beds.

5.2 Recommendations

Based on the study findings the following recommendations are made.

- **a.** The study focused only on women who participated in geophagic practices, therefore a study to investigate the male soil consumers in this area is recommended.
- **b.** As the results showed that the majority of the geophagic consumers practice geophagia even while they are pregnant and those in the child bearing age. It is therefore, important to investigate the effects of these geophagic practices to the unborn babies. This study will further unpack if there are certain symptoms or diseases that they observe with their newly born babies which they suspect as a result of this practice.

c. Since the majority of soil consumers did not process or cook the soil before eating, it is important that baking be encouraged to at least eliminate some of the bacteria and toxics in the soil.

d. Moreover, participants showed that they have specific trees from which they obtain their material. Based on these findings, it is also important to investigate if these trees do not contain toxic materials that may affect the consumers. Among the trees identified, some may contain more harmful toxics than others, thus, there is need to identify these trees and their potential hazards to humans.

e. Although there were no geohelminths ova found in the soil samples from Siloam village, it is important to conduct a study to establish the existence of non-ova biological materials. Other studies have shown that the soil might contain heavy metals, fungal structure, nutrients and other living organism which might be a health hazard to geophagic consumers.

f. Based on the findings, people in Siloam should be encouraged to fetch water and collect the geophagic material from the upstream part of the river as they have negligible risk of microbial infection compared to other sites where open defecation is practised and geophagic material is collected.

g. Moreover, more studies need to be conducted with other villages that surround Nzhelele River as comparative study to check if there is uniformity in the trends of open defecation and geophagic practices in these areas. Such a study will also provide an understanding of the effects of open defecation over the course of the river.

h. There is also a need to implement health awareness programmes by the department of health to raise the awareness about problems associated with soil consumption.

References

Abrahams, P.W. and Parsons, J.A. 1996. Geophagy in the tropics. A literature review. The Geographical Journal. vol. 162, pp.163-172.

Abrahams PW. 1997. Geophagy (soil consumption) and iron supplementation in Uganda. Tropical Medicine and International Health, vol 2, pp. 617-623.

Abrahams, P.W. 2002. Soils. Their implications to human health. Science of Total Environment, vol. 291, pp.1-32.

Abrahams, P.W. 2005. Geophagy and the involuntary ingestion of soil. In: Selinus O, Alloway ,B., Centeno, J.A., Finkelman, R.B., Fuge, R., Lindh, U., Smedley, P., (Eds.), Essentials of medical geology: Impacts of the natural environment on public health. Elsevier Academic Press, Burlington, MA. Chapter 17, pp.434-458.

Abrahams, P.W.,Davies, T.C, Trow, A. and Wragg, J. 2013. Human Geophagia, Calabash Chalk and Undongo: Mineral Element Nutritional Implications. *Plos One,* 8(1).

Ademuwagun, Z.A., Ayoade, J.A.A., Harrison, I.E. and Warren, D.M. 1979.African Therapeutic Systems. Waltham, Massachusetts: Crossroads Press, 273 pp.

Al-Harbi, A.H. 2003. Faecal coliforms in pond water, sediments and hybrid tilapia Oreochromis niloticus, Oreochromis aureus in Saudi Arabia: 34, 517-524

Allende, A. and Monaghan, J. 2015. Irrigation water quality for leafy crops: a perspective of risks and potential solutions. *International journal of environmental research and public health,* 12(7), pp. 7457-7477.

Allport, S. 2006. Women who eat dirt. The Gastronomica Reader, vol. 2, no. 2, pp.10-22.

Amoah, I. D., Singh, G., Stenström, T. A. and Reddy, P. 2017. *Detection and quantification of soil-transmitted helminths in environmental samples: A review of current state-of-the-art and future perspectives.* s.l.:Acta Tropica.

An,Y., Donald, H., Kampbellb, G. and Peter, B. 2002. Escherichia coli and total coliforms in water and sediments at lake marinas. Environmental Pollution 120 (2002) 771–778

Anderle, R. 1988. The Global Positioning System. Royal Society of London, U.K

Anell, I.B. and Lagercrantz, S. 1958. Geophagical Customs, Uppsala University. *Studia Ethnographical Upsaliensa, 17*, 1-84.

Anitei, S. 2008. Eating soil. Effects of eating soil during pregnancy- Uganda. www.about Uganda.com/Uganda health.

Anon, 2017. *Collapse of the African American Family.* Pittsburgh: Dorrance Publishing Co.

Arhin, E. and Zango, M. S. 2017. Determination of trace elements and their concentrations in clay balls: problem of geophagia practice in Ghana. *Environmental geochemistry and health,* 39(1), pp. 1-14.

Asafp-Adjei, R.T., Collett, H., Fontaine, S.M., Gcwensa, F., Khumalo, J., Madiba, L., Sisitka, A., Smut, L.,Strydom T.A. & Tshabang, T. 2013. Focus agricultural grade 10. Sixth ed. Cape Town. Maskew Miller Longman, pp170.

Ash, L.R. and Orihel, T.C. 2007. *Atlas of Human Parasitology*. 5thed. American Society of Clinical Pathologists Press, Chicago, Illinois.

Assefa, L. M., Crellen, T., Kepha, S., Kihara, J.H., Njenga, S.M. and Pullan, R. 2014. Diagnostic accuracy and cost-effectiveness of alternative methods for detection of soil-transmitted helminths in a post-treatment setting in western Kenya. *PLoS neglected tropical diseases,* 8(5), p. e2843.

Aufreiter, S., Hancock, R.G.V., Mahaney, W.C., Stambolic, R.A. and Sanmugadas, K. 1997. Geochemistry and Mineralogy of soils eaten by humans. *International Journal of Food Science and Nutrition, 48*(5): 293-305.

Ayer, J., Agyemang, A., Yeboah, F., Jnr, E.O., Abebrese, S. and Suleman, I. 2016. Comparative analysis of extracted heights from topographic maps and measured reduced levels in Kumasi, Ghana. *South African Journal of Geomatics,* 5(3), pp. 313-324.

Bartas, M. and Ekman, F. 2001. The Soil Eaters, Cabinet, Issue 3. <Available on line> http://www.cabinetmagazine.org/issues/3/soileaters.php. [Accessed 19 Jun 2009].

Bartlett, S. 2003. Water sanitation and urban children: the need to go beyond 'improved' provision. Environ Urban. 2003;15:57–70.

Bateson, E.M. and Lebroy, T. 1978. Clay eating by Aboriginals of the Northern Territory. Medical Journal of Australia, 25(1): 1–3.

Bethony, J., Brooker, S., Albonic, M., Gelger, S.M., Loukas, A., Dlemert, D. and Hotez, P.J. 2006. Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm. The Lancet. 367(9521): 1521 - 1532.

Bergaya, F and Lagaly, G. 2006. General introduction: clays, clay minerals, and clay science. In Handbook of Clay Science. Edited by F Bergaya, BKG Theng and G Lagaly. Developments in Clay Science, vol.1, Elsevier Ltd, Amsterdam.

Bick, R.J., Bennet,t J.M., Cline, M.J., Kass, L., Murano, G., Shohet ,S.B. and Ward, P.C.J.1993. Haematololy Clinical And Laboratory Practice. Mosby-Year. Book, Inc. Vol 1, University of Michigan, Detroit

Blaszkowska, J., Wojcik, A., Kurnatowski, P. and Szwabe, K. 2013. Geohelminth egg contamination of children's play areas in the city of Lodz (Poland). *Veterinary parasitology,* 192(1), pp. 228-233.

Bisi-Johnson, M.A., Obi, C.L. and Ekosse, G.E. 2010. Microbiological and health related perspectives of geophagia: An overview. *African Journal of Biotechnology. 9*(19):5784 – 5791.

Black, D.A.K. 1956. Re-evaluation of Terra Sigillata. *Lancet, 2*, 883-4.

Boyle, J.S. and Mackay, M.C. 1999. Pica: Sorting it out. J. Transcult. *Nurs. 10*(1): 65-68.

Brand, C.E., De Jager, L. and Ekosse, G. 2009. Possible health effects associated with human geophagic practice: an overview. Medical Technology South Africa, vol. 23, pp. 11-13.

Brand, C.E., De Jager, L. and Ekosse, G.E. 2010. Microbiological and health related perspective of geophagia. An overview. African Journal of Biotechnology, vol. 9, no.19, pp. 5784-5791.

Bristow, J.W. 1986. An overview of the geology of the Soutpansberg and volcanic rocks. Koedoe 29: 59-67. Pretoria.ISSN 0075-6458.

Brouillard, M.Y. and Rateau, J.G.1989. Pourvoir d'adsorption de deux argilles, lasmectitiea la kaolin sur des entérotoxines bactériennes. *Gastroenterology Clinical Biology, 13,* 18-24.

Buckley, C.A., Foxon, K.M., Hawksworth, C.A., Pillay, S., Appleton, C., Smith, M. and Rodda, N. 2008. *Prevalence and die-off of Ascaris Ova in Urine Diversion Waste*. TT 356/08 to Water Research Commission. TT 356/08.

Buol, S.W. 1965. Present soil forming factors and processes in arid and semiarid regions. Soil Science, vol. 99, pp. 45-49.

Callahan, G.N. (2003) Eating Dirt. *Emerging Infect. Dis. 9*(8): 1016-1021.

Collapse of the African American Family. 2017. Pittsburgh, United Sates of America: Dorrance Publishing Co.

Colombo, O.L. and Watkins, M.M. 1991. Satellite Positioning, in US National Report to IUGG on Geodesy.

Carretero, M.I. 2002. Clay minerals and their beneficial effects upon human health. A review. Applied Clay Science, vol. 21, pp. 155-163.

Cavdar, A.O, Arcasoy, A., Cin, S., Babacon E and Gözdasoğlu, S. 1983. Geophagia in Turkey: iron and zinc deficiency, iron and zinc absorption studies and response to treatment with zinc in geophagia cases. Progress in Clinical and Biological Research, 129:71 -97.

Casavale, K.O., Stoody, E.E., Rahavi, E., Bevington, F., Rihane, C. and Olson, R.D. 2017. Dietary Guidelines for Americans: The Past, Present, and Future. *Journal of Nutrition Education and Behavior,* 49(7), pp. S19-S20.

Castiano, J. P. and Mkabela, Q. N. 2013. African indigenous knowledge systems: an account: foreword. *Indilinga African Journal of Indigenous Knowledge Systems,* 12(2), pp. 5-11.

