Identifying indigenous non-agricultural uses of soil in selected communities in KwaZulu-Natal, their safety for use and understanding the soil properties that govern these uses

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DECLARATION

I, **Noxolo Immaculate Hlatshwayo,** declare that;

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Dr R. Zengeni (Supervisor)

ABSTRACT

South African communities, especially in rural areas still practise indigenous soil use e.g. applying soil paste as sunscreen and geophagia among others. This study aimed to document non-agricultural uses of soil in communities such as Elandskop, KwaNxamalala, Willowfontein and Pietermaritzburg central in uMgungundlovu district. Information on soil uses was collected through key informant interviews and a baseline survey. The baseline survey was conducted through administering 50 questionnaires in each area. Ten soil samples (used for geophagia and cosmetics) were then collected from each area to analyse for soil physico-chemical and biological properties using standard analytical techniques. The safety of soils for use was also assessed through microbial (bacterial, fungal, and total coliform counts, then *E.coli* identification) and heavy metal determination. Results showed that the soil uses that were ranked as most common were cosmetics, geophagia, medicinal followed by construction as the least used. Cosmetic soil was mostly used as sunscreen or skin cleansers. While geophagia was practised for enjoyment, cravings, and as nutrient supplement. The main side effects of geophagic soil were observed to be constipation, appendix infection and development of gull stones, while side effects to cosmetic soil use were skin irritation, drying and blemishes.

Chemical analysis showed that the cosmetic soils had pHs in the acidic range (4.7 - 6.07), which corresponded with normal skin pH. The CEC was however deemed too low (3.04-24.11 $Cmol_c kg^{-1}$) for these soils to be effect as cleansers as they would not be able to adsorb impurities from the skin. Geophagic soils also had acidic pH ranges (3.73 – 5.84), which corresponded with pH of human saliva, whilst their CEC was also low (3.6 – 25.41 $Cmol_c kg^{-1}$) and typified that of low adsorption kaolinitic clays. Cosmetic soil users preferred red coloured soil as effective sunscreens. This was confirmed by mineralogy analysis that revealed a high presence of haematite in these soils, which has low UV transmission. Both quartz (which was supported by course soil textures) and haematite featured regularly in the cosmetic and medicinal soils, but these soils however lacked metals like zinc oxide and titanium oxide found in commercial sunscreens, making them less effective as sunscreens. The high levels of quartz in cosmetic and medicinal soils can also potentially cause skin abrasion when applied regularly. Geophagic soil colours varied from white through pale yellow, reddish yellow, yellow brown to light grey; which typified a range of minerals from kaolinite, quartz, calcite, and haematite. High levels of quartz however pose a risk to dental enamel damage and intestinal wall abrasion if consumed

in excess, while haematite is a beneficial source of nutritional iron. It was recommended that users select finer textures to consume or apply onto their body to avoid the negative effects of high quartz levels.

The *E.coli* bacterium was found in samples from Elandskop, KwaNxamalala, and Willowfontein, but not in those from PMB central. This could be because vendors in PMB central heat-treated their soils before selling, which helped kill these harmful bacteria. Some geophagic samples also had coliform (381-741 CFU/ml) counts that were above the limit (<200 CFU/ml) set for fresh vegetables, indicating a risk of pathogenic diseases. It was recommended that soil users from other areas should also use heat-treatment to minimise pathogenic contamination in their samples.

Cosmetic soils generally had lower concentrations of trace metal elements compared to similar studies in South Africa. Some of these elements e.g. Pb (0.13 - 6.67mg/kg), Zn (-0.14 - 0.87 mg/kg), Cd (-0.04 - 0.34 mg/kg) actually had concentrations below the recommended safety limits and were thus harmless in cosmetic soils making them safe for use. Geophagic soils mostly had low and safe levels of Cu (-0.88.-1.50 mg/kg), Zn (-0.31-1.15 mg/kg) as well as Cd (-0.0067-0.31), Fe (-3.58 to 15.85 mg/kg), Ni (-0.39-1.27mg/kg), making them essential sources of these nutrients as opposed to being toxic. However, Pb (0.27-5.93 mg/kg) and Mn (-0.19-9.56 mg/kg) levels in geophagic samples were above their safety limits set by WHO/FAO making them unsafe in this regard. Consumers must thus watch out for lead poisoning when consuming geophagic soils.

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THESIS OUTLINE

This thesis comprises six chapters. Chapter one gives a general introduction, the problem statement, aim and objectives of the study. A review of literature pertaining to various non-agricultural soil uses is presented in Chapter 2. The chapter also elucidates on the physico-chemical and microbial soil properties that have been studied. Chapters three is a survey done to understand non-agricultural soil uses, factors that guide these uses and assess how users ensure the safety of soil for use. This was done through key informant interviews and questionnaires. Chapter four addresses the second objective which is to analyses physico-chemical soil properties of the identified soils; while chapter five focuses on the safety of soil for use through microbial load and heavy metal determination. Chapter 6 concludes by making recommendations and suggestions for future research directions. A list of all the references used is provided at the end of the report.

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CHAPTER 1

1. GENERAL INTRODUCTION

1.1 Background and justification

Numerous studies have investigated the potential for combining indigenous knowledge systems with scientific knowledge for improved agricultural sustainability. Indigenous knowledge refers to the knowledge that has been passed on from generation to generation by local people through their direct interaction with the environment (Warkentin, 2006). The indigenous uses of soil for cosmetics (e.g. as sunscreens and skin cleansers), geophagia, medicinal purposes, pottery as well as construction, however, have not been well explored in South Africa. It is important to understand the properties of soil that influence its use for various purposes by indigenous people. Soil can be used for cleansing the skin, detoxification and for protection against ultra-violet radiation (Matike et al., 2011a). The ability of soil to facilitate these functions is influenced by its properties like colour, surface area, particle size distribution, nutrient value, and mineralogy (Matike et al., 2011a). Western societies have long had access to modern cosmetics, while developing countries that consist of more culturally oriented communities have depended on traditional methods to beautify their bodies.

The use of soil in North Africa dates back in history, where Egyptians used to mix white soil and scented oils for skin cleansing and spiritual purposes. In Western Kenya, the Baluyia people used white, blue, red, green, and orange soil hues on their bodies during tribal wars and for beauty purposes. Matike et al. (2010) observed that “Southern Africa, especially South Africa has a record of traditional usage of soils for cosmetics”. For example, before the arrival of modern medicine, women in Pondoland, Eastern Cape, South Africa gave birth in their homes. At the birth of the baby, the whole body was applied with *imbola* (red clays) before removing the umbilical cord. This was done to cleanse the skin and keep the baby warm (Matike et al., 2010). Traditional incision *(izingcabo*) is practised in the Zulu tribe to identify one’s clan and protect against evil spirits. The scars that are usually in the face are smeared with red clay for them to heal faster (Magwa, 2006). Currently in the Eastern Cape and KwaZulu-Natal provinces of South Africa, soils are widely used in the rural areas for cleansing, as sunscreen and for body beautification. Women in rural KwaZulu-Natal use red and white clays for photo-protection and beautifying purposes. This is because they expose themselves to the sun when doing chores like gardening, fetching water and wood. Thus, they use soil as sunscreen since they cannot afford commercial skin products (Dlova et al., 2013). The physical and chemical properties of soils used for cosmetics were well studied especially in the Eastern Cape (Matike et al., 2011a), but there is little documented information on the safety of these soils for use on humans. Matike (2011a) investigated the physico-chemical properties of soil traditionally used for skin cleansing, sunscreen, and body beautification in some communities of Eastern Cape. Based on the results obtained, some red coloured soil inferred the presence of haematite, which is also a constituent of commercial sunscreens. In the investigation of cosmetic soil in KwaZulu-Natal, white-coloured soil was dominated by kaolinite and quartz, while the red soil had kaolinite, quartz, and haematite (Dlova et al., 2013).

In the past, villagers built their houses using soil and stones, while currently some villagers in rural South Africa build their huts and plaster them using local soil. In KwaZulu-Natal, huts are plastered inside with termite mound soil (*isiduli*) and finished with umcako, a slurry of local soils that is made from lime (Mhlaba, 2009). Potters in South Africa also make vessels used for brewing, drinking, and serving traditional beer using soil. Furthermore, small clay pots are used to serve *uphuthu,* a maize-based porridge and *amasi*, a delicacy of sour milk by the Zulu tribe. In Umsinga KwaZulu-Natal, potters sample clays from dry stream beds comprised of drained reddish brown Rensburg and Katspruit calcareous soils (Fowler, 2011). Clay pottery is also an indigenous skill of the Basotho, which is practised in the rural areas of QwaQwa in Free State province. They believe that the knowledge and skill of pot making are slowly being lost because the current generation does not find it interesting. Traditional uses of these clay pots include simple decoration in the household, water, and grain storage as well as for storing traditional beer at cultural events such as weddings, funerals, and family gatherings (Mulaba-Bafubiandi and Hlekane, 2015).

Geophagia on the other hand, is defined as the voluntary consumption of earth material including soil especial by women and children as well as by animals (Ekosse et al., 2011). Various reasons for geophagia have been suggested, including religious, cultural, nutritional and medicinal practices, poverty, enhancement of personal appearance, pregnancy-related cravings and enjoyment of taste, texture or smell of the substance consumed (Mathee et al., 2014). The lack of well documented and peer-reviewed information on geophagia has created many theories in some communities and unbelief in others. In Africa, geophagia is viewed as a common practice of women and is thus not regarded as important to understand (Songca et al., 2010).

Even though there is limited scientific information on the practice of geophagia, studies have been done over the years and more recently using clinical-biological methods (Songca et al., 2010). Studies show that kaolinitic clays are also used as anti-diarrheal medicine, because of their capacity to absorb water from the human digestive tract (Abrahams, 2002). Ingestion of these clays could also result in supplementing elemental nutrients such as iron and zinc, (De Jager et al., 2013). Msibi (2014) studied the practise of geophagia in parts of KwaZulu-Natal, South Africa, and concluded that the commonly ingested soils were red coloured, with local names such as *ibomvu*, *isiduli* and *isibomvu*. The motivation to practise geophagia was found to be cravings induced during pregnancy, which continued even after pregnancy.

Even though geophagia is common in South Africa, there is limited documented information on the properties of the soils consumed. Most South African studies on geophagia focuses on the usage of geophagia more than soil properties and safe use of the soils. Limited information is also available on how safe it is to consume or apply soils by humans (Mpuchane et al., 2010). Malepe et al., (2023) in their study on called for more comprehensive studies into the microbiological, chemical, and physiological effects of soil on its consumers. It is thus vital to study the properties of these soils that are consumed or applied onto the body. The aim of this research was therefore to identify the non-agricultural uses of soils, their safety for use and understand the underlying properties that govern these uses. This study focused on uMgungundlovu District of KwaZulu-Natal in the following areas: Elandskop, KwaNxamalala, Willowfontein and Pietermaritzburg central.

1.2 Specific Objectives

1.2.1 To identify non-agricultural uses of soil in selected communities of KwaZulu-Natal Province.

1.2.2 To characterise the soils used for the different purposes for physico-chemical and biological properties.

1.2. 3 To examine the safety for use of soil that is consumed or applied.

1.3 Research Questions

1.3.1 Which are the most common non-agricultural uses of soil in the selected areas of uMgungundlovu district?

1.3.2 How do the physico-chemical properties of the soil govern each choice for use?

1.3.3 How safe are the soils for use (in terms of heavy metal toxicity and contamination by pathogens)?

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In many African communities the traditional usage of soils as cosmetics is quite common (Matike et al., 2011a). To mention a few, the Himba people of Namibia smear soil on their body to protect their skin from ultraviolet radiation. While the Maasai of Kenya as well as Xhosa of South Africa apply soil for skin cleansing purposes (Matike et al., 2011a). The ability of soil to facilitate these various functions is due to its properties like colour, particle size, specific surface area and cation exchange capacity (Matike et al., 2011a). African communities determine the use of soil for cosmetics according to its colour (Bisi-Johnson et al., 2010). White and red soils are the most commonly used on the continent, but (Mpuchane et al., 2010) reported the use of black, grey, brown, orange, pink and blue soil in some instances. In Southern Africa, geophagia is a widespread practice yet the safety of this practice has not been well established (Bisi-Johnson et al., 2010). Geophagia is defined as the eating of soil or soil-like substances, mostly by women and children but there is no age or gender limit to it (Smit, 2011). There are varied reasons to justify this practice, some of which are cultural and others medicinal (Ekosse et al., 2011). South African urban women tend to entertain the idea that ingesting soil enhances their beauty. While some pregnant women ingest soil in the belief that it facilitates a smooth delivery. Soil is also ingested to supply deficient nutrients to the body (Ekosse et al., 2011).

Another indigenous practice that dates far back into African history is pottery. Traditionally, pottery vessels are used for cooking and serving food, beer brewing, transport and water storage, administering medicines and burning incense (Fowler, 2011). Contact with other cultures and technological developments meant the pottery vessels were replaced by metal pots. Construction of brick and block houses also replaced the indigenous building of houses with local soil as well as grass for roofing. Some communities in rural South Africa still build and plaster their houses with local soils though. The literature review focuses on identifying various indigenous non-agriculture uses of soil and determining specific soil properties that influence these practices. It also examines the safety of these uses, particularly in relation to soil consume in human geophagia and those used in cosmetics.

2.2 The use of soil for traditional purposes and for skin cleansing

Some South African tribes like the Zulus use red soil during a traditional ceremony for young maiden girls called "*Umemulo*", a celebration undertaken by parents to celebrate their daughters' good behaviour, the young girl smear red soil with her entourage in preparation for the ceremony to beautify skin (Magwa, 2006) . In the Xhosa tribe of South Africa, white soil (*ingceke* or *ingxwala*) is mainly used for cleansing. For the duration of the initiation period, "*abakhwetha*" boy initiates and "*intonjane*" (girl initiates) paint their faces and bodies with white soil. It functions as protection and a deep cleanser, and it also helps to identify the boys as in-training initiates since their bodies are covered with the white soil paste. After the circumcision graduation ceremony, the new initiates "*amarkwala*" are painted with red soil (*imbola*) which serves as a toning agent and is usually mixed with unsalted butter to moisturize the skin after the prolonged periods of using white soil during the initiation. Soils are also applied during the training period of traditional healers. The body of the trainee is applied with red soil (*imbola* in Xhosa) and (*ibovu* in Zulu) until the graduation day (Matike et al., 2011b).