Committee on Research Priorities for Earth Science and Public Health, National Research Council. 2007. What we eat. In earth materialsand health. Research priorities for earth science and public health. The National Academies Press Washington, D.C. pp. 83-89.

Chumkwuma M.C, Ekejindu I.M, Agakoba N.R, Ezeagwuna D.A, Anaghalu I.C and Nwosu D.C. 2009. The Prevalence and Risk Factors of Geohelminth Infections among Primary School Children in Ebenebe Town, Amambra State, Nigeria. Middle East Journal of Scientific Research, 4(3): 211- 215.

Crosby, W.H. 1982. Clay ingestion and iron deficiency. Annals of International Medicine, vol. 97, pp. 45-67.

Danford DE. 1982. Pica and Nutrition. Annual Review of Nutrition, 2: 303-322.

Days, G. 2017. *Collapse of the African American Family.* s.l.:Dorrance Publishing.

Davies, T.C. 2008. Environmental health impacts of East African Rift volcanism. *Environmental geochemistry and health, 30*(4), pp.325-338.

Department of Water Affairs and Forestry. 1996. *South African Water quality guidelines, Volume 1*, Domestic water use. 2nd Edition. Pretoria, South Africa.

Department of Water Affairs and Forestry. 2000. Quality of domestic water supplies: Sampling guide. Pretoria: Department of health. *Water Research Commission*.

Department of Water Affairs and Forestry. 2001. Report No. P 0200/00/0301. *Luvuvhu/Letaba Water Management Area: Water resource situation assessment. WSM (Pty).*

Department of Water Affairs and Forestry. 2005. Drinking Water Quality Management Guide for Water Services Authorities Department of Water Affairs Forestry: Pretoria www.dwaf.gov.za/documents

De Silva, N.R., Brooker, S., Hotez, P.J., Montresor, A., Engels, D. and Saviol, L. 2003. Soil-transmitted helminth infections: updating the global picture. *Trends in Parasitology. 19*(12): 547 – 551.

De Silva, M.D., Calijuri, M.L., De Sales, F.J., De Souza, M. and Lopes, I.S. 2014. Integration of technologies and alternative sources of water and energy to promote the sustainability of urban landscapes. *Resources, Conservation and Recycling,* Volume 91, pp. 71-81.

De Smidt, O., Smit, N. J. & Botes, E. 2015. Bacterial diversity in soil from geophagic mining sites in the Qwa-Qwa region of South Africa. *International journal of environmental health research,* 25(2), pp. 184-195.

Deb, T. K. and Majumdar, S. 2013. Removal of reactive dyes from textile wastewater by electrocoagulation process: An effective and clean approach. *International Journal of Environment and Bioenergy,* 6(2), pp. 96-116.

Diko, M. and Diko, C. 2014. Physico-chemistry of geophagic soils ingested to relief nausea and vomiting during pregnancy. *African Journal of Traditional, Complementary and Alternative Medicines,* 11(3), pp. 21-24.

Diko, M. L. and Ekosse, G. E. 2014. Soil ingestion and associated health implications: a physicochemical and mineralogical appraisal of geophagic soils from Moko, Cameroon. *Studies on Ethno-medicine,* 8(1), pp. 83-88.

Diouf, S.B., Camara, M.G., Sall I., Diagne, O, Ndiaye, O. 2000. Protein-energy malnutrition in children less than five years old in rural zone in Senegal (Khombole). Dakar Medical, 45:48-50.

Dominy, N., Davoust, E., Minekus, M. 2004. Adaptive function of soil consumption: an in vitro study modelling the human stomach and small intestine. Journal of Experimental Biology, vol. 207, no 2, pp.319-324.

Dreyer, M.J., Chaushev P.G and Gledhill, R.F. 2004. Biochemical Investigations in Geophagia. *Journal of the Royal Society of Medicine, 97*(1): 48-53.

Droy-Lefaix, M.T. and Tateo, F. 2006. Clays and Clay Minerals as Drugs. In: Bergaya, F., Theng, B.K.G. and Lagaly, G. (Eds), *Handbook of Clay Science.* Elsevier, pp. 743-752.

Dungumaro, E.W. 2007. *Socioeconomic differentials and availability of domestic water in South Africa.*

Durowoju, O., Odiyo, J. O. and Ekosse, G. E. 2016. Horizontal variation in trace elements and soil characteristics at Siloam and Tshipise geothermal springs, Limpopo Province, South Africa. Water SA, 42(4), pp. 694-702.

Edwards CH, McSwain H, Haire S. 1954. Odd dietary practices of women. Journal of the American Dietetic Association, 30(10): 976-981.

Edwards, C.H, Johnson, A.A, Knight, E.M., Oyemade, U.J., Cole, O.E. 1994. Pica in an Urban Environment. Journal of Nutrition, vol. 12, no 4 (Suppl 6), pp.954S-962S.

Ejechi, E.O. and Ejechi, B.O. 2007. Safe drinking water and satisfaction with environmental quality of life in some oil and gas industry impacted cities of Nigeria. 85:211–222.

Ekosse, G. E., de Jager, L and Ngole, V. 2008. X-Ray diffraction study of geophagic soils and clays from Southern Africa. Paper presented at the 1st International Conference: Geophagia in Southern Africa. "Safe soils for a healthier community". 22-24 October, 2008. Central University of Technology, Free State.

Ekosse, G. E., Ngole, V. and De Jager, L. 2013. Human health aspects related to the ingestion of geophagic clayey soils from the Free State and Limpopo provinces, South Africa.

Ekosse, G.E, and Anyangwe, S. 2012. Mineralogical and particulate morphological characterization of geophagic clayey soils from Botswana. Bulletin of the Chemical Society of Ethiopia, 26(3): 373-382.

Ekosse, G. E., and Ngole, V.M. 2012. Mineralogy,geochemistry and provenance of geophagic soils from Swaziland. Applied Clay Science, vol. 57 pp. 25-31.

Ekosse, G.E., De Jager, L., Ngole, V.M. 2010. Traditional mining and mineralogy of geophagic clays from Limpopo and Free State provinces, South Africa. *African Journal. Biotechnology, 9*(47): 8058-8067.

Ekosse, G.E. and Jumbam, D.N. 2010. Geophagic clays: their mineralogy, chemistry and possible human health effects. *African Journal of Biotechnology, 9*(40): 6755-6767.

Ekosse, G.E., Ngole, V.M. and de Jager, L. 2011. Mineralogical and geochemical characteristics of geophagic clayey soils and their possible impact on human health, In: GE Ekosse, L de Jager, VM Ngole (Eds.): An Innovative Perspective on the Role of Clays and Clay Minerals, and Geophagia on Economic Development. *Conference Proceedings of the 1st International Conference on Clays and Clay Minerals in Africa, and 2nd International Conference on Geophagia in Southern Africa*, Bloemfontein, South Africa, pp. 283- 289.

Ekosse, G.E., Ngole-Jeme, V.M. and Diko, M.L. 2017. Environmental Geochemistry of Geophagic Materials from Free State Province in South Africa. *Open Geosciences,* 9(1), pp. 114-125.

Ellis, C.R. and Schnoes, C.J. 2006. Eating Disorder: Pica. eMedicine. [Accessed 30 March 2017]. http://www.emedicine.medscape.com/article/914765-Overview.

Epstein, E. 2015. *Disposal and management of solid waste: Pathogens and diseases.* London: CRC Press..

Esmaeilzadeh, J. and Ahangar, A. G. 2014. Influence of soil organic matter content on soil physical, chemical and biological properties. *Inter. J. Plant Anim. Environ. Sci,* 4(4), pp. 244-252.

Fard, H. K., Pourjam, E., Maafi, Z. T. and Safaie, N. 2016. Distribution of cereal cyst nematode, Heterodera filipjevi, in wheat fields of Isfahan province based on interpolation and relationship of climatic factors with its population densities. *Iranian Journal of Plant Pathology,* 52(3).

Farghly, A.M., Mohamed, S.M., Abdel-Rahman, S.A., Mohammed, F.E., El-Bahaie, E.S., and El-Shafey, M.A. 2016. The relation between the prevalence of soil transmitted parasites in the soil and among school children in Zagazig district, Sharkyia Governorate, Egypt.. *Journal of Parasitic Diseases,* 40(3), pp. 1021-1029.

Ferguson JH and Keaton AG. 1950. Studies of the diets of pregnant women in Mississippi. The ingestion of clay and laundry starch. New Orleans Medical and Surgical Journal, 102: 460-463.

Faustina, O. Mensah, P., Xorse, K. Amenawonyo, C. L., Asomaning K. B. 2010. Pica practice among pregnant women in the Kumasi metropolis of Ghana. International Health. Vol, 2, pp. 282-286.

Garcia, C., Schulbe K., Markowitz R. and Young L. W. 1987. Radiological case of the month perforated gastric ulcer in a rock eater Amj Dis Child, 141, 213-214.

Gawor, J. and Boreka, A. 2017. Quantifying the risk of zoonotic geohelminth infections for rural household inhabitants in Central Poland. Annals of Agricultural and Environmental Medicine, 24(1), pp. 44-48.

Geetha, J. and Kumar, S. 2014. Open defecation: awareness and practices of rural districts of Tamil Nadu, India. Int J Sci Res. 2014;3: 2277–8179.

Geissler, P.W., David, L., Mwani, K., Frederick, T. and Henrik, F. 1997. Geophagy among school childrennin western Kenya, Vol 2: 624-630.

Geissler, P.W., Mwaniki, D.L., Thiogó, F., Michaelsen, K.F. and Friis, H. 1998. Geophagy, iron status and anemia among primary school children in Western Kenya. *Trop. Med. Int. Health, 3*(7): 529-534.

Geissler, P.W., Prince, R.J., and Levene, M. 1999. Perceptions of soil-eating and anaemia among pregnant women on the Kenyan coast, Social.Science and Medicine vol. 48, pp. 1069-1079.

Geissler, P.W. 2000. the significance of earth-eating: social and cultural aspects of geophagy among Luo children. Africa: *Journal of the International African Institute. 70*(4): 653-682.

Ghidiu, M., Lukatskaya, M.R., Zhao, M.Q., Gogotsi, Y. and Barsoum, M.W. 2014. Conductive two-dimensional titanium carbide'clay'with high volumetric capacitance. *Nature,* 516(7529), p. 78.

Ghorbani, H. 2008. Geophagia, a Soil- Environmental Related Disease .International meeting on soil fertility and Management and Agroclimatology Turkey pp.957-967.