2.2.1 The use of soil for skin protection

Indigenous African tribes utilize soil to shield their skin from the impact of the sun (Matike et al., 2010). African women, especially those from rural areas, use local soil material for photo protection. These women's duties and lifestyles require them to be outdoors for many hours each day doing gardening, fetching wood and water, cooking and performing other chores. They lack the means to purchase commercial sunscreen products thus they use soil. Two soils are commonly used: white soil locally known as *umcako* (isiZulu), and a red one known as *ibomvu* (isiZulu). The women mix the soil with water and sometimes glycerine to make a paste which is applied to the face. Figures 2.1 and 2.2 shows how the paste looks like when applied onto the face (Dlova et al., 2013). In the Eastern Cape, soils are also traditionally used by woman for skin protection, where they cover faces with soil pastes as sunscreen. In the past, among the Xhosa, soil called *ingceke* (white in colour) was smeared on crawling children. This was done to protect their skin from dirt, insect bites and the harsh effects of the sun (Matike et al., 2011b).

Figure 2.1: Woman wearing white soil *umcako* and red soil *ibovu* (Dlova et al., 2013)

2.2.2 Physico-chemical properties of soil used for cosmetic purposes

As mentioned above, the ability of soil to be effective as a cosmetic depends on certain properties like colour, particle size, specific surface area and cation exchange capacity (CEC). Many commercial cosmetic products are in the forms of gels, ointments, pastes and are applied externally on the skin. The products must be smooth, adhesive and without grittiness. These properties are mainly influenced by the texture of the product. Finer particles are generally preferred in cosmetics for their smooth application and gentle exfoliation properties. Matike., (2011a) reported texture to be of importance in soil used for traditional purposes in the Eastern Cape, since it influenced its cleansing capacity by exfoliation when applied on the skin. More than 20% of soils investigated for cleansing were dominated by the clay fraction in the order of 95 % (white), 78.4% (pale yellow) and 66.5 % (pale olive) with particle diameters of < 20µm (Matike et al., 2011a). These particle sizes were reported to be similar to those of clay mixtures used for cleansing in thermal centres, where 50-70% of the clay mixtures have particle diameters of 2 to 20µm (Smit, 2011). Eigbike (2016) conducted a study in Edo State in Nigeria to evaluate soils that are used for cosmetics. The results from the particle size analyses of this study showed that the soil samples were dominated by clay size particles ranging from 81.58-91.05% with some silt and very fine sand particles. The samples were classified as silty clay loam, silt, and sandy loam, with the majority of the samples identified as clay loam.

Soils with high CEC have been reported to ensure cleansing through absorption of toxins, bacteria and unwanted substances from the skin during external application (Matike et al., 2011a). Soils with a high CEC can exchange cations with the skin, which can have various effects, such as removing toxins or providing minerals to the skin. Clays with a high CEC are often used in detoxifying treatments. This can ensure retention of undesirable substances from the skin by the soil, consequently guaranteeing a skin cleansing action. Matike et al. (2011a) reported that the CEC of soils used traditionally for cosmetics was between 0.5 - 45 meq/100g, with a high proportion of clay particles in the soil samples justifying the high CEC. Eigbike (2016) reported soils used as cosmetics to have CEC ranges between 25-30 meq/100g. Soil pH is also another key factor that influences its use for cosmetics. According to (Schmid and Korting, 1995), the pH of skin cleansers must be similar to that of skin pH. Usually, the pH_{water} of a healthy skin range from 4.5 to 6.5.

Matike et al. (2011a) reported soil samples that were used as skin cleansers to have pH_{water} ranges of 5-9. Soils with a pH of 5-7 can be considered suitable for cleansing as little chemical reaction is expected to occur when they are applied onto the skin. However, soil samples with pH values > 9 can cause skin irritation due to the alkaline pH (Matike et al., 2011a). Eigbike (2016) reported that soil samples traditionally used for cosmetics had a pH lower than 7 indicating that they were acidic. The pH of these soils (acidic to near neutral) could also impact their ability to beautify the skin. The acidic nature of the skin enables it to function as the body's first defence against bacteria, by creating an unfavourable environment for bacterial growth.

Soil colour mainly influences its sun screening and body beautification abilities. The colour of the soil, often due to the presence of iron oxides, clay minerals, and organic matter, can determine its appeal and specific use in cosmetics. For example, clays like bentonite and kaolin are prized for their natural colours and are often used in facial masks. Table 2.1 presents the soil colours used traditionally as cosmetics as adapted from different studies. Mpuncane., (2011) reported that the common colours used in several modern beatification cosmetics products such as face powders, lip gloss, eye shadow and blusher are white, red, yellow, grey, and brown. These colours also influence the sun screening abilities of such products. Matike (2011a) reported that soil used for sunscreen had a hue of 2.5 YR corresponding to haematite (Fe_2O_3). This hue may also infer the presence of goethite. Both minerals are oxides of iron which are responsible for the reddish and yellowish colour in soil, respectively. Eigbike.,

(2016) also reported that the ability of reddish and yellowish coloured soil to function as sunscreen is influenced by haematite and goethite which have low UV radiation transmission.

Table 2.1: Soil colours used for cosmetics

Uses	Hue /Value Chroma	Colour	References
Sunscreen	2.5YR/4/8	Red	Matike et al., 2011a
Sunscreen	5YR/5/4	Reddish brown	Matike et al., 2011a
Sunscreen	2.5YR/5/8	Red	Matike et al., 2011a
Sunscreen	2.5Y/8/4	Pale yellow	Matike et al., 2011a
Sunscreen	2.5Y/8/2	White	Matike et al., 2011a
Sunscreen	2.5Y/6/4	Light yellowish brown	Matike et al., 2011a
Sunscreen	2.5Y/6/2	Light brownish grey	Matike et al., 2011a
Cosmetics	2.5Y/8/2	White	Eigbike, 2016
Cosmetics	5Y/7/2	Light grey	Eigbike,2016
Cosmetics	5YR/5/4	Reddish brown	Eigbike,2016
Cosmetic	7.5YR/5/8	Strong brown	Eigbike,2016
Cosmetics	2.5Y/N6/O	Grey	Eigbike,2016
Facial powder	10YR7/8	Yellow	Mpuchane et al., 2010
Facial	5YR/3/4	Brownish	Mpuchane et al., 2010
Facial powder	2.5YR5/8	Red	Mpuchane et al., 2010

2.2.3 Biological properties of soil used for cosmetic purposes

Much research has been done on the physico-chemical properties of soil, but the biology of cosmetic soil is an area with relatively scarce information. Mpuncane (2010) investigated the implication and safety of using soils for cosmetics by evaluating their biology. Soils containing minerals like aluminosilicate, kaolinite, montmorillonite etc., commonly have a glue-like property that promotes attachment of microorganisms and nutrients (Mpuchane et al., 2010). In Southern Africa, there are many vendors or traditional healers using soil to cure skin problems like acne or for skin cleansing. Mpuncane (2010a) investigated different properties of soil from Swaziland, Botswana and South Africa that could contribute to the growth of bacteria. Microbiological analysis like the total aerobic mesophilic plate count, coliforms and antimicrobial activity were conducted in this study. The findings showed that of the 425 isolates that were collected from the soil samples, gram positive bacteria were more dominant (65.4%) than gram negative bacteria (31%). Again, fifty percent of the gram-positive bacteria were spore formers with *Bacillus amyloliquefaciens* being the most common isolate. *Bacillus fastidious*, *B. megaterium, B. cereus*/ *ureagenesis* and *B. polymyxin* were also present in significant numbers in the soil samples. Total coliforms which are used as indicators of soil or faecal contamination were detected in only 14 of the 102 soil samples.

However, faecal coliforms particularly *E. coli*, the indicator of faecal contamination, were absent in all soil samples, while *E. vulneris* was isolated from one sample. Bacteria carry net negative charges on their surfaces. However, the capsular material they produce (which is sticky and fimbriae attachment structures) allows them to adhere to soil particles. Positively charged cations on soil colloidal surfaces also supply ionic interactions with bacterial surfaces, resulting in soil harbouring many microorganisms. The soil used for cosmetics in this study were powdery with very little moisture content and some did not have the right surface charges exposed for bacterial interactions (Mpuchane et al., 2010). This resulted in low microbial counts, with some of the soil containing few coliforms that were not considered hazardous to human health. A study by Bisi-Jonshon (2013) to evaluate the microbiological properties of soil used for cosmetics and geophagia, reported fungal counts of between 10^3-10^5 CFU/ml while other samples had extremely low counts, with only 7% of the samples having no bacteria count, while 14.28% had no fungal counts (Bisi-Johnson et al., 2013) . In a study conducted in Durban that was looking at Physical, chemical and biological characteristics of clays from

Durban (South Africa) for applications in cosmetics. The results of biological characteristics red and white clays showed no significant antimicrobial properties against tested strains like *Escherichia coli*, *Klebsiella pneumoniae*, and *Candida albicans*. The lack of activity might be due to the absence or low concentration of active antimicrobial compounds in the clay (Nkosi and Thembane, 2024).

2.3 The practice of geophagia

Geophagia is the intentional consumption of soil and earth-like material that has been practised for centuries. It is common around the world including in South Africa. It appears to be more common in women than men, in black people than white, in rural areas than urban areas and in pregnant women than non-pregnant woman (Mathee et al., 2014). There are many theories about why geophagia is practised. Several studies have theorised ways to explain nutritional, sensory and physiological, neuropsychiatric and cultural beliefs as causes of geophagia (Phakoago, 2017). According to Vermeer and Frate (1979), geophagia may be practised as a result of emotional stress or development problems, with soil being ingested to supply deficient minerals specifically zinc and iron.

It has been hypothesised that geophagic soil is favoured because it contains a high iron content, as it acts as an iron chelator thus alleviates iron deficiency (Rose et al., 2000). The sensory and physiological attributes of geophagia is that people consume soil because they enjoy its smell, taste and texture (Hunter, 1973). In Africa, pregnant women tend to believe that eating soil helps to decrease or prevent morning sickness in the initial stages of pregnancy. There is no conclusive scientific evidence to support this belief however (Henry, 2009).

Several studies have been done to try and evaluate why geophagia is practised in South Africa. The study from a questionnaire survey conducted in Oliver Tambo district in the Eastern Cape of South Africa that the major reason for eating soil was due to cravings during pregnancy. Other reasons were the pleasant taste and smell of consumed soil, while less than 1% of respondents said they consumed soil to supplement nutrients in the body (George and Ndip, 2011). Another study was done by Songca, (2010) in the Free State and Limpopo provinces to understand reasons for consumption of geophagic soils among ethnic groups. The questionnaire results showed that soil craving was the most common, followed by standard practice and pregnancy cravings for Sotho, Pedi, Tswana and Zulu ethnic groups (Songca et al., 2010). Msibi, (2011) conducted a study in uMkhanyakude district of KwaZulu-Natal on the prevalence of geophagia and found that about 83% of interviewees eat soil because of its pleasant taste, 3.2% because of hunger and 3.2% were eating to satisfy cravings. This was in contrast with the findings of the other two authors who found the main reason for practising geophagia to be cravings or pregnancy cravings. Geophagic soils have diverse origins. The vendors in South Africa collect it from mountains, valleys and riversides, while in Kenya and Tanzania they collect it from termite mounds (Phakoago, 2017). The practise of geophaga in other continents, a study In India found that geophagy is practiced among diverse female consumers in Himachal Pradesh, primarily driven by cravings for clay, which is often viewed as an addiction despite health concerns. Increased awareness and open discussions about geophagy among healthcare providers are essential to reduce stigma and improve support for affected individual. The research highlights the need for tailored antenatal care guidelines to include discussions on this practice. Overall, the findings call for systematic investigations to better understand the prevalence and health implications of geophagy in India (Traugott et al., 2019).

2.3.1 Impact of geophagia on human health

Geophagia may lead to a range of health complications such as constipation, stomach cramps, intestinal obstruction, parasitic infestation, bacterial contamination, and perforation of the intestines. Ella (1990) reported in a case study in 1989, that a 31-year-old woman practicing geophagy was admitted to hospital with symptoms of weakness, nausea, pain, fever, and lack of bowel movement. The patient was severely sick and died soon after being admitted. It was discovered that she had been eating 200-300g of soil daily during her pregnancies. This was the first case reported as "maternal death from complication of geophagia" (Smit, 2011). "The complications caused by geophagia are not common but are connected to the amount of soil consumed and usually involve parasitic infestation. The most parasitic infection caused by geophagia is ascariasis which is caused by the worm called *Ascarisis Lumbriocades*. This is characterised by abdominal pain and nausea. Anaemia resulting from geophagia is believed in some cases to be caused by worm or microbial infection of ingested soil (Bisi-John and Ekosse, 2002). The universal burden of geohelminth infections is huge. Worldwide there are approximately 3.5 billion infections with parasitic geohelminths (*Ascarisis, Trichuris*) and hookworms (*Ancylostoma caninum*) from soil ingestion.

2.3.2 Physico-chemical properties of geophagic soil

The physical properties of soil consumed plays a role in why users prefer particular soil types. Soil texture, colour, smell, and taste are parameters that are used during soil sampling. Studies conducted in South Africa show that geophagic consumers favour soils that are soft, smooth and powdery (Ekosse et al., 2010). In areas of the Free State such as Qwa-Qwa and Mangaung, geophagic users preferred silky soil, while in Limpopo province (Sekhukhune and Polokwane) they favoured gritty and powdery geophagic soil (Ekosse et al., 2010). Texture is a common soil property studied when it comes to geophagic soils. A study done by Ngole et. (2010) in the Eastern Cape showed that the geophagic soils assessed were more course in texture compared to other geophagic soils that had been studied in other parts of South Africa. The samples from this study all contained quartz (SiO_2), with at least 50% of them containing plagioclase group of minerals or kaolinite as the dominant mineral. Ingesting soil that contains quartz can have a detrimental effect on dental enamel during chewing because of the hardness of quartz.

Soil pH is an indication of acidity or alkalinity of the soil. In a study by Ngole et al., (2010) the pH_{water} of geophagic soils ranged from 5 to 7, which falls in the range of the pH for the human saliva (Oomen et al., 2000). Since these geophagic soils had pHs similar to human saliva, no significant chemical reactions should occur if the samples were in the mouth. Possible reactions can occur in the stomach because of the acidic pH of gastric juice (pH=2), depending on the material ingested or if it stays in the stomach for more than 2 hours (Oomen et al., 2000).