Glickman, L.T., Camara, A.O., Glickman, N.W. and McCabe, G.P. 1999. Nematode intestinal parasites of children in rural Guinea, Africa: prevalence and relationship to geophagia. International Journal of Epidemiology. 28: 169-174.

Golden, C. D., Rasolofoniaina, B. J., Benjamin, R and Young, S. L. 2012. Pica and amylophagy are common among Malagasy men, women and children

George, G. and Ndip, E. 2011. Prevalence of Geophagia and its possible implications to health- a study in rural South Africa. 2nd International conference on Environmental Science and Development, IPCBEE, 4.

Grigsby, R. K., Thyer, B. A., Waller, R. J., Johnston Jr., G. A. 1999. Chalk eating in middle Georgia: a culture-bound syndrome of pica? Southern Medical Journal 92, 190– 192.

Gumbo, J.R., Gina, R. and Thomas, E.C. 2010. The Isolation and identification of Predatory Bacteria from a Microcystis algal Bloom. *African Journal of Biotechnology, 9*(5), 663-671.

Halsted, J.A. 1968. Geophagia in man: its nature and nutritional effects, Am. J. *Clinical Nutrition. 21*, 1384-1393.

Harvey, W.J.P., Dexter, P.B. and Darton-Hill, I. 2000. The Impact of consuming iron from non-food sources on iron status in developing countries. *Public Health Nutrition. 3*(4): 375-383.

Hong, H., Qiu, J. and Liang, Y. 2010. Environmental factors influencing the distribution of total and feacal coliform bacteria in six water storage reservoirs in the Pearl River Delta Region, China. Journal of Environmental Sciences, 22(5), 663–668.

Holland, C.V. and Kennedy, M.W. 2002. *World Class Parasites: Volume 2* – The Geohelminths: Ascaris, Trichuris and Hookworm. First Edition. Kluwer Academic Publishers, Boston.

Hooda, P.S. 2003. Soil ingestion affects the potential bioavailability of Cu, Mn, and Zn. Proceedings of the 7th International Conference on the Biogeochemistry of Trace Elements, Uppsala, Sweden, and June 15-19, 2003. SP9o-Trace elements issues in developing countries 8-11.

Hooda, P.S., Henry, C.J.K., Seyoum, T.A., Armstrong, L.D.M. and Fowler, M.B. 2002. The potential impact of geophagia on the bioavailability of iron, zinc and calcium in human nutrition. Environmental Geochemistry and Health vol 24 pp. 305-31.

Hooda, P.S., Henry, C.J.K., Seyoum, T.A., Armstrong, L.D.M. and Fowler, M.B. 2004. The potential impact of soil ingestion on human mineral nutrition. Science of the Total Environment, vol. 333, pp.75- 87.

Hotez, P.J. 2000. Pediatric geohelminth infections: Trichuriasis, ascariasis and hookworm infections. *Seminars in Paediatric Infectious Diseases, 11*(4): 236 - 244.

Hotez, P.J., Bundy, D.A.P., Beegle. K., Brooke, S., Drake, L., De Silva, N., Montressor, A., Engels, D., Jukes, M., Chitsulo, L., Chow, J., Laxminarayan, R., Michaud, C.m., Bethony, J., Correa-Oliveira, R., Shu-Hua, X., Fenwick, and Savioli, L. 2006. Chapter 24: Helminth Infections: Soil-transmitted Helminth Infections and Schistosomiasis. In: Disease Control Priorities in Developing Countries. Second edition. Editors: Jamison D.T., Breman J.G, Measham A.R., Alleyne G., Claeson M., Evans D.B, Jha P., Mills A. and Musgrove P., World Bank Publications, Oxford.

Hunter, J.M. 1973. Geophagy in Africa and the United States: Culture- Nutrition hypothesis. *Geographical Review, 63*, 170-195.

Hunter, J.M. and de Kleine, R. 1984. Geophagy in Central America. *Geographical. Rev. 74*, 157-169.

Hunter, J.M., Horst, O.H. and Thomas, R.N. 1989. Religious geophagy as a cottege industry: The holy clay Tablet of Esquipulas, Guatemala. *National geography, 4*, 2-13.

Hunter, J.M. 1993. Macrotermegeophagy and pregnancy clays in Southern Africa. *Journal of cultural geography, 14*, 69-92.

Hunter, B.T. 2003. The widespread practice of consuming soil. Consumer's research magazine. [Accessed 31 March 2017].http://www.highbeam.com/doc/1G1-112542811.html

Hunter-Adams, J. 2016. Interpreting habits in a new place: migrants' descriptions of geophagia during pregnancy. *Appetite,* 105(1), pp. 557-561.

Institute of Soil, Water and Climate. 1994. Land type inventory, GIS staff, Pretoria, South Africa, ISBN 1 86845 709 5.

Jacobson, G. and Lan, I.E. 1988. Cited in "Australia ground water systems under stress", Water Quality Bulletin, Vol. 13, pp. 107-116.

Jain, A. 2015. *A clinical study on the Effect of vaghbhatokta nimbadi yoga in the Management of geophagia in children.* Belgaum, Karnataka: (Doctoral dissertation, KLE University).

Johns, T. 1986. Detoxification functions of geophagy and domestication of the potato *Journal of the Chemical Ecology, 12*, 635-646.

Johns, T. and Duquette, M. 1991. Detoxification and mineral supplementation as functions of geophagy. *American Journal of Clinical Nutrition, 53*, 448-456.

Jumbam, N.D. 2013. Geophagic materials: the possible effects of their chemical composition on human health. *Transactions of the Royal Society of South Africa,* 68(3), pp. 177-182.

Jyothi, N. 2015. A Case Report on Pica: A rare pregnancy related complication. *Asian Journal of Nursing Education and Research,* 5(1), p. 137.

Kabanda, T.A. 2004. Climatology of long-term drought in the northern region of the Limpopo province of South Africa (Doctoral dissertation, University of Venda).

Kanyoka, P., Farolfi, S. and Morardet, S. 2008. Households' preferences and willingness to pay for multiple use water services in rural areas of South Africa: An analysis based on choice modelling.

Karagiannis-Voules, D.A., Biedermann, P., Ekpo, U., Garba, A., Langer, E., Mathieu, E. and Sacko, M. 2015. Spatial and temporal distribution of soil-transmitted helminth infection in sub-Saharan Africa: a systematic review and geostatistical meta-analysis. *The Lancet infectious diseases,* 15(1), pp. 74-84.

Karimi MR, Kadivar R, Yarmohammadi H. 2002. Assessment of the prevalence of iron deficiency anemia, by serum ferritin, in pregnant women of Southern Iran. Medical Science Monitor, 8: CR448-492.

Karsils, L. 2004. Published by Department of Water Affairs and Forestry. http://www.dwaf.gov.za/events/water week/2004.

Kawai, K., Saathoff, E., Antelman, G., Msamanga, G. and Fawzi, W.W. 2009. Geophagy (Soil-eating) in Relation to Anemia and Helminth Infection among HIV–Infected Pregnant Women in Tanzania. *The American Journal of Tropical Medicine and Hygiene, 80*(1): 36 – 43.

Key, T.C., Horger, E.O. 3rd and Miller, J.M. Jr. 1982. Geophagia as a cause of maternal death. *Obstetrics and Gynaecology, 60*, 525–526.

Keyton, J. 2006. Communication research: Asking questions, finding answers. Second Edition. McGraw-Hill. [Accessed 11 February 2011] http://highered.mcgrawhill.com/sites/0073049506/student_view0/glossary.html

Kikouama, J.R.O, Konan, K.L., Katty, A., Bonnet, J.P., Baldé, L. and Yagoubi, N. 2009. Physiochemical characterization of edible clays and release of trace elements. Applied Clay Science. 43: 135 – 141.

Knishinsky, R. 1998. The Clay Cure. First edition. Healing Arts Press, Rochester Vermont.

Knudsen, J.W. 2002. Earth eating habit: A social and Cultural practice among Chagga women on the slopes of Mount Kilimanjaro, *African Journal of Indigenous Knowledge Systems, 1*, 19-25.

Knudsen JW. 2004. Akulu udongo (eart eating habits): A social and cultural pratice among Chagga women on the slope of Mount Kilimanjaro. Indilinga: African Journal of Indigenous Knowledge Systems, 1(1):19-26.

Kolandaivelu, G. and Balan, V. 1979. Pica. Journal of India Medical Aobt, 73, 193-196.

Krause, R.J., Koski, K.G., Pons, E., Sandoval, N., Sinisterra, O. and Scott, M. 2015. Ascaris and hookworm transmission in preschool children from rural Panama: role of yard environment, soil eggs/larvae and hygiene and play behaviours. *Parasitology,* 142(12), pp. 1543-1554.

Krishnamani, R. and Mahaney, W.C. 2000. Geophagy among primates: adaptive significance and ecological significances. *Animal Behavior, 55*(5), 899-915.

Kuczynska, E. and Shelton, D.R. 1999. Method for Detection and Enumeration of Cryptosporidium parvum Oocysts in Feces, Manures, and Soils. Applied and *Environmental Microbiology. 65*(7), 2820 – 2826.

Kutalek, R., Wewalka, G., Gundacker, C., Auer, H.,Wilson, J.,Haluza, D., Hululescu, S., Hillier, S., Sager, M. and Prinz, A. 2010. Geophagy and potential health implications: geohelminths, microbes and heavy metals. Transactions of the Royal Society of Tropical Medicine and Hygiene, vol. 104, pp. 787-795.

Lachlan C and Bodkin. 2011. Health and social impacts of geophagia in panama. MSURJ. McGill Undergraduate Research Journal, vol 6 no 1.

Lambert, V., Pouget, K., Basurko, C., Boukhari, R., Dallah, F. and Carles, G. 2013. Geophagy and pregnancy: current knowledgement and management. Clinical experiences of an abstetrical department in French Giuiana. Journal of Gynecology and obstetrics Biology Reproduction. Available from http://www.ncbi.nlm.nih.gov/pubmed/23871612 accessed Nov 05,2013.

Laufer, B. 1930. Geophagy Field Museum of Natural History and Anthropology Series, vol.18, pp. 99-198.

Lupele, J.K. 2002. Action Research case studies of participatory materials development in two community contexts in Zambia. *M.Edu Thesis. Rhodes University*, Grahamstown.

Luoba, A.I., Geissler, P.W., Estambale, B., Ouma, J.H., Magnussen, P., Alusala, D., Ayah, R., Mwaniki, D. and Friis, H. 2004. Geophagy among pregnant and lactating women in Bondo District, western Kenya. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, *98*(12): 734 - 741.