Ngole (2010) reported that geophagic soils from Swaziland have significantly higher CEC values compared to those from South Africa ($p < 0.005$) with mean CEC values of 9.60 and 7.28 meq/100g, respectively. According to Ngole (2010), these CEC values were lower than those reported by Abrahams and Parson, (1997). The adsorption capacity of these soils could be categorised as low, and their consumption is not likely to result in adsorption of cations from gastric intestinal tracts. This capability is influenced by their acidic pH values which may encourage clay flocculation. High CEC has been reported to reduce diarrhoea by shielding the gastrointestinal tract from diarrhoea-causing toxins (Ngole et al., 2010). In another study done in the Eastern Cape, CEC ranged from 4-17 Cmolc/kg in geophagic soils. This was relatively low and unlikely to absorb nutrients present in the intestine (Ngole and Ekosse, 2012).

2.3.3 Use of soil for nutritional and medicinal purposes

Red soil is consumed in many communities to prevent iron (Fe) deficiency because it is inferred to have a high Fe content. Healing practices of ancient cultures as well as modern society have relied on clay minerals with powerful adsorptive and absorptive properties to cure a variety of diseases. The Zimbabweans, Chadians, Malians, people from Eastern Europe and Native Americans have since used soil for healing purposes. In Southern Africa, many types of soils are sold by vendors or used by traditional healers to treat skin diseases and gastrointestinal tract problems (Matike et al., 2010). The Xhosa tribe uses grey soil called *isinuka* to cure acne (Matike et al., 2011b), while some edible white clays (kaolin) are used to remedy diarrhoea (Msibi, 2014).

In many African communities' traditional incisions or scarring known as *izingcabo* in IsiZulu is a widespread practice. According to (Brain), 1979 "scarring is defined as incisions on the body but more specifically in the face, leaving marks on the forehead, cheeks and the chin". Figures 2.3 show pictures of human face scarring. Red soil, locally called *ibomvu* is then applied onto the scar to help it heal faster (Magwa, 2006).

Figure 2.2: Linear scars on a man from the Zondi Clan in Richmond and Mchunu girl in Clermont (Magwa, 2006)

2.3.4 Physico-chemical properties of soil used for medicinal purposes

Soils used for medicine are chosen based on properties like colour, particle size, pH, CEC, and mineral content. Therefore physico-chemical soil properties play a significant role in accessibility of nutrients in ingested soils. The clay mineralogy also plays a significant role in using soils for medicinal purposes. Bentonite for example, has been reported as a natural intestinal detoxifier which is used to treat constipation, allergies, diarrhoea, indigestion, and ulcers. Kaolinitic clays are also used as anti-diarrhoeal medicine because of their ability to absorb water from the human digestive tract (Abrahams, 2002). The use of clays is related to the arrangement of aluminosilicates and other ions which are dominant in the mineral structure and determine the negative charge.

When treating different diseases; it is important to avoid possible intoxication via ingestion or skin absorption of elements in the soil. Hence, it is crucial to determine the concentration of toxic or potentially dangerous soil elements. For soil to supplement any nutrient, it must be present in the available form. Availability of the nutrient in the soil is influenced by the soil texture, mineralogy, organic matter, and pH.

2.3.5 Biological properties of soil used for geophagia and medicine

There is scarce documented information on the biology of geophagic soils. Scientific evaluation of microbiology of soils used for geophagia must be done to obtain information on the safety implications of consumption of these soils. According to Bisi-Johnson (2010), from a microbiological point of view, numerous risks are related to soil eating as the soil harbours many pathogenic microorganisms. Thus, the practice of geophagia is a channel for potential transmissions of pathogens to the human host through soil consumption (Bisi-Johnson et.al, 2010). Bacteria are the most abundant soil organisms as more than 100 million bacterial cells can be found per gram of soil. Most organisms are found in the top 15cm of soil, with bacteria requiring optimum temperatures of between 10^{o} C to 35^{o}C, adequate soil moisture and optimal pH ranges of 5.5 to 8.0. Mpuncane (2010) evaluated microbial characteristics of soil samples from Southern Africa used in medicine and cosmetics. The microbial analysis carried out were total aerobic mesophilic counts, coliforms, and antimicrobial activity. The samples contained some coliforms, but none were considered hazardous to human health. Smit (2011) did a qualitative study of selected micro-organism in geophagic soils from Qwa-Qwa that involved isolation of bacteria from mining sites and from vendors. Results showed that *Bacellus cereus* was commonly isolated from most of the soil samples. These included all the samples from geophagic mining sites, two of five controls and 10 of 13 vendor soil samples. Two other distinct species of anaerobic bacteria identified were *Clostridium perfringens* and *Clostridium paraputrificum*, which were isolated from eight of 17 geophagic mining sites. *Clostridium spp* are often observed in the surface layers of soil as a result of human and animal excreta. There were no anaerobic bacteria isolated from the vendor soils. This may be caused by the processing (heat treatment e.g., boiling) of soil samples before they are sold.

Numerous fungi were also isolated in this study from 13 of sites, four of the control mines and only three of the vendors soils samples. The fungi isolated included *Penicillium spp, Aspergillus fumigatus, Aspergillus flams, Aspergillus spp, Alternaria spp, Paecilomyces spp, Mucor spp, Trychoplyton rubrum and Candida albicar*. It was observed that the vendor soil samples contained less organisms than most of the soil samples from mining sites. This again was attributed to processing of soil by heat treatment or baking as has been reported, to decrease the pathogens from soil because there is less moisture for microorganisms (Bis-Johnsono.al., 2010).

2.4 Indigenous use of soil for construction

Indigenous building of houses like huts is a widespread practice in rural areas of African communities. The Xhosas (Eastern Cape, South Africa) use soil and wood or stones in construction of buildings. The use of locally available materials makes it easy to build traditional huts that are resistant to any weather. The Tswana tribe (from Botswana) build their houses from hand-moulded mud bricks of assorted sizes and shapes which are placed in vertical layers. Furthermore, the walls are plastered with a rough coating of mud then later, one or two more coatings are added as a final coating with cow dung as a binder. Botswana soils traditionally used for building houses have low silt content, but high proportions of sand and clay. This is an advantage since the clay makes the soil stick while sand gives it strength (Lyamuya and Alam,2013)

In northern KwaZulu Natal, communities make use of locally available material to build their huts. A distinct walling system that is dominant in these areas is usually of timber frame and a thorn tree (*Acacia s.l.*). Then the wall is plastered with termite mound soil (*isiduli*) and finished with *umcako* a slurry of a special selection of local soils (Mhlaba, 2009). In Eastern Cape Transkei in Mdumbi village, huts have always been made with soil and clay either using the wattle and daub or mud brick method. Figure 2.5 shows an example of what a wattle and daub mud house look like. In these areas there are many people making mud bricks along roadsides. While Figure 2.6 shows a small brick making business in Transkei in Mdumbi, Eastern Cape (Delport-Voulgarelis, 2014).

Figure 2.3: Wattle and Daube building method (Delport-Voulgarelis, 2014)

Figure 2.4: Mud bricks drying in the sun (Delport-Voulgarelis, 2014)

2.5 The use of soil in pottery

Potters in South Africa make vessels they use for brewing, drinking, and serving traditional beer. Furthermore, small clay pots are made to serve *uphutho*, a maize - based porridge and *amasi* a delicacy of sour milk (the Zulu tribe). In Umsinga KwaZulu-Natal, potters sample soil from dry stream beds comprised of drained reddish brown Rensburg and Katspruit calcareous soils (Fowler, 2017). Clay potting is also an indigenous skill of the Sotho that is practised in rural lands of Qwa Qwa in Free State province. They believe that the knowledge and skill of pot making is slowly being lost because the current generation does not find it interesting. The traditional uses of these clay pots include for simple decoration in the household, drinking water storage, grain storage, for drinking traditional beer at cultural events such as weddings, funerals, and family gatherings (Mulaba-Bafubiandi and Hlekane, 2015)

2.5.1 Physico-chemical properties of soil used in pottery

A study by Dacosta et al (2013), at Mukondeni village in the Limpopo province investigated three soil types used for pottery namely, a gritty reddish clay (RCSH), a black fine and smooth clay (BCSH) and a green smooth textured clay (GCSH). The mineralogy of these soil obtained from X-ray diffraction was dominated by quartz, feldspar, hornblende, talc as well as smectite clays. RCSH had lower smectite content (37.7%) than BCSH (55.08%) and GSCH (55.69%), which were characterised as highly plastic and sticky. The SiO_2 content of the clays was 58.01, 66 and 62.01% for BCSH, RCSH and GCSH respectively, whereas the Al_2O_3 content was 14.38, 16.07 and 14.09 % for BCSH, RCSH and GCSH, respectively. Silica (SiO_2) was the highest component in all the clay soils. The oxides (SiO_2 and Al_2O3) influenced the loss on ignition (LOI); thus, LOI values were 4.3% (RCSH), 7.71% (GCSH) and 12.47% (BCSH). The LOI values were significant in clays as they indicated weight loss during the heat treatment process such as firing during the making of pottery (Dacosta et al., 2013).

The most influential property of clay soils that determines their effectiveness in pottery is their plasticity. The above Mukondeni soils had a liquid limit of 29, 45.3 and 35.3 % for BCSH, GCSH RCSH irrespectively. While the plastic limit values were 24, 23 and 29 % for BCSH, GCSH and RCSH, respectively. This resulted in plasticity indices of 5, 22.3 and 6.3% for BCSH, GCSH and RCSH, respectively. This indicates that BSCH and RSCH have less PI compared to GCSH. The high plasticity index of the black and green clays suggests they are prone to cracking easily while the pottery products are being burned. The presence of lower levels of smectite and plastic index values in red clay resulted in decreased plasticity, stickiness, and poor moldability. Therefore, it is suggested to combine red clay with black or green clays when creating ceramic pots and water filters. This will enhance the shaping characteristics of red clay while decreasing the tackiness of green and/or black clay with a significant amount of smectite (Dacosta et al., 2013).

Another study by Jumbam et al., (2013) in Port St Johns, Eastern Cape also characterised soil used for pottery. Four of the samples were collected in Mbutho near Nkoneni village, while three samples were collected from Qhaka village, and the eighth sample commonly used for commercial pottery in the region was used as a control (Denis et al., 2013). Results showed low aluminium oxide (Al_2O_3) contents ranging from 5-12 (%) weight, while silicon oxide (SiO_2) was high ranging from 52-76 (%) by weight. Results from the Fourier-transform infrared spectroscopy (FTRI) showed the same bands for soil used for both traditional and commercial pottery. Results from the OH stretching band were between 1634-3699 cm^{-1} and OH deformation bands ranged from 910-912 cm^{-1}. Bands related to SiO stretching ranged from 692 -798 cm^{-1} and SiO deformation bands were 100-1003 cm^{-1}. These bands were close to those of kaolinite, smectite and quartz. The major oxides were aluminium oxide (Al_2O_3) and silicon oxide (SiO_2) for kaolinite, smectites and quartz (Denis et al., 2013)

2.6. Conclusion

Soils used for cosmetics are mostly used as a sunscreen, skin cleansers and for cultural purposes. In some African cultures, soil is painted on the face to show tribal identity. While the Xhosa and Zulu ethnic groups of South Africa use soil for initiation rituals, with the traditional trainees smearing it on their bodies. Women mostly use soil for photo-protection, with the dominant soil colours used being red and white. These colours influence the soil sun screening properties, as it is believed that a hue of 5YR contains haematite, which results in low UV radiation. The soil is first pulverised and mixed with water before application to smoothen its texture.

Geophagia is also practiced for several reasons that could be cultural, cravings, medicinal etc. It is popular in culture-oriented communities of Africa and regarded as normal behaviour. Geophagia is more common in females than males. Course textured soil may cause dental problems as it usually contains quartz, which is a hard mineral. The pH of the soil also influences its taste, as well as reactions in the stomach. Acidic soil mostly leaves a sour taste when consumed. There is little documented information on the safety of using soil for cosmetics and for geophagia, however. It is presumed that the soil used for cosmetics is fairly safe since it is boiled and/or baked before application on skin thereby killing most harmful microorganisms.

On the other hand, soil used for medicinal purposes helps in treating digestive tract problems, indigestion, and acne. Traditionally vendors sell soil to treat acne and other skin problems, with mineralogy playing a significant role on how effective these soils are. Kaolin specifically is used as an anti-diarrheal medicine, while bentonite clay treats constipation. The construction of traditional houses using mostly soil is still being done, but no longer extremely popular as most people now use industrial building materials. In some rural areas of South Africa, locals still build their huts using soils and other natural materials like wood. Pottery is another indigenous practise that is slowly vanishing. However, in some parts of KwaZulu-Natal e.g., in Umsinga, there are still some traditional potters that make clay pots used to store water, food, and beer for cultural events.

CHAPTER 3

NON-AGRICULTURAL USES OF SOIL BY SELECTED COMMUNITIES IN UMGUNGUNDLOVU DISTRICT AND THEIR SAFETY FOR USE

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3.1 Introduction

The safety of soil for use in cosmetics, medicinal purposes, geophagia, and pottery have not been well explored. The arrival of modern cosmetics did not change the reliance on soil for dermatological beautification as traditional use of soil for cosmetic purposes is still a common practice among many African communities (Matike et al., 2010). African women, especially those who reside in rural areas also use local soils for photo-protection (Matike et al., 2011a). These mix red soil (*ibomvu*) or white soil (*umcako* in isiZulu) with water to produce a paste that is applied onto the face (Dlova et al., 2013). Red soil paste is also applied onto traditional incisions or scars to aid in fast healing (Magwa, 2006). Here, soil used for cosmetics is mainly distinguished by colour; with white and red soil being preferred.

Geophagia is the intentional ingestion of earth material (Mathee et al., 2014), that dates back historically in African communities (Phakoago, 2017). A variety of reasons for practicing geophagia include religious, nutritional, and medicinal benefits, enhancement of personal appearance, pregnancy-related cravings and enjoyment of the taste, texture, or smell of the soil (Mathee et al., 2014). The prevalence of geophagia differs widely but is still practised in many parts of the world. Geophagic soils across the African continent are unique in origin. While vendors in South Africa get geophagic soils from the wilds of mountains, valleys and riversides, those from Kenya and Tanzania source them from termite mounds (Phakoago, 2017). The soil physical properties such as their texture, structure, colour, smell, and taste play an important role during selection (Ekosse et al., 2010). Our study sought to understand if users were aware of the dangers posed by soil use and whether they had strategies to curb them.

Pottery and the construction of houses are among other practices that utilise local soil. In South Africa there are many different types of traditional housing structures. In the Eastern Cape, a traditional hut can be built using wooden poles, with gaps between poles filled using a strong type of grass then plastered with soil. Other traditional huts can be built using stones that are then plastered with soil, (Makaka and Meyer, 2006). In the KwaZulu-Natal (KZN) province, there are still homesteads built with mud blocks and painted with an earthy-coloured finish (*umcako* or ibomvu) (Mhlaba, 2009). Research indicates that pottery vessels since ancient times were used for cooking, water storage and sorghum beer brewing (Fowler, 2011). Potters in Umsinga district, KZN use clay (*ubumba* in isiZulu) to make vessels. These clays are sampled from dry stream beds, with soil types that include reddish-brown Rensburg and Katspruit calcareous soils (Fowler, 2011). With all these vast uses, it is important to know how safe soil is to users. Mpuncane (2010) investigated cosmetic soils from Swaziland, Botswana and South Africa and found only 14 of the 102 soil samples to have faecal coliform contamination. Bisi-Johnson (2010) also reported geophagia to have a range of health complications such as constipation, stomach cramps, parasitic infestation, and dental damage. The aim of the study was thus to assess non-agricultural soil uses practised by people in selected communities of uMgungundlovu district, and how they ensure safety for use. This was done through a survey in three communities using questionnaires and key informant interviews.

A survey was done in Umgungundlovu district in three areas i.e. Elandskop, KwaNxamalala and Willowfontein to gather information about uses of soil practised in these selected communities through the use of questionnaires and key informant interviews. Specific objectives included:

3.2 Objectives

3.2.1 To document common non-agricultural uses of soil in the selected communities of KwaZulu-Natal.

3.2.2 Evaluate the factors that guide users to select soil for a particular use.

3.2.3 To identify handling and storage techniques used to ensure safety of soil for use.

3.3 Methods and Materials

3.3.1 Site description

The study was conducted in three areas namely Elandskop (S29.7274º E30.1350º), KwaNxamalala (S29.7078 E30.3045º) and Willowfontein (S29.7185 E30.3151º) that fall under the uMgungundlovu district of uMsunduzi local municipality in KwaZulu-Natal province (Figure 3.1). The soil forms that were managed to be classified was geophagic soil from Elandskop being Clovelly and few cosmetics from Willow to be Hutton. Other geophagic material were almost stoney material hard to be even grinded when prepared for soil analysis.

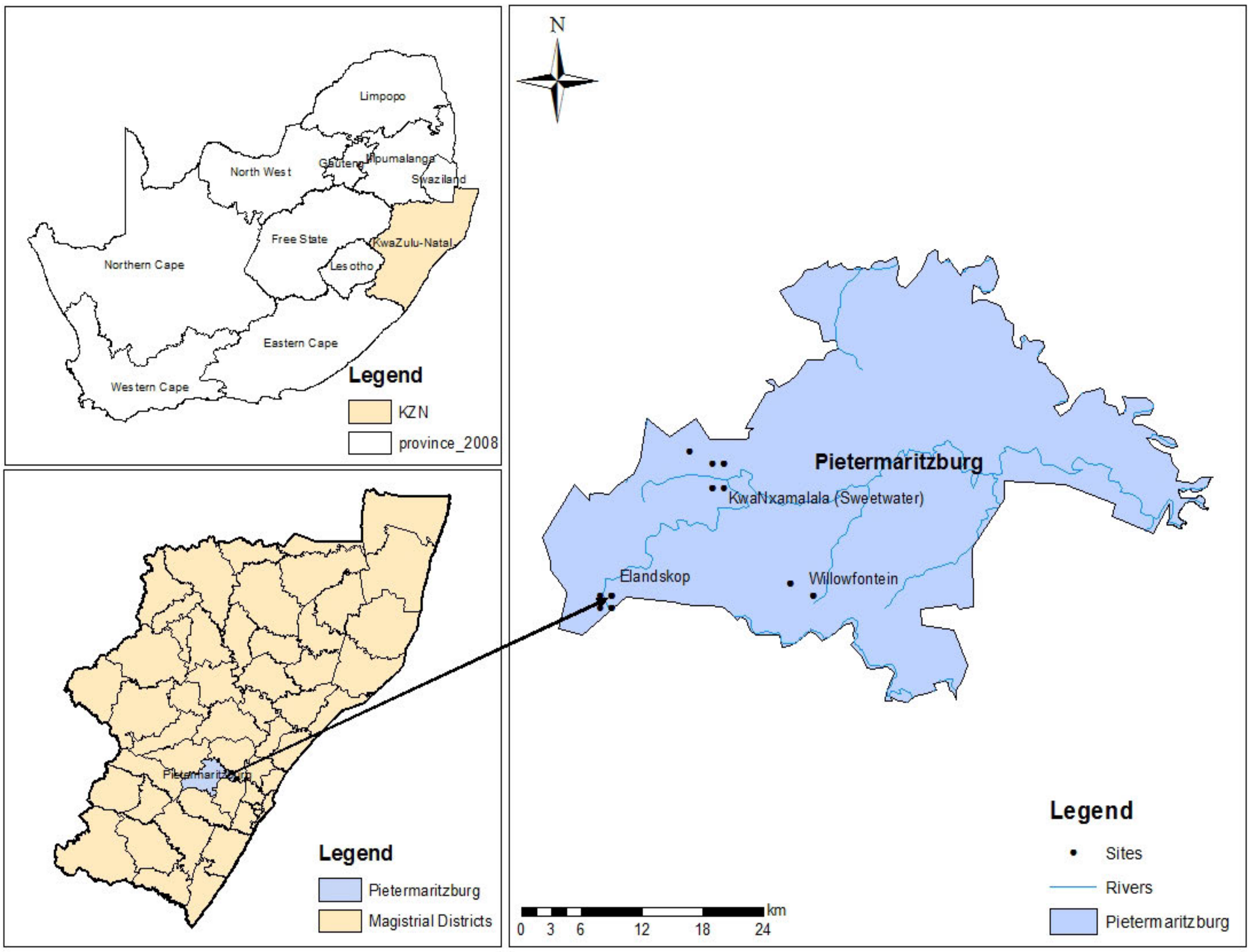

Figure 3.1: Map showing study areas for the survey

3.3.2 Research design and sampling procedure

Information was gathered through interviews with key informants and household questionnaires in each of the three areas. A total of five (5) key informant interviews were done, while fifty (50) questionnaires were also administered in each area. The participants were chosen according to their availability and willingness to be part of the survey. Each participant was at least 18 years old, and both genders were represented. Interviews were conducted in the local Zulu language which was familiar to the participants. The duration of the interviews was 15-20 minutes.

3.3.3 Key Informant Interviews (KIIs)

The interviews were conducted on five members of each community. These included councillors, agricultural officials, as well as vendors from communities in each area that sell their soils in Pietermaritzburg (PMB) central. The interviews were done to assess the knowledge they have about indigenous soil uses. The vendors gave information about sampling sites, uses and how they process the soil before selling.

3.3.4 Baseline survey

A questionnaire with structured questions (Appendix A) was administered on community members after the KIIs (with non-structured questions) to identify the most common soil uses and understand the guiding principles behind these uses. These questionnaires targeted 50 people per area (since the chosen areas were not that big/densely populated) making a total of 150. Ethical clearance (appendix B) as required by the university, as well as gatekeeper permission from community leaders was sought prior to the survey. Participation was voluntary and anonymous, so no one was made to answer questions they were uncomfortable with.

3.3.5 Statistical analysis

Data was analysed using SAS Institute Incl 9.4 statistical package, (2013). Demographic information such as gender, age and educational level was analysed using the PROC FREQ procedure of SAS 9.4 Institute. (SAS 9.4 Inst.2013). The PROC GLM procedure SAS 9.4 using least mean squares was used to analyse the responses. These were ranked from 1 for frequently used, with a higher number representing decreasing frequency of use. The results of ranking were described using the least mean square, with a lower mean square describing the most used variable.

3.4 Results

3.4.1 Demographic information of respondents from the selected areas

There were more females compared to men that participated in the survey in all areas, with Willowfontein having 82% female respondents followed by Elandskop with 76% and KwaNxamalala with 66% (Table 3.1). The ages of participants varied, but mostly ranged between 18-30 years in all areas, with Willowfontein having 44%, Elandskop 38%, and KwaNxamalala 36% of participants in this age range. The educational level was dominated by participants who had secondary education, with 76% in Elandskop, while Willowfontein and KwaNxamalala had 62% each. Very few people had no formal education, i.e. 8 % in KwaNxamalala, 4% in Elandskop and 2% in Willowfontein.

		Elandskop	KwaNxamalala	Willowfontein
Gender (%)	**Female**	76	66	82
	Male	24	34	18
Age (%)	**18-30**	38	36	44
	31-40	16	18	24
	41-50	18	20	8
	51-60	12	20	6
	61-70	12	6	12
	>70	4		6
Educational level (%)	**Primary**	18	18	22
	Secondary	76	62	62
	Tertiary	2	12	14
	No formal education	4	8	2

Table 3.1: Demographic information of respondents from study sites

3.4.2 The non-agricultural soil uses in the studied areas

Table 3.2 presents mean scores of common soils uses in Elandskop, KwaNxamalala and Willowfontein, with lower values representing the most commonly used and higher values the least used. Soil is mostly used for cosmetics in all areas, followed by geophagia in KwaNxamalala and Willowfontein, while in Elandskop the second most common use was construction. There were no significant differences in soil use for cosmetics in all areas ($p > 0.05$), while use as geophagia was more popular in KwaNxamalala and Willowfontein. More respondents from Willowfontein used soil for medicinal purposes compared to the other two areas, while there were more respondents using it for construction in Elandskop, ($p < 0.05$). None of the respondents used soil for pottery in any area of the study.

Table 3.2: Common non-agricultural soil uses in the studied areas

	Least square means		
Common soil uses	**Elandskop**	**KwaNxamalala**	**Willowfontein**
Cosmetics	1.53^a	1.67^a	1.67^a
Geophagia	2.73^b	1.98^a	2.04^a
Medicinal	3.52^b	3.53^b	3.06^a
Construction	1.77^a	2.36^b	2.29^b
Pottery	ND	ND	ND

Values in the table represent the least mean square (LSmeans) of common soil uses, with lower values being the most used.
Values with different superscript letters are significantly different ($p < 0.05$).
ND = not determined (or not chosen as a response).

3.4.3 The uses of soil applied onto the skin

Table 3.3 presents information on soil applied onto the skin, with soil being mostly used as sunscreen in all areas. The use of soil as sunscreen or skin cleanser did not significantly differ with area ($p>0.05$). This practice is the second most common skin soil use in KwaNxamalala and Willowfontein. Umemulo is a ritual done when a Zulu girl is transitioning to womanhood and involves application of red and white soil to the body as skin cleanser (Magwa, 2006). This soil use proved to be the least popular in all areas.

Table 3.3: Different uses of soil applied onto the skin

	Least square means		
Soil use	**Elandskop**	**KwaNxamalala**	**Willowfontein**
Sunscreen	1.06^a	1.02^a	1.02^a
Skin Cleanser	1.94^a	2.60^a	2.50^a

Applied by traditional trainees (*Ukuthwasa*)	2.41[b]	2.0[a]	2.25[b]
Applied for ritual (*umemulo*)	3.05[a]	2.88[a]	2.96[a]

Values in the table represent the least square means for soil skin application, with lower values being the most used. Values with different superscript letters are significantly different ($p < 0.05$).

3.4.4 Reasons for practising geophagia

The most common reasons for practising geophagia included cravings and enjoyment (Table 3.4). The practice of geophagia as a nutrient (iron) supplement was more common at Willowfontein but not the other two areas. No significant differences between areas was observed in the use of soil for enjoyment.

Table 3.4: The main reasons for practicing geophagia in the study areas

	Least significant means		
Reasons for Geophagia	**Elandskop**	**KwaNxamalala**	**Willowfontein**
Cravings	1.16[a]	1.55[b]	1.32[a]
Nutrient Supplement	3[b]	3[b]	1[a]
Enjoyment	1.52[a]	1.33[a]	1.29[a]

Values in the table represent the least square means of reasons to practise geophagia, with lower values being the most common. Values with different superscript letters are significantly different ($p < 0.05$).

3.4.5 Use of soil for medicinal purposes

The use of soil for medicinal purposes was mostly done when treating traditional incisions locally called *ukugcaba* (more so at KwaNxamalala and Willowfontein), followed by treating skin ailments such as rash and acne (Table 3.5). This was characterised by application of a soil paste onto the wound or skin ailment. The use of soil to treat indigestion was done more at

KwaNxamalala than Willowfontein, while there was no evidence of this at Elandskop. Community members in Willowfontein also use soil to treat diarrhoea.

Table 3.5: The use of soil for medicinal purposes in the study areas

	LS means		
Medicinal use	**Elandskop**	**KwaNxamalala**	**Willowfontein**
Skin problems	1.78^{a}	1.71^{a}	1.29^{a}
Indigestion	ND	1	3
Diarrhea	ND	ND	2
Healing incisions (*ukugcaba*)	1.26^{b}	1.05^{a}	1.06^{a}

Values in the table represent the least square means of uses of soil for medicinal purposes with lower values being the most used.
Values with different superscript letters are significantly different ($p < 0.05$).
ND = not determined (not chosen as a response).

3.4.6 The sources of soil used for various purposes

Table 3.6 shows sources from which soils are sampled in the different areas. Soil used for cosmetics was mostly collected from the mountain (38.87%), by the roadside (24.49%) or bought from vendors (22.45%) in Elandskop. While in KwaNxamalala cosmetic soil was mostly obtained from the mountain (45.83%), vendors (33.33%) and by the riverside (16.67). In Willowfontein the dominant sources of cosmetic soil were mostly the mountain (73.4%), with a few samples bought from vendors (10.2 %), or collected by the roadside (10.2 %). Geophagic soil samples on the other hand in Elandskop were mostly obtained by the roadside (76.62%), with a few bought from vendors (15.38%). In KwaNxamalala however, geophagia soil was mostly from the mountain (59.57%) or near roadsides (36.17%). While in Willowfontein most geophagia practitioners get their soil by the roadside (75%), with a few from the mountain (20.83%). The soil used for medicinal purposes was mostly bought from vendors in Elandskop (35.71%) or got from the mountain (32.14 %), which was more or less the same pattern in KwaNxamalala. In Willowfontein, most medicinal soil is sourced from the mountain (68%).