Luoba, A.I., Wenzel Geissler, P., Estambale, B., Ouma, J.H., Alusala, D., Ayah, R., Mwaniki, D., Magnussen, P. and Friis, H. 2005. Earth-eating and reinfection with intestinal helminths among pregnant and lactating women in western Kenya. Tropical medicine and international health, 10(3), pp.220-227.

Macheka, L. R., Olowoyo, J., Matsela, L. and Khine, A. 2016. Trace metals in blood and urine of pregnant women practicing geophagia at Dr. George Mukhari Academic Hospital, Pretoria, South Africa. *Medical Technology SA,* 30(1), pp. 45-48.

Majorin, F., Torondel, B., Routray, P., Rout M. and Clasen, T. 2017. Identifying Potential Sources of Exposure Along the Child Feces Management Pathway. *A Cross-Sectional Study Among Urban Slums in Odisha, India.*

Mahaney, W.C., Hancock, R.G.V. & Inoue, M. 1993. Geochemistry and clay mineralogy of soils eaten by Japanese macaques. Primates, vol. 34, pp. 85-91.

Mahaney, W.C., Milner, M.W., Mulyono, H.S., Hancock, R.G.V., Aufreiter, S., Reich, M., Wink, M. 2000. Mineral and chemical analyses of soils eaten by humans in Indonesia. *Int. J. Environ. Health, 10*: 93-109.

Mahaney, W.C., Krishnamani, R. 2003. Understanding geophagy in animals: Standard procedures for sampling soils. J. Chem. Ecol., 29(7): 1503-1523

Maier, R.M., Pepper, I.L. and Gerba, C.P. 2000. *Environmental Microbiology*. First Edition. Academic Press, San Diego, California.

Makungo, R., Odiyo, J.O., Ndiritu, J.G. and Mwaka, B. 2010. Rainfall–runoff modelling approach for ungauged catchments: A case study of Nzhelele river sub-quaternary catchment. *Physics and Chemistry of the Earth, Parts A/B/C, 35*(13). 596-607.

Makungo, T.E. 2008. The adequacy of water supply to meet the demand in Siloam Village of Limpopo Province of South Africa, University of Venda, South Africa.

Malaza, N. 2014. *Basin analysis of the Soutpansberg and Tuli coalfields, Limpopo province of South Africa.* s.l.:(Doctoral dissertation, University of Fort Hare).

Matangila, J.R., Lufuluabo, J., Ibalanky, A., Da Luz, R.A., Lutumba, P. and Van Geertruyden, J.P. 2014. Asymptomatic Plasmodium falciparum infection is associated with anaemia in pregnancy and can be more cost-effectively detected by rapid diagnostic test than by microscopy in Kinshasa, Democratic Republic of the Congo. *Malaria journal,* 13(1), p. 132.

Mathee, A. 2014. Towards the prevention of lead exposure in South Africa: Contemporary and emerging challenges. *Neurotoxicology,* 45(1), pp. 220-223.

Mathee, A., Naicker, N., Kootbodien, T., Mahuma, T., Nkomo, P., Naik, I. and De Wet, T. 2014. A cross-sectional analytical study of geophagia practices and blood metal concentrations in pregnant women in Johannesburg, South Africa. *South African Medical Journal,* 104(8), pp. 568-573.

McClain, J. and Paye, P.D. 2017. *Household Water Quality and Management Survey: Paynesville City.* Paynesville: Greater Monrovia.

McDaniel, C. and Gates, R. 2010. Marketing research essentials, 5thed., Wiley, Hoboken.

Mcloughlin, I.J. 1987. The pica habit. Hosp. Med., vol 37, pp. 286-290

Mills, C.F. 1996. Geochemical aspects of the aetiology of trace element related diseases. Geological Society, London, Special Publications, 113(1), pp.1-5.

Mogongoa, L.F., Brand, C.E., de Jager L., and Ekosse, G.E. 2011. Haematological and iron ststus of Qwaqwa women in South Africa who ingest clays. Central University of Technology. Bloemfontein. South Africa.

Momoh, A., Davies, T.C., Akinsola, H.A. and Akinyemi, O. 2011. Mineralogical Characteristics of Consumed Earth Materials from Vhembe District, Limpopo Province, South Africa. In: Ekosse, G-I. E., de Jager, L., Ngole, V.M., (eds). An Innovative Perspective on the Role of Clays and Clay Minerals and Geophagia on Economic Development. Proceedings of the 1st International Conference on Clays and Clay Minerals in Africa, and 2nd International Conference on Geophagia in Southern Africa; Bloemfontein, South Africa.

Momoh, A., Henry, A. A., Nengovhela, M., Akinyemi, S. A. and Ojo, J. O. 2015. Geophagic Practice in Vhembe District, Limpopo Province, South Africa. Journal Human Ecology. 51(3): 273-278.

Momoh, A., Davies, T., Akinsola, H., Akinyemi, S.A., Mhlongo, S., Gitari, W., and Pindihama, G.K. 2013. Human bioaccessibility of Fe, Mn, Zn and Cu from consumed earth materials in Vhembe District, South Africa. *Transactions of the Royal Society of South Africa,* 68(1), pp. 33-39.

Moriarity, P. 2001. WATSAN and rural livelihoods approaches. Paper prepared for the 27th WEDC Conference, People and Systems for Water, Sanitation and Health, Lusaka, Zambia.

Moruff, M. 2012. Cultural understanding of space and waste disposal habit among the urban populace in Ibadan Metropolis, South Western Nigeria. J Sustain Dev Africa. 2012; 14:82–95.

Mpuchane, S.F., Ekosse, G.E., Gashe, B.A., Morobe, I. and Coetzee, S.H. 2008. Mineralogy of Southern African medicinal and cosmetic clays and their effects on the growth of selected test microorganisms. *Fresenius Environmental Bulletin*, 17(5): 547-557.

Msibi, A.T., van Onselen, A., Siwela, M. and Chivenge, P. 2014. The Prevalence and Practice of Geophagia in Mkhanyakude District of KwaZulu-Natal, South Africa, School of Agricultural, Earth and Engineering Sciences, University of KwaZulu-Natal.

Mundalamo, H. 2003. *The water quality of Nzhelele Valley earth movement in Nzhelele, Milaboni location, Bsc honours in department of mining and geology project*, University of Venda, South Africa.

Murray, P.R., Rosenthal, K.S. and Pfaller, M.A. 2009. *Medical Microbiology*. Sixth Edition. Mosby Elsevier, Philadelphia.

Nchito, M., Geissler, P.W., Mubila, L., Friis, H. and Olsen, A. 2004. Effects of iron andMultimicronutrient supplementation on geophagy: a two-by-two factorial study among Zambian school children in Lusaka. *Transactions of the Royal Society of Tropical Medicine and Hygiene 98*(4) 218 – 227.

Ngole, V.M., Ekosse, G.E., de Jager, L. and Songca, S.P. 2010. physicochemical characteristics of geophagic clayey soils from South Africa and Swaziland. *African Journal of Biotechnology, 9*(36), 5929–5937.

Ngozi, P.O. 2008. Pica practices of pregnant women in Nairobi, Kenya. *East Afr. Med. J. 85*(2), 72-79.

Njiru, H., Elchalal, U. and Paltiel, O. 2011. Geophagy during pregnancy in Africa: A Literature review. Obstetrical and Gynecological Survey, vol. 66, no.7, pp. 452-459.

Nnorom, I. C. 2016. Major and minor element contents of calabash clay (nzu) from Abia State, Nigeria: evaluation of potential intake benefits and risks. *Toxicological & Environmental Chemistry,* 98(2), pp. 149-166.

Nock, I.H., Duniya, D. and Galadima, M. 2003. Geohelminth eggs in soil and stool of pupils of some primary schools in Samaru, Zaria, Nigeria. *Nigerian J. Parasitol., 24*, 115–22.

Norman, I.D., Binka, F.B. and Godi, T.N. 2015. Geophagia: A culturalnutrition health-seeking behavior with no redeeming psycho-social qualities. *South Eastern European Journal of Public Health,* Volume 38, pp. 38-48.

Norman, I.D., Binka, F.N., Aikins, M.K., Zotor, F. and Godi, A. 2015. Geophagia a Health-Seeking behavior or an Ethnic Remedy towards a Greater Personal Resilience. *Donnish Journal of Neuroscience and Behavioral Health,* 1(1), pp. 1-11.

Nyabeze, P.K., Venter, J.S., Oliver, J. and Motlakeng, T.R. 2010. Characterisation of the thermal aquifer associated with the Siloam Hot Spring in Limpopo Province, South Africa.

Nyaruhucha, C.N.M. 2009. Food cravings, aversions and pica among pregnant women in Dar es Salaam, Tanzania. Tanzania Journal of Health Research. Vol 11, No 1, pp 29-34

Nwafor, A.O. Maringowitz, G.J.O and Clark, C.C. 2008. Reasons pregnant women who attend antenatal care in Mecklenburg hospital eat soil. Department of Family Medicine of the University of Limpopo (Medunsa campus).

Odongo, A. O., Moturi, W. & Mbuthia, E. K. 2016. Heavy metals and parasitic geohelminths toxicity among geophagous pregnant women: a case study of Nakuru Municipality, Kenya. *Environmental geochemistry and health,* 38(1), pp. 123-131.

Ogbe, M.N., Edet, E.E. and Isichel, N.N. 2002. Intestinal Helminth infection in primary School Children in areas of operation of shell petroleum Development Company of Nigeria (SPDC) western division in Delta State. *The Nig. J. Parasitiol., 23*, 3-10.

Okullo, J.O., Moturi, W.N., and Ogendi, G.M. 2017. Open Defaecation and Its Effects on the Bacteriological Quality of Drinking Water Sources in Isiolo County, Kenya. *Environmental Health Insights*, *11*, 1178630217735539. http://doi.org/10.1177/1178630217735539

Oliver, M.A. 1997. Soil and human health: A review. *European Journal of Soil Science, 48*(4), 573–592.

Onabanjo, V. 2010. Local government investment outreach and sustainability of microfinance institutions: A case study of BURO, Bangladesh. The Journal of Social, Political, and Economic Studies, 34, 318-346.

Otto, C.C. 2014. *In Vitro and In Vivo Assessment of the Mechanism of Action and Efficacy of Antibacterial Clays for the Treatment of Cutaneous Infections..* s.l.:Arizona State University.