However, construction soil is mostly sampled around the yard (homestead) in all three areas: Elandskop (90.7 %), KwaNxamalala (79.41 %) and Willowfontein (88.89 %). There were no users of pottery soil in all areas.

Table 3.6: Sources of soil used for different purposes in the study areas

		Elandskop (%)	KwaNxamalala (%)	Willowfontein (%)
Soil sampling sites for Cosmetics	River	4.08	16.67	6.12
	Mountain	38.87	45.83	73.47
	Anthill	4.08	ND	ND
	Tree bark	6.12	ND	ND
	Vendor	22.45	33.33	10.20
	Other (Roadside)	24.49	4.17	10.20
Soil sampling sites for Geophagia	River	ND	2.13	ND
	Mountain	5.13	59.57	20.83
	Anthill	ND	ND	ND
	Tree Bark	2.56	ND	ND
	Vendor	15.38	2.13	4.17
	Other (Roadside)	76.92	36.17	75
Soil Sampling sites for Medicinal	River	3.57	ND	8
	Mountain	32.14	31.25	68
	Anthill	3.57	ND	ND
	Tree bark	14.29	ND	ND

	Vendor	35.71	56.25	12
	Other (roadside, Yard)	10.71	12.50	12
Soil sampling sites for Construction	River	2.33	2.94	3.70
	Mountain	6.98	17.65	ND
	Anthill	ND	ND	ND
	Tree bark	ND	ND	ND
	Vendor	ND	ND	7.41
	Other (roadside, Yard)	90.70	79.41	88.89
Soil sampling sites for Pottery	River	ND	ND	ND
	Mountain	ND	ND	ND
	Anthill	ND	ND	ND
	Tree Bark	ND	ND	ND
	Vendor	ND	ND	ND
	Other (Roadside, Yard)	ND	ND	ND

ND =Not determined (not chosen as a response).

3.4.7 Sampling techniques used to collect geophagic soils by users

Figure 3.2 shows the different techniques used to collect soil for geophagia. The most frequently used sampling method was digging with a knife especially in KwaNxamalala and Elandskop. This was followed by sampling using a spade particularly in Willowfontein, which was not significantly different from selective hand-picking. Sampling using a hand-hoe proved unpopular, more so in Willowfontein.

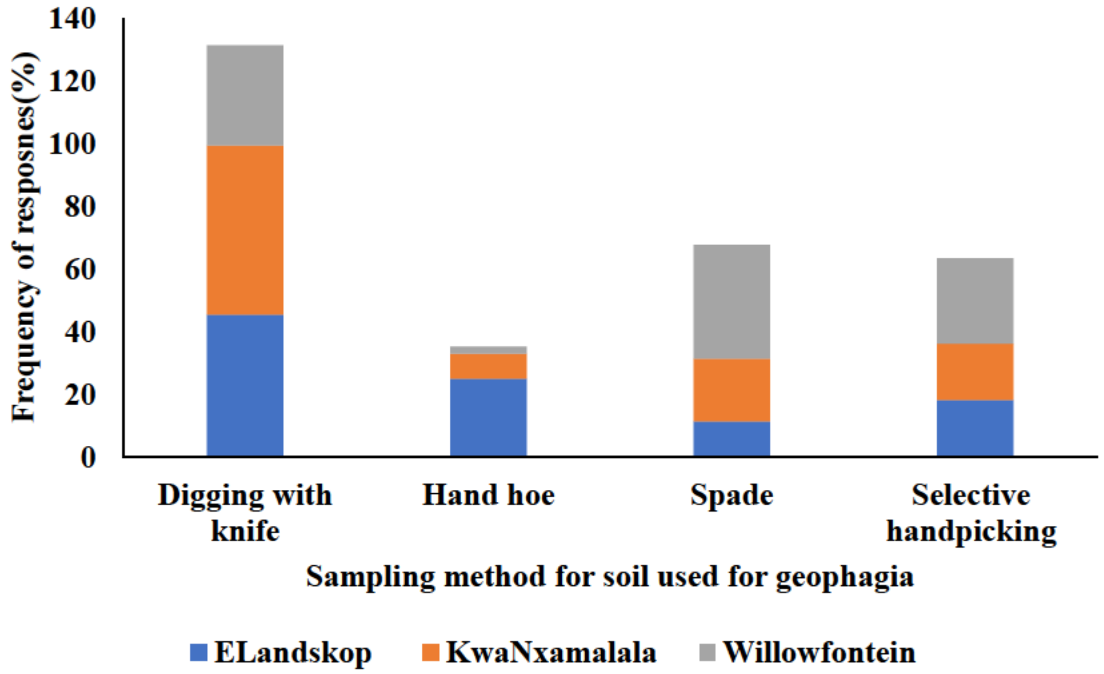

Figure 3.2: Field sampling methods used for geophagic soil

3.4.8 Methods of storing geophagic soils

The storage options for soil used for geophagia are shown in Figure 3.3. Soil samples are mostly stored in plastic bags, followed by plastic containers (e.g. lunchboxes), with sacks being the least popular storage option in all areas. The use of plastic bags was more common in KwaNxamalala, as compared to Elandskop and Willowfontein. While the use of containers for storage was more common in Elandskop and Willofontein compared to KwaNxamalala.

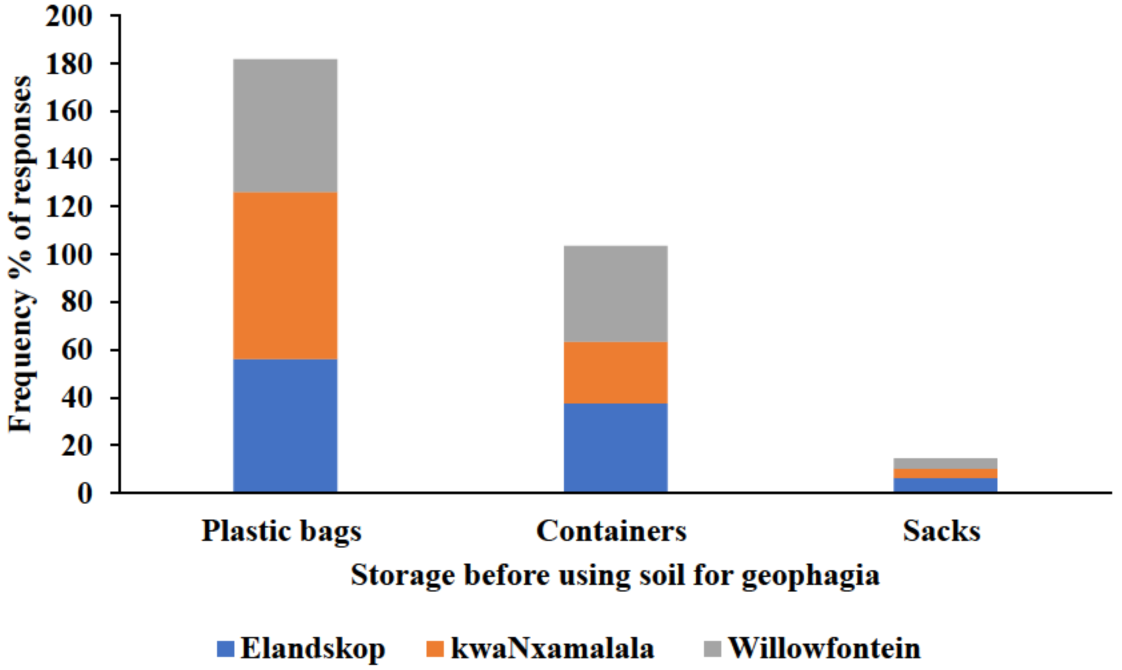

Figure 3.3: Storage options used on geophagic soils

3.4.9 Methods used to process soil that is applied onto the skin

Figure 3.4 shows the sample preparation options for soil applied onto the skin (cosmetics purposes). Boiling seemed to be the most popular soil treatment technique, especially at Elandskop. Here soil is boiled in water, cooled then used as a paste that is applied onto the skin. Soil burning, (though not so popular) involves moistening soil with water then moulding into a ball structure before hardening with fire. The option denoted 'combined' is when users add lotion to a boiled soil paste before application. This is done in an attempt to prevent skin dryness induced by the soil paste. In some instances, users mix soil with boiled water soon after sampling to make a paste which is then applied onto the skin.

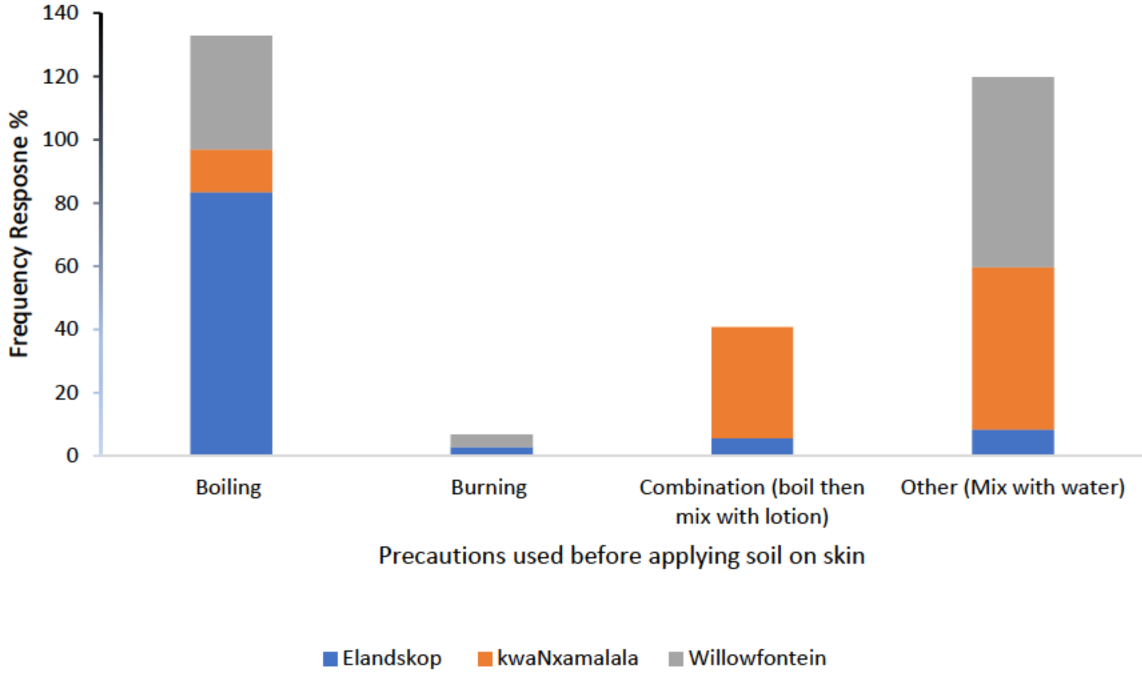

Figure 3.4: Precautionary soil treatment methods before applying onto skin

3.4.10 Reasons why users started to consume soil

Table 3.7 shows some of the reasons why users started to practise geophagia. This refers to only people that really consume soil. These include peer pressure, own initiative etc. In some cases, the smell and taste of soil (especially after a rainfall event) induces people to crave it. In Elandskop the main reasons why people started to eat soil was because of enticing taste and smell, while others merely started on their own (with no external pressures). In KwaNxamalala respondents mostly consume soil due to influence from others or own initiative. In Willowfontein, the main reasons users started to eat soil include in ascending order: influence from other people, enticing taste and smell, and own initiative.

Table 3.7: The reasons for practising geophagia in different communities

	Elandskop (%)	KwaNxamalala (%)	Willowfontein (%)
Peer pressure	4.76	ND	ND
Tradition	ND	ND	ND

Own initiative	23.81	38.36	15.38
Saw someone else	19.05	54.55	57.69
Taste and smell	52.38	9.09	26.92

ND=not determined (not chosen as a response).

3.4.11 Properties used to identify soil for the various uses

Table 3.8 shows the frequency of responses on how users identify soil for different uses. The options to choose from were nutrients, colour, taste and smell. Respondents who use soil for cosmetics mostly considered its colour and texture. These prefer red-coloured and fine textured soil which gives a smooth feel to the skin. Geophagic soil users mostly considered the soil colour and texture, but also other traits like its smell, taste, and sometimes nutritional value. They associate red soil with having iron and so regarded it as being nutritious, thus colour is a dominant deciding trait for geophagic users in all areas. They also distinguish between gritty and fine textured soil using fingers to feel the texture and prefer fine textured soil. In KwaNxamalala and Willowfontein, taste and the smell are also common traits used to choose soil by geophagic users. The taste and smell of soil after a rainfall event was mentioned to be preferred. Users who use soil for medicinal purposes mostly consider its colour, and in a few instances the texture or taste. In construction, texture (followed by colour) is the most used indicator used, with gritty soil preferred for building, while the smoother soil is used for plastering.

Table 3.8: The properties used to identify soil for different uses

		Frequency count of responses (n=50)		
		Elandskop	**KwaNxamalala**	**Willowfontein**
Cosmetics	**Nutrient**	ND	ND	ND
	Colour	38	49	47
	Texture	25	3	28
	Smell	ND	ND	2
	Taste	ND	ND	ND
Geophagia	**Nutrient**	ND	2	ND
	Colour	30	39	43
	Texture	16	4	9
	Smell	5	9	25
	Taste	7	8	23
Medicinal Purposes	**Nutrient**	ND	ND	ND
	Colour	10	14	17
	Texture	2	ND	10
	Smell	1	ND	ND
	Taste	4	1	1
Construction	**Nutrient**	ND	ND	ND
	Colour	22	8	8
	Texture	25	24	22
	Smell	2	2	ND
	Taste	ND	ND	1

ND=not determined (not chosen as a response)

3.4.12 The side effects of different soil uses

Table 3.9 shows the respondents' perceptions about side effects of different soil uses. In the case of cosmetic soil, side effects included pinkish blemishes on the cheekbones, skin irritation or creation of dry skin (especially if the soil is not well prepared or mixed with lotion). Skin blemishes were more common at KwaNxamalala, while skin irritation was more prevalent at Willowfontein, and dry skin at Elandskop. The side effects for soil used for medicinal purposes included constipation and diarrhoea but these were only observed at Elandskop. The other side effect of skin irritation also occurs if used in traditional incisions. Soils used for geophagia give rise to problems of constipation mostly, while other complications include stomach aches, development of gall stones or infections of the appendix. Appendicitis is a medical condition in which the appendix (a small, finger-shaped organ attached to the large intestines) becomes swollen and inflamed (Bennington-Castro, 2018). While gallstones are solid particles that form from bile cholesterol (Balentine & Stoppler, 2014). In construction, the dominant side effect is having dry hands (from gritty soil) as a result of soil mixing during construction. The other minor side effect of construction was the development of skin ring worms.