Pandey, P.K., Kass, P.H., Soupir, M.L., Biswas, S. and Singh, V.P. 2014. Contamination of water resources by pathogenic bacteria. *AMB Express,* 4(1), p. 51.

Perridge, A. 2010. Geophagic practices and geophagic soil nematode content in Thabo Mofutsanyane district, South Africa (MTech, Bloemfontein: Central University of Technology, Free State).

Perridge, A., Fossey, A., Olivier, D., Ekosse, G.E. and de Jager, L. 2011. Geophagic soil colour nematode content in the District of Thabo Mofutsanyane, Free State, South Africa. In: GE Ekosse, L de Jager, VM Ngole (Eds.): An Innovative Perspective on the Role of Clays and Clay Minerals, and Geophagia on Economic Development. Conference Proceedings of the 1st International Conference on Clays and Clay Minerals in Africa, and 2nd International Conference on Geophagia in Southern Africa, Bloemfontein, South Africa. 314-320.

Peters, W. and Gilles, H.M. 1989. A Colour Atlas of Tropical Medicine and Parasitology. Third edition. English Language Book Society, London: Wolfe Publishing.

Peter, G. 2011. Geophagia in Swaziland: Habits and characteristics of geophagic individuals. In: G.E Ekosse, L de Jager, V.M Ngole (Eds.): An Innovative Perspective on the Role of Clays and Clay Minerals, and Geophagia on Economic Development. Conference Proceedings of the 1st International Conference on Clays and Clay Minerals in Africa, and 2nd International Conference on Geophagia in Southern Africa, Bloemfontein, South Africa, pp. 353-361.

Phakoago, M. V. 2017. Geophagic practice and characterisation of plant remains in geophagic soils in sekhukhune area, limpopo province, south africa. *masters dissertation submitted at the university of venda.*

Phiri, K., Whilty, C.L.M. and Graham, S.M. 2002. Urban/rural differences in prevalence and risk factors for intestinal helminth infection in southern Malawi. *J Parasitiol, 18*, 461-466.

Platts-Mills, J., Babji, S., Bodhidatta, L., Gratz, J., Haque, R., Havt, A. and Shakoor, S. 2015. Pathogen-specific burdens of community diarrhoea in developing countries: a multisite birth cohort study (MAL-ED). *The Lancet Global health,* 3(9), pp. e564-e575.

Prasad, A.S. 2014. Zinc is an antioxidant and anti-inflammatory agent: its role in human health. *Frontiers in nutrition,* Volume 1.

Profet, M. 1982. Pregnancy sickness as adaptation: A deterrent to maternal ingestion of teratogens. In: SL Young, MJ Wilson, S Hiller 2010 (Eds.): Differences and Commonalities in Physical, Chemical and Mineralogical Properties of ZanzibariGeophagic Soils. *J ChemEcol, 36*, 129- 140.

Prüss-Ustün, A., Bartram, J., Clasen, T., Colford, J.M., Cumming, O., Curtis, V. and Freeman, M.C. 2014. Burden of disease from inadequate water, sanitation and hygiene in low-and middle-income settings: a retrospective analysis of data from 145 countries. *Tropical Medicine & International Health,* 19(8), pp. 894-905.

Rainville, A.J. 1998. Pica practices of pregnant women are associated with lower maternal haemoglobin level at delivery. Journal of the American Dietetic Association, 98:293-296.

Rajagopal, S., Hotez, P. and Bundy, D. A. 2014. Micronutrient supplementation and deworming in children with geohelminth infections. *PLoS neglected tropical diseases,* 8(8), p. e2920.

Rajgire, A.V. 2013. Open Defecation: A Prominent Source of Pollution in Drinking Water in Villages. International Journal of Life Science Biotechnology and Pharma Research, Vol. 2, No.1.

Rana, A.M. 2009. Effect of Water, Sanitation and Hygiene Intervention in reducing self-reported Waterborne Diseases in Rural Bangladesh. BRAC Centre, Bangladesh. (Online). Available: www.brac.net/research. (Accessed 25 May 2017).

Raphuthing, M., 2015. *Association between geophagia and haematological parameters of iron deficiency anaemia amongst geophagic Qwa-Qwa women.* s.l.:(Doctoral dissertation, Bloemfontein: Central University of Technology, Free State).

Rashid, H., Robert, S., and Neville, A. 2005. Conditions and trends working group of the Millennium Ecosystem Assessment (program), Island press, South Africa, 917 pp.

Reid, R.M. 1992. Cultural and medical perspectives on geophagia. *Medical Anthropology, 13*, 337-351.

Reilly, C. and Henry, J. 2000. Geophagia: Why do humans consume soil? Nutr. *Bull. 25*(2), 141-144.

Riang'a, R.M., Broerse, J. and Nangulu, A.K. 2017. Food beliefs and practices among the Kalenjin pregnant women in rural Uasin Gishu County, Kenya. *Journal of ethnobiology and ethnomedicine,* 13(1), p. 29.

Saathoff, E., Olsen, A., Kvalsvig, J. D. and Geissler, P. W. 2002. Geophagy and its association with geohelminth infection in rural schoolchildren from northern KwaZuluNatal, South Africa Transactions of the Royal Society of Tropical Medicine and Hygiene. 96 (5): 485-90.

Saathoff, E., Olsen, A, Kvalsvig, J.D and Appleton, C.C. 2004. Patterns of geohelminth infection, impact of albeeendazole treatment and re-infection after treatment in school children from rural KwaZulu-Natal, South Africa. Infectious Diseases, vol. 4, pp. 27.

Sage JC. 1962. The practice, incidence and effect of starch eating on Negro women at Temple University Medical Centre. MS thesis, Temple University, Philadelphia.

Santos, A.M., Benute, G.R., Nomura, R.M., Santos, N.O., De Lucia, M.C. and Francisco, R.P. 2016. Pica and Eating Attitudes: A Study of High-Risk Pregnancies. *Maternal and child health journal,* 20(3), pp. 577-582.

Sandor, F. and Estrada, J. (2008) Soil Testing: Perennial Crop Support Series, Jalalabad Afghanistan. Roots of Peace. 2008-001-AFG.

Saunders, C., Padilha, C.P. and Della, L.B. 2009. Pica: epidemiology and association with pregnancy complications (in Portuguese). Rev. Bras Ginecol Obstet., vol 31, pp 440-446.

Schistosomiasis Research Group. 2009. Nematode. University of Cambridge. [Accessed 18 October 2010].

Severance, H.W., Holt, T., Patrone, N.A. and Chapman, L. 1988. profound muscle weakness and hypokalaemia due to clay ingestion. *Southern Medical Journal, 18*, 272-274.

Shen, Y., Oki, T., Kanae, S., Hanasaki, N., Utsumi, N. and Kiguchi, M. 2014. Projection of future world water resources under SRES scenarios: an integrated assessment. *Hydrological Sciences Journal,* 59(10), pp. 1775-1793.

Shinondo C, Mwinkuma G. 2009. Geophagy as a risk factor for helminth infections in pregnant women in Lusaka, Zambia. Medical Journal of Zambia, vol. l, no. 35, pp. 48-52.

Shivoga, W.A. and Moturi, W.N. 2009. Geophagia as a risk factor for diarrhoea. J Infect Developing Countries, 3(2):94-98.

Simon, S.L. 1998. Soil ingestion by humans: a review of history, data and aetiology with application to risk assessment of radioactively contaminated soil. Health Physiology, vol. 74, pp. 647-672.

Simpson E, Mull J, Longley E, East J. 2000. Pica during pregnancy in low-income women born in Mexico. Western Journal of Medicine, 173:20-24.

Singer, M.J. and Munns, D. N. 2006. Soils. An Introduction, 6th E . Pearson Pentice Hall, Upper Saddle River, New Jersey.

Slamova, R., Trckova, M., Vondruskova, H., Zraly, Z., Pavlik, I. 2011. Clay minerals in animal nutrition. Appl. Clay Sci., 51: 395-398.

Sobsey, M.D. 2002. Managing water in the home: Accelerated health gains from improved water supply. Geneva: World Health Organisation.

Soller, J.A., Schoen, M.E., Varghese, A., Ichida, A., Eftim, S. and Ravenscroft, J.E. 2014. Human health risk implications of multiple sources of faecal indicator bacteria in a recreational waterbody. *Water research,* Volume 66, pp. 254-264.

Songca, S.P, Ngole V., Ekosse G., de Jager, L. 2010. Demographic characteristics associated with consumption of geophagic clays among ethnic groups in the Free State and Limpopo provinces. Indilinga African Journal of indigenous knowledge systems, Vol 9 no.1 pp.110-123

Stokes, T. 2006. The Earth –Eaters. Nature publishing group. NATURE, vol. 444, pp. 543-544.

Sumbele, I.U.N., Ngole, V.M., and Ekosse, G.E. 2011. Health risks associated with ingestion of some geophagic soils from Eastern Cape Province, South Africa. In Ekosse et al. (eds.) an innovative Perspective on the role of clays and clay minerals, and geophagia on Economic Development. Book of Conference Proceedings of the 1st International Conference on clays and clay minerals in Africa, and 2nd International Conference on geophagia in Southern Africa, Bloemfontein, South Africa. pp. 323-331

Tateo, F., Summa, V., Boneli G.C. and Bentivenga, G. 2001. Mineralogy and geochemistry of herbalist's clays for internal use: simulation of the digestive process. Applied Clay Science, vol. 20, pp. 97-109.

Tateo, F., Summa, V., Giannossi, M.L. and Ferraro, G. 2006. Healing Clays: Mineralogical and geochemical constraints on the preparation of clay-water suspension (argillic water). Application of Clay Science, vol. 33, no. 3-4, pp. 181-194.

Tayie, F.A., Koduah, G.G. and Mork, S.A.P. 2013. Geophagia clay soil as source of mineral nutrients and toxicants. Francis Tayie. Vol. 13, no. 1, pp. 7157-7170.

Thompson, C.J.S. 1913. Terra Sigillata: A famous medicament of ancient times. Trans 17th International Medical Congress, London. *History of Medicine, 23*, 433-433.

Thomson, J. 1997. Anaemia in pregnant women in eastern Caprivi, Namibia. South African Medical Journal, 87:1544-1547.

Tumwine, J.K. 2005. clean drinking water for homes in Africa and other less developed countries*. British Medical Journal,* 331:468.

Traversa, D., di Regalbono, A.F., Di Cesare, A., La Torre, F., Drake, J. and Pietrobelli, M. 2014. Environmental contamination by canine geohelminths. Parasites and vectors, 7(1), p. 67.

Tshibalo, A.E., Dhansay, T., Nyabeze, P., Chevallier, L., Musekiwa, C. and Olivier, J. 2015. Evaluation of the geothermal energy potential for South Africa. *Evaluation,* Volume 19, p. 25.

University of Chicago press journal. “Eating dirt can be ood the belly researchers find.” Science daily, 4 June 2011.

USAID. 2003. USAID Investments in Drinking Water Supply and Related Activities A Report to the U.S. House and Senate Appropriations Committees.

Utara, S. 2002. Chemical analyses of pica soil eaten by the villagers in Sisaket Province. MSc Unpublished thesis, Suranaree University of Technology, ISBN 974-533-252-6, Thailand. p.71.

Water aid. 2011. URL: www.wateraid.org (cited on 24th Dec. 2011)].

Van Onselen, A., Walsh, C., Veldman, F. J. and Brand, C. 2015. The Impact of Geophagia on the Iron Status of Black South African Women. *World Academy of Science, Engineering and Technology, International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering,* 9(7), pp. 819-824.

Van Wyk, M. 2013. The investigation of iron and mineral deficiency associated with the practice of geophagia. Central University of Technology: (Doctoral dissertation, Bloemfontein).

Vermeer, D.E. (1966) Geophagy among the Tiv of Nigeria. Annals of the Association of American Geographers, 56(2), pp.197-204.

Vermeer, D.E. and Frate, D.A. 1979. Geophagia in rural Mississippi: environmental and cultural contexts and nutritional implications. *The American Journal of Clinical Nutrition.32*, 2129 – 2135.

Vermeer, D.E. and Ferrell, R.E. Jr. 1985. Nigerian geophagical clay: a traditional antidiarrheal pharmaceutical. Science, 227:634-636.

Walker, A.R.P., Walker, B.F., Sookaria, F.I., Canan, R.J. 1997. Pica. Journal of Royal Social Health, vol.1147(5): pp. 280-284.

White, H. 2000. A reality check for data snooping. Econometria, 68 (5), pp.1097-1126.

WHO/UNICEF Joint Water Supply, and Sanitation Monito. 2014. *Progress on drinking water and sanitation: 2014 update.* s.l.: World Health Organization.

WHO. 1996. Fighting Disease, Fostering Development. In the World Health Report, W.H.O, Geneva.

WHO and UNICEF. 2000. Global water supply and sanitation assessment report. USA: WHO/UNICEF.

WHO. 2004. Draft research agenda: International network to promote safe household water treatment and storage. Geneva: World Health Organisation.

WHO. 2008. Soil-transmitted helminthiasis. *Weekly Epidemiological Record. 83*, 237 - 252. Geneva.

WHO. 2012. Progresss on Drinking Water and Sanitation: 2012 Update; Joint Monitoring Programme, UNICEF: New York, NY, USA, 2012.

WHO. 2010. WHO Statistical Information System. Geneva: World Health Organisation.

Wiley, A.S, and Katz, S.H. 1998. Geophagy in pregnancy: A test of a hypothesis, current *Anthropology, 39*, 532-545.

Wiley, J.M., Sherwood, L.M. and Wolverton, C. 2008. Staphylococcae Prescott, Harley and Klein's Microbiology 7th edition. pp 968-972.

Wilson, M.J. 2003. Clay mineralogical and related characteristics of geophagic materials. *Journal of Chemical Ecology, 29*(7): 1525-1545.

Winn, W., Allen, S., Janda, W., Koneman, E., Procop, G., Schreckenberger, P. and Woods, G. 2006. Koneman's Colour Atlas and Textbook of Diagnostic Microbiology. Sixth edition. Philadelphia: Lippincott Williams and Wilkins.

Worrell, C.M., Wiegand, R.E, Davis, S.M., Odero, K.O., Blackstock, A., Cuellar, V. and Fox, L.M. 2016. A cross-sectional study of water, sanitation, and hygiene-related risk factors for soil-transmitted helminth infection in urban school-and preschool-aged children in Kibera, Nairobi. *PloS one,* 11(3), p. e0150744.

Woywodt, A. and Kiss, A. (1999) Perforation of the sigmoid colon due to geophagia. *Archives of Surgery, 134,* 88-89.

Woywodt, A. and Kiss, A. 2002. Geophagia: the history of earth-eating. J. *Royal Soc. Med. 95*, 143-146.

Yanai, J., Noguchi, J., Yamada, H., Sugihara, S., Kilasara, M. and Kosaki, T. 2009. "Function of geophagy as supplementation of micronutrients in Tanzania". Soil Science and Plant Nutrition, 55:215-223.

Young, S.L., Goodman, D., Farag, T.H., Ali, S.M., Khatib, M.R., Khalfan, S.S., Tielsch, J.M. and Stoltzfus, R.J. 2007. Geophagia is not associated with Trichuris or hookworm transmission in Zanzibar, Tanzania. *Transactions of the Royal Society of Tropical Medicine and Hygiene. 101*(8): 766 - 772.

Young, S.L., Ali, S.M.; Wilson, J.; Hillier, S.; Rasmussen, K.M. and Stoltzfus, R.J. 2008. Pica is associated with pregnancy, anemia and gastrointestinal distress among Zanzibar women. In; Ekosse, G.I.E. and de Jager L (Eds) Book of Abstracts, 1st International Conference: Geophagia in Southern Africa, Central University of Technology, Bloemfontein, Free State, South Africa, 22nd -24th October 2008.

Young, S.L., Wilson, M.J., Hillier, S., Delbos, E., Ali, S.M., and Stoitzfus, R.J. 2010. Differences and Commonalities in physical, chemical and mineralogical properties of Zanzibar geophagic soils. *Journal of Chemical Ecology, 36*, 129-140.

Zedlitz K. 2010. Pica – a historical “eating disorder” Wurzbg Medizinhist Mitt, 29: 402-433.

Ziegler, J.L. 1997. Geophagy: A vestige of paleonutrition? Trop. *Med. Int. Health, 2*(7), 609-611.

APPENDICES

APPENDIX 1: QUESTIONNAIRE (HUMAN GEOPHAGIA)

Individual Questionnaire Related to Human Geophagia

Introduction

The University of Venda, South Africa is carrying out a study to characterize habits related to human and enzootic geophagia in South Africa. It is also designed to physicochemical, microbiologically, mineralogical and ecologically characterize the soils that are preferred by geophagic individuals in the country. This exercise is mainly for academic purposes. However, information provided may be generally used to improve methods of harvesting geophagic soils that will guarantee the health of geophagic individuals. Strict confidentiality of the information will be guaranteed at all times. Respondents are therefore requested to cooperate with the interviewees in order to facilitate this study.

Date of interview…………………………………………………...

Name of interviewee (optional)…………………………………...

Area (Address)……………………………………………………...

A. DEMOGRAPHIC INFORMATION

1. **Geographic Information**

1. Location	1. Mark the correct option		2. Specific town or area
2. Location	Rural	Suburban	Urban
3. Specify town or area	Rural	Suburban	Urban

2. **Personal and Demographic Information**

4. Sex	Male	Female			
5. Age					
6. Number of children					
7. Ages of children					
8. Sex of children					
9. Marital status	Married	Divorced	Single	Living together	Cohabiting
10. Income source	Wage employment	None wage employment	Others, please specify		
11. Occupation					
12. Income					
13. Educational level	Illiterate	Primary	Secondary	Vocational	Technical
	Teacher training	Higher education	Post graduate	Professional	Other (specify)

B. SOCIO-ECONOMIC AND CULTURAL ASPECTS

1. Habits

14. Are you presently consuming soil?	Yes		No	
15. If yes how often do you consume the soil?	Once a month	Once a week	Once a day	More than once a day

16. If yes, for how long have you been consuming soil?					
17. What is the reason for consuming soil?	Standard practice (cultural, traditional, spiritual)	Craving	Medical value	Complement diet	
	Ritualistic	When hungry	When pregnant	Don't know	Others (specify)
18. Do you crave to eat soil?	Regularly once a month	Regular weekly	Regular daily	Only when pregnant	
19. When do you crave for the soil?	Pregnant	Lactating	Both pregnant and lactating	Experiencing sleeplessness	
	Nauseated but not pregnant	Constipated	Feeling weak	Others (specify)	
20. When pregnant how often do you consume the soil?	Once a month	Weekly	Daily	Others (specify)	
21. Do you consume other none food substances?	Yes		No		
22. If yes name the substance					
23. How often do you consume this substance?	Daily	More than a week	Weekly	Monthly	
24. How much of the substance (handfuls) do you consume	Daily	More than once a day	Weekly	Monthly	
25. Do other people know that you consume clay?	Yes	No	Don't know		
26. If yes who are aware?	Family members	Extended family members	Friends	Others (specify)	
27. How do people perceive this habit of eating non-food substances	Positive	Negative	Indifferent	Don't know	
28. Is this practice more common among certain members of the community?	Yes	No	Don't know		

29. If yes, specify	

C. INDIGENOUS KNOWLEGDE

30. What substances are consumed?	Soil	Clay	Soil from termite mounds	Others (specify)
31. How are substances consumed?	Wet	Dry	With other food	Others (specify)
32. What are the traditional names of substances consumed				
33. Where do you obtain the substance	From the wild	Bought	Given	Others, specify
34. If you buy, give the brand name				
35. If you buy indicate the price per handful				
36. What is the colour of substance consumed	Reddish	Whitish	Blackish	Yellowish
	Khaki	Others (specify)		
37. Why do you prefer to consume the specific colour type	Taste	Tradition/belief	It is easily accessible	Other (specify)
38. Method of storage of substance				
39. Length of storage				

D. PHYSICO-CHEMICAL, MINERALOGICAL, GEOLOGICAL AND CHEMICAL ASPECTS

40. Where does the substance you consume come from	Hill/mountain	River bed	Termitaria	valley	Others (specify)
41. If from a mound, where specifically on the mound is substance collected	Surface	Inside mound above the surface of the soil	Inside mound below the surface of the soil	Does not matter	Not sure