Table 3.9: The side effects of using soil for different purposes in the study areas

		Elandskop (%)	KwaNxamalala (%)	Willowfontein (%)
Cosmetic	Blemishes	20.83	63.64	14.29
	Skin irritation	50	22.73	71.43
	Other (dry skin)	29.17	13.64	14.29
Medicine	Nausea	0	0	0
	Constipation	60	0	0
	Diarrhea	20	0	0
	Other (skin irritation if used for traditional incision (*ingcabo*)	20	0	0
Geophagia	Constipation	75.68	39.02	60.61
	Stomach ache	5.41	17.07	ND
	Other (appendix infection, gall stones)	18.92	43.90	39.39
Construction	Dry Hands	97.37	96.97	85.71
	Ring worm	2.63	3.03	14.29

3.7 Discussion

More females than males participated in the survey. This was because men thought women were more knowledgeable about non-agricultural soil uses since these practices were usually undertaken by women. All interviewees were at least 18 years of age, because people below 18 were considered rather unknowledgeable as far as soil uses are concerned. The older generation also had low numbers, with users being mostly between 18 and 50 years. This could be because most soil users are women, who consume it (because of cravings developed during pregnancy) or use it for cosmetic purposes. S'khosana, (2017) in a study in uMzinyathi and uMgungundlovu showed cravings to be the main reason for practising geophagy by women. Songca et al., (2010) in a study to understand the demographic characteristics associated with geophagia also found that consumers had strong cravings for soil. The literacy level of participants was mostly secondary education, while there were very few people with no formal education. The study showed common soil uses to be cosmetics and geophagy, with construction and medicinal uses being not that popular, while pottery did not appear to be practiced at all in the studied areas. Cosmetic soil was mostly as sunscreen or a skin cleanser, but in some cases, soil was applied by traditional trainees for ritual purposes like *umemulo*. Dlova et al., (2013) suggested that women use soil as a sunscreen because they cannot afford commercial products. Elandskop and KwaNxamalala are semi-rural areas where women are often involved in chores like gardening that exposes them to UV light, so they apply a soil paste to protect them from the sun. This shows that though users might not have the scientific knowledge but rely on indigenous knowledge passed on from generation to generation, they have an understanding that soil offers some protection or can serve as a cleanser to their skin.

There is evidence to show that soil is a common ingredient in toners and cleansers that are used commercially in beauty spars. Smit, (2011) in a study of textural properties of soil used as cleanser by traditional trainees showed that 50-70% of the soil samples had particle diameters of 2 to 20µm, which were similar to those of clay mixtures used for cleansing in commercial Thermal Centres. Common colours of soil applied on skin by users were white and red. Mpuchane., (2010) also reported these colours together with yellow, grey, and brown to be commonly used in several modern cosmetics products such as face powders, lip gloss, eye shadow and blushers; as they influence the sun screening and toning abilities of such products. The locals also identify soil for various uses using mostly its colour and texture. People who practice geophagia in South Africa use textural feel such as grittiness, silkiness and the powdery nature of the soil to decide on its palatability (Ekosse et al., 2010). "Studies conducted in South Africa show geophagic consumers prefer soils that are soft, smooth, and powdery" (Ekosse et al., 2010).

Medicinal soil use is mainly practised by traditional healers to heal incisions. These are scars made by a sharp object in the face to show which clan one belongs to. Here red soil is applied to heal the incisions or wounds in general (Magwa, 2006). Matike et al., (2011b) also highlighted the vast uses of soil by traditional initiates to include it serving as a deep cleanser, toner or for identification purposes during initiation. As noted, users also apply soil to treat skin problems like acne and rashes, while the use of soil to treat indigestion is less common. Bisi-Johnson et al., (2013) reported that soils containing minerals like aluminosilicate, kaolinite or montmorillonite commonly had a glue-like property that promoted attachment of microorganisms and nutrients. This might explain their effectiveness in treating ailments,

The survey indicated that respondents sourced soil from a variety of locations, with cosmetic soil primarily obtained from mountains or purchased already processed from vendors. Additionally, some users collected soil from riverbanks and roadsides. Matike (2011a) noted that users gathered soil samples for cosmetic purposes from these same riverbanks and roadsides. In alignment with this, a study by Dlova et al. (2013) in Durban identified riverbanks as the most common source of soil for cosmetic use. This consistent trend suggests that riverbanks may offer soil with desirable characteristics for cosmetic applications, likely due to its fine texture and mineral composition, making it a preferred option. In contrast, soil used for geophagia was predominantly collected from roadside excavations created during road construction and from mountains. A portion of the users in the study areas also purchased this soil directly from vendors. Furthermore, in a study conducted in Limpopo, respondents reported collecting geophagic soil from mountain sources (Phakoago, 2017). The preference for soil taken from roadside excavation sites may be due to easier access or the belief that such soil is uncontaminated and fresh due to recent exposure.

In the case of sampling techniques, most geophagic soils were sampled by digging using a knife, spade, hand hoe or selective handpicking in all areas. A study by Msibi, (2014) also found that most consumers collected soil by digging using a knife. The use of these tools ensures that soil is obtained from specific locations, often targeting the layers believed to be considered more palatable by consumers. The choice of sampling tool is often determined by local availability and practicality, but it is significant in shaping the quality of the collected soil

Soil processing was mainly done for cosmetic soil, while for geophagia, respondents consumed the soil directly as is without processing it. After collection, the soil used for cosmetics was treated by boiling with water in an effort to lower pathogenic microbial populations, as users believe the heat from the boiled water is effective in killing pathogens. This was also done to make the soil smoother when applying.

According to the respondents, there are side effects associated with the different soil uses. Cosmetic soil for example may cause skin blemishes, irritation, and dryness. These side effects are worsened by over-application of the soil paste or applying it without it having been mixed with lotion. The findings highlight the need for caution and proper preparation to mitigate adverse effects. According to the respondents, geophagic soils may cause constipation, appendicitis, and gallstones. Msibi, (2014) as well as Phakoago, (2017), also noted that geophagic soil caused severe constipation from their studies. The health implications of geophagic soil consumption are likely due to the mineral content, which may disrupt normal digestive processes.

These findings indicate that the study managed to provide an overview of soil uses, with users convinced that their storage and handling techniques (boiling, burning, and baking) made the soil safe for use. However, the limitation of the research was that it was mostly done in peri-urban areas since these were easily accessible from the university. More uses such as pottery could have been explored in deeper rural areas. In short, the study found that in addition to enjoyment of geophagic soil, users felt selected soils were an effective sunscreen and skin cleanser and were safe for use as long as heat treatment (and sometimes the addition of lotion to prevent dryness) was done for cosmetic soil. Some users even suggested that soil use was effective at treating wounds and other skin ailments such as acne and rashes. Respondents highlighted that care should be taken, however, not to over-consume geophagic soil as it could cause problems of constipation and development of gallstones among others, while over-applying cosmetic soil could cause skin dryness.

3.8 Conclusion

The study revealed that soil use for non-agricultural purposes is still common practice, with women users applying it as a sunscreen or conditioner or consuming it for enjoyment; while males use it in construction. Traditionally, soil is applied during ceremonies and rituals, while medicinal use to treat traditional incisions or wounds was not very common. With all our study areas being peri-urban, pottery was not practiced at all. Pottery use might be a practise that is common in deeper rural areas, so more research on this could be directed there. Soil colour and texture are the main traits used by locals to differentiate soils for different uses. The texture plays an important role to differentiate between choices for use, as soil used for cosmetics needs to be finer-textured while construction soil is mostly gritty. The texture also influences how consumers select the soil they will ingest. Smell and taste of the soil after it had rained are also used as a guide for geophagia by users from Willowfontein.

In an attempt to ensure safety for use of cosmetic soil, users process the soil through heat treatment e.g. boiling, burning, or baking before use. Users believe such pre-treatment is effective in reducing microbial contaminants in soil. Users are aware of the health challenges (constipation, skin irritations etc.) associated with consuming soil, but strongly believe that their pre-treatment methods decontaminate soil so that it is safe for use. More comparative analysis on microbial (particularly of pathogens) and heavy metal loads before and after heat treatment of the soils to ensure effectiveness of safety measures employed by users have been probed in a separate study. The validity of effectiveness of soil to treat ailments such as skin rashes, acne, wounds, indigestion, and diarrhoea needs further investigation.

CHAPTER 4

PHYSCO-CHEMICAL PROPERTIES OF SOIL USED FOR VARIOUS PURPOSES IN SELECTED COMMUNITIES OF UMGUNGUNDLOVU DISTRICT

4.1 Introduction

The use of soil as an active ingredient in skincare remains prevalent in many African communities, even with the rise of modern cosmetics. Individuals employ soil as a natural sunscreen to shield their skin from ultraviolet radiation and for overall skin conditioning. Many women create a paste by combining red soil and white soil with water and glycerine, which they then apply to their faces (Dlova et al., 2013). Soil can also serve as an effective cleanser. In the Xhosa and Pondo communities of the Eastern Cape, it is a tradition to apply white soil to both male and female initiates during their annual rites of passage. This ritual is believed to purify their skin and remove impurities as they transition into adulthood. Various factors influence the use of soil in commercial cosmetics, such as its colour, particle size, and cation exchange capacity, among others (Matike et al., 2011a).

Geophagia, the deliberate consumption of soil, remains widespread globally, including in parts of Africa. This practice is more commonly observed among women, especially during pregnancy, due to cultural, nutritional, and medicinal reasons. Recent studies highlight the preference for specific types of soil with desirable textures and taste, often those that are soft and smooth. Geophagic soils are sometimes consumed to address mineral deficiencies like iron and zinc (Phakoago, 2017; Abrahams et al., 2023). Additionally, research indicates that certain geophagic soils possess properties that could aid in detoxification or provide digestive benefits (Bisi-Johnson et al., 2020). Vendors and traditional healers often sell these soils, which are valued not only for their texture but also for their chemical properties, making them suitable for addressing gastrointestinal issues and other ailments (Anderson et al., 2023; Ekosse et al., 2010).

In Southern Africa, various soil types are sold by vendors or traditional healers to cure skin diseases, gastro-intestinal tract disturbances, and as skin cleansers (Mpuchane et al., 2010). The physical and chemical composition of such soil determines its effectiveness for various uses. The objective of this study was to examine the physico-chemical properties of soil used for multiple purposes. Thus, soils were sampled from different source sites in uMgungundlovu district in KwaZulu-Natal province such as Elandskop, KwaNxamalala, Willowfontein; and these were compared with processed soils bought from vendors in Pietermaritzburg central.

4.2 Method and Materials

4.2.1 Soil sample collection, storage, and preparation

Soil Sampling

This study was conducted in Elandskop, KwaNxamalala, and Willowfontein, which served as the primary sources of soil samples. Additionally, samples were purchased from vendors in Pietermaritzburg Central. For each area, ten samples were randomly collected: five intended for cosmetic use and five for geophagic use. These primary source samples were collected using an auger or shovel at a depth of 10 cm. The soil from these primary sources was taken directly from locations such as mountains and roadsides and had not been processed. Soil identification was guided by the respondents' answers, with locals helping in pinpointing the exact locations where soil samples were taken for specific uses. The samples for geophagy and other purposes did not consist solely of soil but also included stoney materials, which the locals referred to as "ukhetho."

During the purchasing process, researchers asked the vendors several questions regarding the sources of the samples and their intended medicinal and cosmetic purposes, particularly in relation to geophagia. The responses from the vendors helped in selecting the study areas. Since the vendors live in the locations where they collect their samples, it is likely that their experiences reflect common practices among other residents, such as using soil for medicinal purposes, cosmetics, and geophagy. All cosmetic or medicinal soil samples, referred to as "ibovu" for red soil, were collected from various depths depending on the location of the samples. For example, soil samples taken near the roadside were collected from already exposed soil profiles, and we took samples from the sub horizon. Similarly, samples near riverbanks were collected vertically. In contrast, the secondary source soil was obtained from vendors in Pietermaritzburg, where the soil had already been processed (by boiling or baking). This processed soil was sourced by vendors from opened soil profiles @ random soil depths guided by ease of accessibility to the soil of interest. Figure 4.1 illustrates a roadside sampling site in Elandskop designated for geophagic use, while Figure 4.2 depicts cosmetic soil purchased from vendors. After collection, both sets of soil were air-dried for two days and ground to pass through a 2-mm sieve before analysis.

Figure 4.1: Geophagic soil sampled by the roadside in Elandskop

Figure 4.*2*: Cosmetic soil bought from a street vendor in Pietermaritzburg Central

4.2.2 Soil colour determination

Soil colour was determined using the Munsell soil colour chart to obtain the hue, value, and chroma of the samples as described by Matike et al., (2011a).

4.2.3 Soil pH

Soil pH was determined using 10g of each soil to 25ml solution of water. The solution was stirred and left to stand for 30 minutes. Calibration of the pH meter (Ohaus 2100 model) was done with buffer solutions at pH 4 and 7 before analysis (Vilakazi, 2017).

4.2.4 Particle size analysis using the hydrometer method

50g of soil was weighed and placed in a stirrer cup, and 50 ml of Calgon solution was added along with 500 ml of distilled water. The mixture was stirred for five minutes and transferred to a measuring cylinder and water was added to raise the volume to 1000ml. The temperature of the suspension was recorded before mixing using a plunger, and then immediately the hydrometer was used to take the first reading (R_1), for clay and silt content. The second reading R_2 was done to determine the clay content as guided by its settling time in the suspension. The contents were then transferred to pass through a 53µm sieve into a waste bucket. This was done to remove the fine fraction (silt and clay). The remaining coarse sand fraction on the sieve was then dried in an oven at 105ºC. The dried mass was passed through a sieve net of 500 and 250 µm sieve size with a receiver at the bottom, which represented the course, medium and fine sand fraction. A textural triangle was used to determine the textural class using the percentages of sand, silt and clay obtained (Bouyoucos, 1962).