42. Are substances obtained close to rocks	Yes	No	Not sure		
43. If yes, what is the type of rock	Very hard	Hard	Soft	Very soft	
44. How is the substance collected	Digging	Hand grabbing	Scrapping	Selective hand picking	Other (specify)
45. If digging how deep	0-10 cm	10-20 cm	20-30 cm	>30 cm	Others (specify)
46. How does the substance feel when collected?	Gritty	Silky	Powdery	Does not matter	Don't know
47. When are substances collected?	Wet	Dry	Does not matter	Others (specify)	
48. If collected wet, how does the substance feel?	Very sticky	Sticky	Very soapy	Soapy	Neither
49. Are substances processed before consumption?	Yes	No	Sometimes yes/no		
50. If yes, how are they processed?	Grinding	Pounding	Sieving	Slurring	Other (specify)
51. Is there any heat treatment of substance before consumption?	Yes	No	Sometimes yes/no		
52. If yes specify type of heat treatment	Baking	Boiling	Burning	Combinations (specify)	Others (specify)

E. ECOLOGICAL ASPECTS

53. If you consume substance from a termitaria, from which one	Mound	Tree		
54. If substance is collected from termite mound (section C), describe the height of the mound preferred	<0.5 m	0.5-1 m	1-2 m	>2 m
55. What is the shape of the mound	Conical	Flat topped	Dome shaped	Others (specify)
56. Do you prefer to consume the substance when	Newly constructed	Old	Does not matter	Not sure

57. What type of terrain do you normally find these mounds?	Flat	Hilly	Undulating	Valley	Others (specify)

58. Do you collect the substance from	Mound	Base of the mound	Some distance from the mound

59 if substance is collected from a tree, do you prefer it from a particular tree	Yes	No	Not sure	Does not matter
60. If yes, name the preferred tree type				

F. HUMAN HEALTH ASSOCIATED WITH GEOPHAGIA

61. Height					
62. Weight					
63. Do you know that the substance could be harmful to your health	Yes		No		
64. If yes, in what sense	Constipation	Abdominal pains	Poison the body	Causes tooth decay	Others (specify)
65. Were you ever operated upon for stomach problems?	Yes		No		
66. If yes, how many times and for what reason?					
67. Are you aware of the harmful substances/ parasites that may be present in the substance?	Yes		No		
68. Do you know the content of the substance	Yes		No		
69. If yes name these contents	Vitamins	Calcium	Iron	Salt	Others (specify)
70. Why do you consume substance?	To clean your body	For additional nutritional value	To protect against infections	Do not know	Others (specify)

71. Do you often get infected (common cold, flu etc)	More than once a month	Once a month	Once every three months	Twice yearly	Yearly
72. Do you ingest these substances when infected	Yes		No		Sometimes
73. Do you experience chronic illnesses	Yes			No	
74. If yes, which of these?	Headaches	Dizziness	Blood in stool	Fatigue	Chest pains
	Coughs	Muscle pains	Tremors	Blood in urine	Nose bleeding
75. Number of still born					
76. Number of children born with abnormalities					
77. Name the abnormalities					
78. Did these children reach the expected developmental and growth stages	Yes		No		Others (specify)
79. Did the children experience any pains in the muscle or joints	Yes		No		Others (specify)
80. Children under age of three that experienced parasite infections					
81. Medical condition diagnosed/ experienced	Iron deficiency	High blood pressure	Constipation	Constant headaches	Other

University of Venda
Creating Future Leaders

APPENDIX 2: ETHICAL CONSIDERATIONS

RESEARCH AND INNOVATION
OFFICE OF THE DIRECTOR

NAME OF RESEARCHER/INVESTIGATOR:
Ms FR Ravuluvulu

Student No:
11572148

PROJECT TITLE: **Effects of open defecation on geophonic soils and water resources: A case study of Siloam village in Limpopo Province, South Africa.**

PROJECT NO: SES/17/HRW/05/2811

SUPERVISORS/ CO-RESEARCHERS/ CO-INVESTIGATORS

NAME	INSTITUTION & DEPARTMENT	ROLE
Prof GE Ekosse	University of Venda	Promoter
Prof JO Odiyo	University of Venda	Co - Promoter
Ms FR Ravuluvulu	University of Venda	Investigator – Student

ISSUED BY:
UNIVERSITY OF VENDA, RESEARCH ETHICS COMMITTEE

Date Considered: December 2017
Decision by Ethical Clearance Committee Granted
Signature of Chairperson of the Committee: ....
Name of the Chairperson of the Committee: Senior Prof. G.E. Ekosse

UNIVERSITY OF VENDA
DIRECTOR
RESEARCH AND INNOVATION
2018 -01- 24
Private Bag X5050
Thohoyandou 0950

University of Venda
PRIVATE BAG X5050, THOHOYANDOU, 0950, LIMPOPO PROVINCE, SOUTH AFRICA
TELEPHONE (015) 962 8504/8313 **FAX** (015) 962 9060
"A quality driven financially sustainable, rural-based Comprehensive University"

APPENDIX 3: CONSENT FORM

LETTER OF INFORMATION

Title of the Research Study: Effects of open defecation on geophagic soil and water resources: A case study of Siloam village in Limpopo Province, South Africa

Principal Investigator/s/ researcher: Ravuluvulu F.R, a student who have a degree of Bachelor of Earth Science in Hydrology and Water Resources and currently doing master's degree.

Co-Investigator/s/supervisor/s: Prof G.E Ekosse and Prof J.O Odiyo

Brief Introduction and Purpose of the Study: A questionnaire titled (Human and enzootic geophagia questionnaire) developed by Ekosse (2007) will be administered as part of the investigation to obtain information about the practice of human geophagia in Siloam village. This questionnaire was used to gather data about the demographic, socio-economic, medicinal and cultural beliefs of geophagic practitioners who consume geophagic soils. Simultaneously, information was gathered on the importance of consuming geophagic soils and the practitioners' indigenous knowledge pertaining to the practice of geophagia. This questionnaire was distributed to the practitioners in Siloam village. These questionnaires also seek information on the specific areas where the geophagic soils are mined.

Outline of the Procedures: Participants were interviewed using a structured questionnaire. The participants were interviewed individually at the comfort of their own home and they also decide what time they want to be interviewed and the interviews will only take approximately 10 minutes of each participant.

Risks or Discomforts to the Participant: None

Benefits: Publications, the participants will gain knowledge regarding consumption of geophagic material and they will be aware of the risks involved when practicing geophagia and how their health will be negatively affected if they continue practicing it.

Reason/s why the Participant May Be Withdrawn from the Study: illness, discomfort, adverse reactions, etc. There were no adverse consequences for the participant if they choose to withdraw

Confidentiality: The participants were not being required to fill in their names and the information that was obtained did not specify who provided the information when reporting.

Persons to Contact in the Event of Any Problems or Queries: Please contact the researcher (Ravuluvulu F.R) on 082 761 9124, myco-supervisor (Prof. J.O Odiyo) on015 962 8511 or the University Research Ethics Committee Secretariat on 015 962 9058. Complaints can be reported to the Director: Research and Innovation, Senior Prof G.E Ekosse on 015 962 8504 or Georges Ivo.Ekosse@univen.ac.za

CONSENT

Statement of Agreement to Participate in the Research Study:

•I hereby confirm that I have been informed by the researcher, Ravuluvulu Funanani Rachel, about the nature, conduct, benefits and risks of this study- Research Ethics clearance number………….

•I have also received, read and understood the above written information (Participant Letter of Information) regarding the study.

•I am aware that the results of the study, including personal details regarding my sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.

•In view of the requirements of research, I agree that the data collected during this study can be processed in a computerized system by the researcher.

•I may, at any stage, without prejudice, withdraw my consent and participation in the study.

•I have had sufficient opportunity to ask questions and (of my own free will) declare myself prepared to participate in the study.

•I understand that significant new findings developed during the course of this research which may relate to my participation will be made available to me.

Full Name of Participant Date Time Signature

I, Ravuluvulu Funanani Rachel, herewith confirm that the above participant has been fully informed about the nature, conduct and risks of the above study

Full Name of Researcher Date Signature

Full Name of Witness (If applicable) Date Signature

Full Name of Legal Guardian (If applicable) Date Signature

APPENDIX 4: STATISTICAL DATA

4. A DEMOGRAPHIC INFORMATION

Q4 Sex

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	male	7	2.3	2.5	2.5
	female	270	88.2	97.5	100.0
	Total	277	90.5	100.0	
Missing	System	29	9.5		
Total		306	100.0		

Q9 Marital status

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	married	38	12.4	13.7	13.7
	divorced	13	4.2	4.7	18.3
	single	190	62.1	68.3	86.7
	living together	37	12.1	13.3	100.0
	Total	278	90.8	100.0	
Missing	System	28	9.2		
Total		306	100.0		

Q10 Income source

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wage employment	41	13.4	16.9	16.9
	none wage employment	198	64.7	81.5	98.4
	others	4	1.3	1.6	100.0
	Total	243	79.4	100.0	
Missing	System	63	20.6		
Total		306	100.0		

Q13 Educational level

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	illiterate	14	4.6	5.1	5.1
	primary	17	5.6	6.3	11.4
	secondary	124	40.5	45.6	57.0
	vocational	22	7.2	8.1	65.1
	technical	34	11.1	12.5	77.6
	teacher training	5	1.6	1.8	79.4
	higher education	34	11.1	12.5	91.9
	postgraduate	7	2.3	2.6	94.5
	professional	15	4.9	5.5	100.0
	Total	272	88.9	100.0	
Missing	System	34	11.1		
Total		306	100.0		

4. B SOCIO-ECONOMIC AND CULTURAL ASPECTS

Q14 Are you presently consuming soil?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	199	65.0	70.6	70.6
	no	83	27.1	29.4	100.0
	Total	282	92.2	100.0	
Missing	System	24	7.8		
Total		306	100.0		

Q15. If yes how often do you consume the soil?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	once a month	12	3.9	6.4	6.4
	once a week	22	7.2	11.7	18.1
	once a day	85	27.8	45.2	63.3
	more than once a day	69	22.5	36.7	100.0
	Total	188	61.4	100.0	
Missing	System	118	38.6		
Total		306	100.0		

Q17. What is the reason for consuming soil?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	craving	125	40.8	58.1	58.1
	medical value	1	.3	.5	58.6
	complement diet	1	.3	.5	59.1
	when hungry	9	2.9	4.2	63.3
	when pregnant	45	14.7	20.9	84.2
	don't know	32	10.5	14.9	99.1
	other	2	.7	.9	100.0
	Total	215	70.3	100.0	
Missing	System	91	29.7		
Total		306	100.0		

Q18. Do you crave to eat soil?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	once a month	11	3.6	5.9	5.9
	weekly	18	5.9	9.6	15.5
	daily	140	45.8	74.9	90.4
	when pregnant	18	5.9	9.6	100.0
	Total	187	61.1	100.0	
Missing	System	119	38.9		
Total		306	100.0		