4.2.5 Exchangeable bases determination using the ammonium acetate method

Air-dried soil (2g) was weighed and transferred into a centrifuge tube. Then 20ml of 1M ammonium acetate was added as an extraction solution for calcium (Ca), potassium (K), magnesium (Mg) and sodium (Na). The mixture was shaken for 30 minutes using a horizontal shaker and filtered using Whatman paper No.1. The filtrate was then analysed for bases using the Atomic Absorption Spectrophotometer (AAS) set at the wavelength of 422.7nm for Ca, 766.5nm for K, 285.2nm for Mg and 589nm for Na (Reeuwijk, 2002)

4.2.6 Exchangeable acidity determination

About 5g of soil was weighed and transferred into a 100 ml plastic centrifuge tube. Then 25ml of 1M KCL was added, and the mixture was shaken for four minutes using a horizontal shaker, before centrifuging for two minutes and filtering through Whatman No.1 filter paper. A 12.5ml extract was then transferred into a conical flask and titrated with 0.01M NaOH with five drops of phenolphthalein indicator. The solution was titrated until it remained pink for at least 30 seconds and exchangeable acidity was calculated in $Cmol_c$/kg (Vilakazi, 2017).

4.2.7 Cation Exchange Capacity (CEC)

The CEC was calculated by adding Exchangeable bases (Ca, Mg, K and Na) and Exchangeable acidity (Al^{3+} and H^+).

4.2.8 Mineralogical analysis

The soil samples were prepared by grinding in mortar resulting in a powdery form and sent to the University of Zululand for analysis. Thermogravimetric analysis (TGA) was conducted using a TGA analyser (Perkin Elmer Pyres 6). Samples ranging from 10-15 mg were heated at a temperature range 30 to 700°C at a heating rate of 5°C per min under a nitrogen environment at a flow rate of 20 ml.min-1.The TGA profile provides a thermal decomposition “fingerprint” that aids in identifying clay minerals by comparing the temperature ranges and magnitude of weight losses with known decomposition patterns for specific minerals. The phase identification of minerals was done using X’pert of high score software.

4.2.8 Statistical analysis

The results of chemical analyses were subjected to one way analysis of variance (ANOVA) unbalance design using GenStat 18th edition. The treatment factors were area. The area means were separated using the least significant difference (Bonferroni at $p < 0.05$).

4.3 Results

4.3.1 Chemical properties of cosmetic and medicinal soil from the study areas

The pH, exchangeable acidity, and cation exchange capacity (CEC) for cosmetic and medicinal soil are presented in Table 4.1. Soil pH significantly differed with area and ranged from 4.9 to 6.07 at Elandskop, 4.7 to 5.58 at KwaNxamalala, 5.19 to 5.65 at Willowfontein, while PMB Central had pHs of 5.08 to 5.29 ($p = 0.007$). Overally, the mean pH was highest at Elandskop.

Meanwhile, exchangeable acidity had the widest range at Elandskop (0 to 14.67 Cmolc/kg), compared to KwaNxamalala (4.45 to 9.87 Cmolc/kg), Willowfontein (3.88 to 23.87 Cmolc/kg) and PMB (3.40 to 18.42 Cmolc/kg), with no significant difference in acidity between all areas.

However, the cation exchange capacity (CEC) had a wider range at PMB central (6.28 to 24.11 Cmolc/kg) than Elandskop (7.57 to 16.61 Cmolc/kg), KwaNxamalala (3.04 to 14.36 Cmolc/kg) and Willowfontein (3.15 and 13.68 Cmolc/kg) but also did not significantly differ among sites overally.

Table 4.1: The pH, exchangeable acidity and CEC of cosmetic and medicinal soil

Area	Source	pH_{water}	Exchangeable acidity ($Cmol_c$/kg)	CEC ($Cmol_c$/kg)
Elandskop	$Hillside_1$	4.90	14.67	16.61
	Roadside	5.69	0	7.57
	$Hillside_2$	5.39	1.733	11.39
	$Hillside_3$	6.07	0	13.23
	$Hillside_4$	5.88	1.73	9.97
	Mean	**5.59**	**3.63**	**11.75**
KwaNxamalala	$Roadside_1$	5.01	7.47	9.88
	$Mountain_1$	5.58	9.87	12.18
	$Mountain_2$	5.48	9.60	13.25
	$Mountain_3$	4.70	4.45	3.04
	$Roadside_2$	5.00	8.93	14.36
	Mean	**5.15**	**8.06**	**10.54**
Willowfontein	Hillside	5.62	23.87	12.40
	$Roadside_1$	5.41	5.83	5.36
	$Roadside_2$	5.19	4.75	12.19
	$Roadside_3$	5.65	8.03	13.68
	Mountain	5.46	3.88	3.15

	Mean	**5.47**	**9.27**	**9.36**
PMB Central	Mountain$_1$	5.29	3.40	12.58
	Roadside	5.08	18.42	24.11
	Mountain$_2$	5.18	9.48	6.28
	Mountain$_3$	5.18	4.94	6.30
	Mountain$_4$	5.12	6.92	6.49
	Mean	**5.17**	**8.63**	**11.15**
	LSD	**0.29**	**11.23**	**2.4**

4.3.2 The chemical properties of soil used for geophagia in the study soil

Soil pH varied across different locations in geophagic soils. It was lowest at Willowfontein (range of 3.73 to 5.74), and highest at PMB (5.53 to 5.79) while Elandskop (4.33 to 5.84) and KwaNxamalala (4.92 to 5.63) had moderate ranges.

KwaNxamalala (range 6.93 to 23.87 Cmolc/kg) had the highest mean exchangeable acidity ($p<0.01$) while the other 3 sites were not that different.

The CEC was lowest at Willowfontein (4.42 – 7.73 $Cmol_c$/kg), followed by Elandskop (3.97 – 16.12 $Cmol_c$/kg) and PMB central (5.01- 25.07), while KwaNxamalala (11.55 – 25.41 $Cmol_c$/kg) had the highest mean CEC ($p <0.01$).

Table 4.2: The pH, exchangeable acidity, and CEC of geophagic soil

Area	**Source**	**pH in H_2O**	**Exchangeable Acidity (Cmol$_c$/kg)**	**CEC (Cmol$_c$/kg)**
Elandskop	Roadside$_1$	5.84	15.33	16.12
	Roadside$_2$	4.33	10.27	11.60
	Yard	5.53	0.53	3.97
	Roadside$_3$	5.38	4.40	6.03

	Roadside4	5.68	0.54	5.19
	Mean	**5.31**	**6.21**	**8.58**
KwaNxamalala	Roadside 1	4.92	6.93	11.55
	Roadside2	5.21	17.47	18.97
	Roadside3	5.63	17.87	22.23
	Roadside4	5.20	12.00	14.88
	Roadside5	5.32	23.87	25.41
	Mean	**5.26**	**15.63**	**18.61**
Willowfontein	Yard	5.50	0.84	6.03
	Hillside1	5.74	1.08[a]	7.33
	Roadside1	3.73	10.56	3.60
	Hillside2	5.25	4.46	6.17
	Roadside2	5.63	1.28	4.42
	Mean	**5.17**	**3.64**	**5.51**
PMB Central	Mountain1	5.76	0.43	9.29
	Mountain2	5.58	0.55	5.01
	Roadside1	5.65	6.21	9.12
	Roadside2	5.53	20.43	25.07
	Roadside3	5.79	0.54	7.98
	Mean	**5.66**	**5.63**	**11.29**
	LSD(Area)	**0.47**	**5.71**	**4.53**

)

4.3.3 The physical properties of cosmetic and medicinal soil in the study areas

The soil used for cosmetic & medicinal purposes in Elandskop had mostly a silt loam texture (Table 4.3). While in KwaNxamalala most soils were sandy loam, with two being clay loam and silt clay loam. In Willowfontein most soils were mostly silt clay with two samples being clay and sandy loam. Soil from PMB central were silty clay to silty clay loam.

The dominant soils colours in Elandskop, KwaNxamalala and PMB central were light red to red, while in Willowfontein all soils were red.

Table 4.3: The texture and colour of cosmetic and medicinal soil in the study areas

Places	Source	Sand (%)	Silt (%)	Clay (%)	Textural Class	Colour
Elandskop	$Hillside_1$	24	51	25	Silt Loam	Light Red
	Roadside	22	40	38	Silt Loam	Light Red
	$Hillside_2$	23	50	27	Silt Loam	Light Red
	$Hillside_3$	29	51	20	Silt Loam	Red
	$Hillside_4$	30	47	22	Loam	Light Red
KwaNxamalala	$Roadside_1$	25	36	39	Silt Clay Loam	Red
	$Mountain_1$	75	14	10	Sandy Loam	Light Red
	$Mountain_2$	27	39	34	Clay Loam	Red
	Mountain $_3$	74	15	11	Sandy Loam	Light Red
	$Roadside_2$	70	17	13	Sandy Loam	Light Red
Willowfontein	Hillside	5	40	55	Silt Clay	Red
	$Roadside_1$	8	45	47	Silt Clay	Red
	$Roadside_2$	67	20	13	sandy loam	Red
	$Roadside_3$	5	42	52	Silty Clay	Red
	Mountain	9	37	54	Clay	Red
PMB Central	$Mountain_1$	6	49	45	Silt Clay	Light Red
	Roadside	13	46	41	Silt Clay	Red
	$Mountain_2$	12	46	42	Silt Clay	Red
	$Mountain_3$	11	50	40	Silty Clay Loam	Light Red
	$Mountain_4$	5	59	36	Silty Clay Loam	Light Red

Table 4.4 shows the texture and colour of soils used for geophagia in the studied areas. Elandskop soils were predominantly silt loam and sandy loam. In KwaNxamalala and PMB central, geophagic soils varied from sandy loam to clay, while in Willowfontein they were sandy loam to silty clay.

Soil colours were pale yellow to red in Elandskop, yellow to strong brown in KwaNxamalala, pale yellow to yellow brown in Willowfontein, while samples from PMB central had more variable colours from white, through grey colours to light yellowish-brown (Table 4.4)

Table 4.4: Texture and colour for geophagic soils in the study areas

Places	Source	Sand (%)	Silt (%)	Clay (%)	Textural Class	Soil colour
Elandskop	Roadside$_1$	46	20	34	Sandy Loam	Pale Yellow
	Roadside	50	27	23	Silt Loam	Reddish Yellow
	Yard	43	20	37	Silt Loam	Reddish yellow
	Roadside$_3$	73	13	14	Sandy Loam	Pale Yellow
	Roadside$_4$	68	11	21	Sandy Clay Loam	Red
KwaNxamalala	Roadside $_1$	36	33	31	Clay Loam	Reddish Yellow
	Roadside$_2$	20	33	46	Clay	Yellow
	Roadside$_3$	12	57	31	Silty Clay Loam	Yellow
	Roadside$_4$	25	20	55	Clay	Strong brown
	Roadside$_5$	75	16	9	Sandy Loam	Yellow
	Yard					
Willowfontein		54	22	27	Sandy Clay Loam	Yellow
	Hillside$_1$	4	45	51	Silty Clay	Pale Yellow
	Roadside$_1$	18	51	31	Silty Clay Loam	Pale Yellow
	Hillside$_2$	56	21	23	Sandy Clay Loam	Yellow brown
	Roadside$_2$	65	19	16	Sandy Loam	Yellow brown
PMB Central	Mountain$_1$	23	59	18	Silt Loam	Light Grey
	Mountain$_2$	11	37	53	Clay	White
	Roadside$_1$	5	56	38	Silty Clay Loam	Light Grey
	Roadside$_2$					
	Roadside$_3$	62	27	11	Sandy Loam	Light Yellowish-brown
	roadside (3)	53	28	19	Sandy Loam	Light Greenish Grey

Mineralogical determinations for cosmetic and medicinal soil are shown in Table 4.5. The dominant mineral in Elandskop soils was quartz (SiO_2), followed by haematite (Fe_2O_3), with a few soil samples also having fluorite and calcite ($CaCO_3$). KwaNxamalala soils also followed this order, except for one soil from Roadside2 that had 100% haematite, and two samples from the Mountain1&2 that had corundum. All Willowfontein soils had quartz, though in some instances minerals such as haematite, fluorite and chromium were more dominant. PMB central soils were dominated by haematite, except for one sample from Mountain1 that had more quartz.

Table 4.5: Qualitative analysis of minerals found in cosmetic and medicinal soils from the study (%)

Area	Source	Quartz	Hematite	fluorite	Halite	Eskolaite	Corundum	Calcite	Chromium	Bornite
Elandskop	Hillside$_1$		61	22						
	Roadside	57	43							
	Hillside$_2$	77	23							
	Hillside$_3$	89	11							
	Hillside$_4$	25	9					66		
KwaNxamalala	Roadside$_1$	48	30			22				
	Mountain$_1$	27	30				43			
	Mountain$_2$	38.4	16.2				45.5			
	Mountain $_3$	66	34							
	Roadside$_2$		100							
Willowfontein	Hillside	25	43	32						
	Roadside$_1$	78	22							
	Roadside$_2$	20	56	24						
	Roadside$_3$	13	87							
	Mountain	42							58	
PMB central	Mountain$_1$	91	9							
	Roadside		100							
	Mountain$_2$	27	73							
	Mountain$_3$	23	77							
	Mountain$_4$	38	49		13					

Geophagic soils from Elandskop had quartz and haematite as the dominant minerals, as so did soils from the other three study areas (Table 4.6). In some instances, you would also find minerals such as fluorite, halite, eskolaite, corundum, calcite and bornite present in the samples. Soil sampled from $Mountain_2$ from PMB central was dominated by calcite.