Q19. When do you crave for the soil?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	pregnant	72	23.5	44.7	44.7
	lactating	10	3.3	6.2	50.9
	pregnant & lactating	3	1.0	1.9	52.8
	sleeplessness	74	24.2	46.0	98.8
	nauseated	1	.3	.6	99.4
	feeling weak	1	.3	.6	100.0
	Total	161	52.6	100.0	
Missing	System	145	47.4		
Total		306	100.0		

Q20. When pregnant how often do you consume the soil?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	once a month	3	1.0	3.9	3.9
	weekly	11	3.6	14.3	18.2
	daily	63	20.6	81.8	100.0
	Total	77	25.2	100.0	
Missing	System	229	74.8		
Total		306	100.0		

Q21. Do you consume other none food substances?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	22	7.2	14.2	14.2
	no	133	43.5	85.8	100.0
	Total	155	50.7	100.0	
Missing	System	151	49.3		
Total		306	100.0		

Q23. How often do you consume this substance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	daily	3	1.0	13.6	13.6
	weekly	11	3.6	50.0	63.6
	monthly	8	2.6	36.4	100.0
	Total	22	7.2	100.0	
Missing	System	284	92.8		
Total		306	100.0		

Q24. How much of the substance (handfuls) do you consume

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	daily	3	1.0	15.0	15.0
	weekly	9	2.9	45.0	60.0
	monthly	8	2.6	40.0	100.0
	Total	20	6.5	100.0	
Missing	System	286	93.5		
Total		306	100.0		

Q25. Do other people know that you consume clay?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	116	37.9	62.4	62.4
	no	28	9.2	15.1	77.4
	don't know	40	13.1	21.5	98.9
	4.00	2	.7	1.1	100.0
	Total	186	60.8	100.0	
Missing	System	120	39.2		
Total		306	100.0		

Q26. If yes who are aware?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	family members	71	23.2	56.8	56.8
	extended family members	9	2.9	7.2	64.0
	friends	45	14.7	36.0	100.0
	Total	125	40.8	100.0	
Missing	System	181	59.2		
Total		306	100.0		

Q27. How do people perceive this habit of eating non-food substances

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	positive	44	14.4	24.6	24.6
	negative	58	19.0	32.4	57.0
	indifferent	6	2.0	3.4	60.3
	don't know	71	23.2	39.7	100.0
	Total	179	58.5	100.0	
Missing	System	127	41.5		
Total		306	100.0		

Q28. Is this practice more common among certain members of the community?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	94	30.7	51.6	51.6
	no	6	2.0	3.3	54.9
	don't know	79	25.8	43.4	98.4
	4.00	3	1.0	1.6	100.0
	Total	182	59.5	100.0	
Missing	System	124	40.5		
Total		306	100.0		

4. C INDIGENOUS KNOWLEDGE

Q30. What substances are consumed?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	soil	40	13.1	20.8	20.8
	clay	143	46.7	74.5	95.3
	soil from termite	9	2.9	4.7	100.0
	Total	192	62.7	100.0	
Missing	System	114	37.3		
Total		306	100.0		

Q31. How are substances consumed?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wet	3	1.0	2.8	2.8
	dry	104	34.0	97.2	100.0
	Total	107	35.0	100.0	
Missing	System	199	65.0		
Total		306	100.0		

4. D PHYSICO-CHEMICAL, MINERALOGICAL, GEOLOGICAL AND CHEMICAL ASPECTS

Q41. If from a mound, where specifically on the mound is substance collected

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	surface	7	2.3	43.8	43.8
	inside mound	3	1.0	18.8	62.5
	doesn't matter	5	1.6	31.3	93.8
	not sure	1	.3	6.3	100.0
	Total	16	5.2	100.0	
Missing	System	290	94.8		
Total		306	100.0		

Q42. Are substances obtained close to rocks

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	33	10.8	30.0	30.0
	no	65	21.2	59.1	89.1
	not sure	12	3.9	10.9	100.0
	Total	110	35.9	100.0	
Missing	System	196	64.1		
Total		306	100.0		

Q43. If yes, what is the type of rock

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very hard	1	.3	2.9	2.9
	hard	11	3.6	31.4	34.3
	scrapping	23	7.5	65.7	100.0
	Total	35	11.4	100.0	
Missing	System	271	88.6		
Total		306	100.0		

Q44. How is the substance collected

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	digging	90	29.4	59.2	59.2
	hand grabbing	29	9.5	19.1	78.3
	scrapping	17	5.6	11.2	89.5
	selective hand picking	16	5.2	10.5	100.0
	Total	152	49.7	100.0	
Missing	System	154	50.3		
Total		306	100.0		

Q45. If digging how deep

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-10cm	10	3.3	15.4	15.4
	10-20cm	14	4.6	21.5	36.9
	20-30cm	41	13.4	63.1	100.0
	Total	65	21.2	100.0	
Missing	System	241	78.8		
Total		306	100.0		

Q46. How does the substance feel when collected?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	gritty	5	1.6	5.1	5.1
	silky	4	1.3	4.1	9.2
	powdery	5	1.6	5.1	14.3
	doesn't matter	82	26.8	83.7	98.0
	don't know	2	.7	2.0	100.0
	Total	98	32.0	100.0	
Missing	System	208	68.0		
Total		306	100.0		

Q47. When are substances collected?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	wet	13	4.2	9.3	9.3
	dry	78	25.5	55.7	65.0
	doesn’t matter	49	16.0	35.0	100.0

Q48. If collected wet, how does the substance feel?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	very sticky	1	.3	11.1	11.1
	sticky	4	1.3	44.4	55.6
	very soapy	3	1.0	33.3	88.9
	neither	1	.3	11.1	100.0
	Total	9	2.9	100.0	
Missing	System	297	97.1		
Total		306	100.0		

	Total	140	45.8	100.0	
Missing	System	166	54.2		
Total		306	100.0		

Q49. Are substances processed before consumption?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	1	.3	.6	.6
	no	148	48.4	96.1	96.8
	sometimes	5	1.6	3.2	100.0
	Total	154	50.3	100.0	
Missing	System	152	49.7		
Total		306	100.0		

4. E ECOLOGICAL ASPECTS

Q51. Is there any heat treatment of substance before consumption?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	46	15.0	25.7	25.7
	no	132	43.1	73.7	99.4
	sometimes	1	.3	.6	100.0
	Total	179	58.5	100.0	
Missing	System	127	41.5		
Total		306	100.0		

Q52. If yes specify type of heat treatment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	baking	42	13.7	84.0	84.0
	boiling	1	.3	2.0	86.0

Q53. If you consume substance from a termitaria, from which one

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	mound	17	5.6	51.5	51.5
	tree	16	5.2	48.5	100.0
	Total	33	10.8	100.0	
Missing	System	273	89.2		
Total		306	100.0		

	burning	7	2.3	14.0	100.0
	Total	50	16.3	100.0	
Missing	System	256	83.7		
Total		306	100.0		

Q55. What is the shape of the mound

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	flat topped	1	.3	16.7	16.7
	dome shaped	5	1.6	83.3	100.0
	Total	6	2.0	100.0	
Missing	System	300	98.0		
Total		306	100.0		

Q56. Do you prefer to consume the substance when

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	newly constructed	24	7.8	77.4	77.4
	old	4	1.3	12.9	90.3
	doesn't matter	3	1.0	9.7	100.0
	Total	31	10.1	100.0	
Missing	System	275	89.9		
Total		306	100.0		

Q57. What type of terrain do you normally find these mounds?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	flat	4	1.3	66.7	66.7
	hilly	1	.3	16.7	83.3
	valley	1	.3	16.7	100.0
	Total	6	2.0	100.0	
Missing	System	300	98.0		
Total		306	100.0		

Q58. Do you collect the substance from

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	mound	16	5.2	88.9	88.9
	base of mound	1	.3	5.6	94.4
	some distance from mound	1	.3	5.6	100.0
	Total	18	5.9	100.0	
Missing	System	288	94.1		
Total		306	100.0		

Q59.if substance is collected from a tree, do you prefer it from a particular tree

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	13	4.2	76.5	76.5
	no	3	1.0	17.6	94.1
	doesn't matter	1	.3	5.9	100.0
	Total	17	5.6	100.0	
Missing	System	289	94.4		
Total		306	100.0		

4. F HUMAN HEALTH ASSOCIATED WITH GEOPHAGIA

Q63. Do you know that the substance could be harmful to your health

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	54	17.6	28.9	28.9
	no	133	43.5	71.1	100.0
	Total	187	61.1	100.0	
Missing	System	119	38.9		
Total		306	100.0		

Q66. If yes, how many times and for what reason?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	1	.3	50.0	50.0
	no	1	.3	50.0	100.0
	Total	2	.7	100.0	
Missing	System	304	99.3		
Total		306	100.0		

Q65. Were you ever operated upon for stomach problems?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	1	.3	.5	.5
	no	185	60.5	99.5	100.0
	Total	186	60.8	100.0	
Missing	System	120	39.2		
Total		306	100.0		

67. Are you aware of the harmful substances/ parasites that may be present in the substance?

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	50	16.3	26.9	26.9
	no	136	44.4	73.1	100.0
	Total	186	60.8	100.0	
Missing	System	120	39.2		
Total		306	100.0		

Q68. Do you know the content of the substance

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	1	.3	.5	.5
	no	183	59.8	98.9	99.5
	4.00	1	.3	.5	100.0
	Total	185	60.5	100.0	
Missing	System	121	39.5		
Total		306	100.0		

Q 71. Do you often get infected (common cold, flu etc.)

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	once a month	7	2.3	3.7	3.7
	once every 3 months	34	11.1	18.2	21.9
	twice yearly	59	19.3	31.6	53.5
	yearly	87	28.4	46.5	100.0
	Total	187	61.1	100.0	
Missing	System	119	38.9		
Total		306	100.0		

72. Do you ingest these substances when infected

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	30	9.8	16.6	16.6
	no	120	39.2	66.3	82.9
	sometimes	29	9.5	16.0	98.9
	4.00	2	.7	1.1	100.0
	Total	181	59.2	100.0	
Missing	System	125	40.8		
Total		306	100.0		

73. Do you experience chronic illnesses

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	yes	38	12.4	20.7	20.7
	no	145	47.4	78.8	99.5
	3.00	1	.3	.5	100.0
	Total	184	60.1	100.0	
Missing	System	122	39.9		
Total		306	100.0		