Table 4.6: Quantitative analysis of minerals found in geophagic soils from the study (%)

Areas	Uses	Source	Quartz	Hematite	fluorite	Halite	Eskolaite	Corundum	Calcite	Chromium	Bornite
Elandskop	Geophagia	Roadside$_1$	47	53							
		Roadside	36	64							
		Yard	24.2	30.3	22.2	23.2					
		Roadside$_3$	36	64							
		Roadside$_4$	87			13					
KwaNxamalala	Geophagia	Roadside $_1$	21.8	48.5			29.7				
		Roadside$_2$	52	18	29						
		Roadside$_3$	13	21			13	53			
		Roadside$_4$	11	62		-	27	-			
		Roadside$_5$	21.8	48.5	16.8		12.8				
Willowfontein	Geophagia	Yard	63	37							
		Hillside$_1$	78	22							
		Roadside$_1$	33	49		18					
		Hillside$_2$	60	40							
		Roadside$_2$	62		38						
PMB	Geophagia	Mountain$_1$	19.2	54.5	20.2	6.1					
		Mountain$_2$	13	23					61		3
		Roadside$_1$	38	49		13					
		Roadside$_2$	38	49		13					
		Roadside$_3$	37	48		12					

4.4 Discussion

The pH of cosmetics and medicinal soil was acidic in all four areas, ranging from 4.7 - 6.07. Matike (2011a) observed an average pH of 6.31 in soil used as sunscreen in the Eastern Cape, while Madikizela et al., (2017), recorded a pH of 4.9. Skin pH, which is normally acidic ranges from 4.5 – 6.5 (Matike et al., 2011a, Ali and Yosipovitch, 2013). Thus, the samples used for cosmetics in the four study areas were considered to have suitable pH for skin application. The acidic pH of the skin enables it to act as the body's first defence against bacteria by creating an unfavourable environment for bacterial growth (Ali and Yosipovitch, 2013). Matike et al., (2011a) affirmed that a suitable pH for skin application must range from 5-7 to avoid skin damage. The studied geophagic soil pH was slightly more acidic as it ranged from 3.73 – 5.84 in the four areas. Ngole et al., 2010 reported a pH lower than 7 for South Africa and a pH lower than 5.69 for Swaziland geophagic soils in their study. Since the pH of human saliva varies between 5 and 8 (Ngole et al., 2010), the soils used in this study fall within this pH range and so pose no danger to users. The human stomach gastric juice pH ranges from 1.5-2.0 (Fujimori, 2020).

The exchangeable acidity of soil used for cosmetics and medicinal purposes ranged 0-23.87 $Cmol_c$ /kg. Another conducted study in KwaZulu Natal reported lower acidity (0.04-0.22 $Cmol_c$ /kg) for healing and cosmetic soil (Buthelezi-Dube et al., 2022). The CEC of soil used for cosmetics and medicinal purposes ranged from 3.04-24.11 $Cmol_c$ /kg. Soils with CEC >15 $Cmol_c$/kg have a high absorption capacity, which can influence the exchange of ions from the soil when applied to the skin and vice versa (Tateo and Summa, 2007). The exchange of ions between the soil paste and the skin can allow the absorption of toxins and germs from the skin while ensuring skin cleansing action. Only 2 out of 20 soil samples had CEC above 15 Cmolc/kg and thus have potentials to be used for skin cleansing since they have high absorption capacity. The other 18 out 20 soils had CEC values lower than 15 $Cmol_c$/kg, meaning they may not absorb compounds from the skin but can still supply the skin with nutrient ions (e.g. Ca^{2+}, K^+, Na^+ and Mg^{2+}) depending on their concentrations. Matike (2011a) also reported soil samples from the Eastern Cape used for cosmetics (cleansing, sunscreen, and beautification) as having CEC lower than 15 $Cmol_c$/kg.

Geophagic soil CEC ranged from 3.60-25.41 $Cmol_c$/kg. The CEC of 15 out 20 soil sample in this study lies within 1:1 clay minerals CEC values of 3-15 $Cmol_c$/kg (Ngole et al., 2010). Thus, the adsorption capacity of the studied soil is classified as low, and their ingestion is not likely to result in the adsorption of cations from the gastro-intestinal tract. Soil with a high CEC has been reported to absorb diarrhoea-causing enterotoxins (Matike et al., 2011a, Ngole et al., 2010).The 5 soil samples with high CEC > 15 $Cmol_c/kg$ can be used treat diarrhoea. Those soil samples with CEC < 15 $Cmol_c/kg$ for geophagic soil are classified as having low adsorption capacity thus they are safe to use.

Soil texture from the current studied areas ranged from silty loam to clay. Matike (2011a) reported similar textures for cosmetic soil samples from Eastern Cape that were silt loam and silty clay loam. The particles size of ranges of silty loam and clay are fine, and thus suitable for application as the paste will not be gritty. A few samples were sandy loam, which meant they had sizeable proportions of sand particles. This is not suitable for skin application as sand (quartz) is course and gritty thereby creating potential to bruise the skin.

Most geophagic soil samples were dominated by silt loamy and sandy loamy textures. Sand particles contain a majority of the quartz (SiO_2) mineral, and it is a hard mineral measuring 7 on Mohr's hardness scale (Ngole et al., 2010). The human dental enamel has calcium phosphate as the dominant mineral; which is much softer than quartz (its hardness is 5 on Mohr's hardness scale). Too much quartz in the sand fraction could cause damage to the dental enamel through grinding, cracking, splitting and breakage during chewing (Ngole et al., 2010).

Cosmetic and medicinal soils were yellow-red to red, with a hue of 2.5YR. This was similar to findings by Matike (2011a) for cosmetic soils sampled from the mountains and roadsides in Eastern Cape, South Africa. A hue of 2.5YR suggests the occurrence of haematite and goethite; which are responsible for the reddish and yellowish colour respectively (Matike et al., 2011a). Our mineralogical analysis also confirmed high presence of haematite in cosmetic soils (Table 4.5). Hoang-Minh (2010) reported goethite and haematite to have low UV radiation transmission due to their high refractive indices, making red-coloured soils to be effective sunscreens. The studied geophagic soils had various colours ranging from white through pale yellow, reddish yellow, yellow brown to light grey. Ngole (2010) reported geophagic soil used in the Eastern Cape as mostly white and yellow brown. Ekosse (2012), in a study conducted in Botswana (Gaborone) also noted that the geophagic soils bought from street vendors were white, light grey, yellow and light-yellow brown. Soil colour varies with location as we can attest from the different cited studies.

Results from mineral qualitative phase identification showed that cosmetic and medicinal soils were dominated by quartz and haematite in all areas, with occasional occurrences of minerals like fluorite, halite, eskolaite, corundum, calcite, and chromium in a few samples. A study done in Port St Johns on clayey soil from Isinuka traditional spa also showed a dominance of quartz in the samples (Jumbam, 2013). Dlova (2013) again reported that red soil traditionally used for UV protection as having quartz and haematite as the dominant peaks in XRD analysis. Most commercial sunscreen products however contain metals such as titanium dioxide or zinc oxide as active ingredients, (Dlova et al., 2013). The soils in the studied area do not have these metals so they might not be effective as commercial sunscreen.

Geophagic soils in all areas were also dominated by quartz and haematite, with a few samples having halite, eskolaite, corundum, calcite and bornite. Ngole and Ekosse (2012) also observed quartz in their geophagic soil samples. Quartz is known to be resistant to chemical change. The main inorganic component of the human tooth is made of calcium dominant mineral with a Mohr's hardness of 5, which could be damaged by quartz grains. Ingested quartz particles could also scratch the walls of the intestines (Georges-Ivo and Stella, 2012). The survey data showed that another reason why people ingest soil is that they want to supplement nutrients, without precise information of the type of nutrients that are found in such soil (Ngole-Jeme and Ekosse, 2015). Our study proved that geophagic soils had haematite (Fe_2O_3) in high amounts, and so could be a beneficial source of iron for human nutrition.

4.5 Conclusion

In conclusion, the findings indicate that while the studied soils are generally safe for topical application and ingestion, their effectiveness for cosmetic and geophagic uses varies. The acidic pH of the soils aligns closely with that of human skin, reducing the risk of irritation and supporting their potential as skin cleansers by inhibiting bacterial growth. However, the low cation exchange capacity (CEC) of many tested soils limits their ability to adsorb toxins and essential ions, which may diminish their cleansing efficacy when applied to the skin. Additionally, the presence of sand particles raises concerns about potential skin bruising. For geophagia, the soils are deemed safe due to their pH being compatible with human saliva, though their low CEC suggests limited absorption of beneficial cations in the gastrointestinal tract. Ultimately, while the reddish colour and haematite content of these soils may enhance their sunscreen properties and nutritional iron content, their overall effectiveness in both cosmetic and geophagic applications is constrained by their low CEC and limited toxin adsorption capabilities. Users should be aware of these factors when considering the use of these soils for their intended purposes.

The soils utilized for cosmetic and medicinal purposes contain beneficial minerals like hematite, their high quartz content raises concerns regarding safety and effectiveness. Furthermore, the absence of metals commonly found in commercial sunscreens, such as zinc oxide and titanium dioxide, reduces their efficacy as sun protection agents. Considering these factors, consumers seeking effective and safe options should consider choosing finer-textured soils or commercially formulated sunscreens that provide better protection and minimize the risk of skin irritation or damage.

CHAPTER 5

ASSESSING THE SAFETY OF SOIL USED FOR VARIOUS PURPOSES THROUGH MICROBIAL AND HEAVY METAL LOAD DETERMINATION

5.1 Introduction

Soils are not only vital for agriculture but also have important applications in the pharmaceutical industry, where clay minerals like palygorskite, kaolinite, and smectites are used as gastrointestinal protectors and dermatological agents (Carretero et al., 2010). In African communities, soil is commonly used for cosmetics; women in rural areas, especially in KwaZulu-Natal and the Eastern Cape, apply it as sunscreen and skin conditioner (Matike et al., 2011a). This traditional practice, however, raises concerns due to the potential exposure to toxic substances and pathogens present in the soil. Geophagia is defined as the voluntary consumption of soil that has been practiced for centuries. There are various reasons why people consume soil including cravings, appetising taste and smell, for cultural and medicinal purposes (Mathee et al., 2014).

Geophagy, commonly practiced among pregnant women and children in Africa, is believed to offer nutritional benefits, such as iron and calcium supplementation, but poses health risks like lead exposure and parasitic infections. Significant research gaps exist regarding its health impacts and nutrient bioavailability. Further studies are needed to assess its long-term health effects and chemical composition (Davies, 2023).Traditionally, soil can be applied onto body incisions (*ingcabo*) made during ceremonies to help them heal faster, with most traditional incisions done on the forehead, cheeks, or chin. In the Zulu tribe, these incisions are made as an identity to one's clan or used as a guard against evil, leaving behind visible body scars (Magwa, 2006). Many studies on geophagia have been carried out in South Africa, but these mostly focused on studying the physico-chemical properties of soil (Ngole et al., 2010, Ekosse et al., 2010, Ekosse et al., 2011). According to Mpunchane (2010), not many studies have been undertaken in Southern Africa to investigate microbiological properties of geophagic and cosmetic soils.

Consumption of soil that is contaminated could lead to health complications that arise from infectious soil pathogens such as geohelminths (Ekosse et al., 2017). Soil also contains pathogenic microorganisms that can be passed on to people consuming it. Common pathogenic organisms include *Sporotrichum schenck, Escherichia coli, faecal coliform, Shigella* bacteria, etc. from contaminated soil. Studies showed that consuming soils that contain elevated concentrations of trace elements like iron may also result in health complications (Ekosse et al., 2017). Consuming soil may expose users to toxic or harmful heavy metals, pathogenic bacteria, fungi, and viruses. Geological processes (e.g. weathering) and anthropogenic activities (e.g. industrial waste disposal) contribute to the occurrence of elevated concentrations of heavy metals in the soil (Nkansah et al., 2016). Research done in Ghana showed that geophagic soils sold by vendors contained high levels of arsenic (As), lead (Pb), mercury (Hg), cadmium (Cd), and cobalt (Co), that were higher than WHO/FAO recommended safe levels (Woode and Hackman-Duncan, 2014). The consumption of soil with high heavy metal content may cause health complications. Acute exposure to lead (Pb) could affect the human central nervous system resulting in deterioration of the kidney, liver, and heart (Nkansah et al., 2016).

Heavy metals can also get into the body through skin application and may remain there for a long time since they are not biodegradable. Metals such as Pb and Cd may cause cell death increasing the risk of cancer and related diseases. Soils used as cosmetics (sunscreens or cleansers), for medicinal purposes (to treat traditional incisions), and geophagia are therefore potentially harmful. This study aimed to assess soils sampled from uMgungundlovu district in Elandskop, KwaNxamalala, Willowfontein, and Pietermaritzburg (PMB) central for microbial loads and heavy metal (Fe, Pb, Mn, Cu, Cd, Zn, and Ni) contamination, in an attempt to understand their safety for use.

5.1.1 Objectives

1. To evaluate the microbial load of soil consumed or applied onto the body.

2. To assess heavy metal toxicity of soil used for cosmetic/medicinal and geophagic purposes.

5.2 Methodology

5.2.1 Study sites

The study was conducted in the uMgungundlovu District under uMsunduzi local municipality in Elandskop (Ward 7; S29.7274º E30.1350º), KwaNxamalala village in Sweetwater (Ward 3; S29.7078; E30.3045), Willowfontein (Ward 14; S29.7185; E30.3151º), and Pietermaritzburg (PMB) central (29.6006°S; 30.3794°E). Two sources of the soil were considered, namely a primary source where the soil was initially collected from Elandskop, KwaNxamalala, and Willowfontein; either by the roadside, mountainous areas, or near riverbanks. While the secondary source consisted of soil samples bought from street vendors in PMB central; which were already processed either by boiling, drying, etc.

5.2.2 Soil sample collection, storage, and preparation

Biological soil samples were collected from both primary and secondary sources using a methodology similar to that described in Chapter 4.2.1, while ensuring that aseptic techniques were applied. Ten samples were collected in each area, with five replicates each of cosmetics and geophagic soil, with all sampling equipment initially disinfected with 70% ethanol. The soil samples were then transferred into ziploc bags then placed in cooler boxes to prevent desiccation. The samples were sieved while fresh from the field and stored in the refrigerator until analysis.

5.2.3 Bacterial and fungal plate counts

One gram of soil was weighed and transferred into 9ml of sterile distilled water, then homogenised by shaking until the soil dispersed. About 1 ml of dispersed soil was aseptically transferred to another 9 ml of pure distilled water using a sterile pipette to make a dilution of 10^{-2}. Serial dilutions were done up to 10^{-6} dilutions. One ml aliquots of dilutions 10^{-3}-10^{-6} were then transferred into labelled sterile petri plates. The plates for bacteria comprised molten nutrient agar, while those for fungi had malt extract agar. One ml of tetracycline, penicillin, and streptomycin (50µg/ml) was also added to the fungal plates. All plates were then swirled in a clockwise and anticlockwise motion, allowed to set, and incubated in an inverted position for 24hr at 37ºC for bacteria and 5-7 days at 25ºC for fungi. After incubation, colony counts were then done (Bisi-Johnson et al., 2013).

5.2.4 Total coliform bacteria and *Escherichia coli* (*E.coli*) determination

Ten grams of soil was transferred into 90ml sterile water to make dilutions of 10^{-1} to 10^{-3}. Aliquots of 0.1, 1 and 10ml were then transferred into glass tubes containing 10 ml lactose nutrient broth with Durham tubes. These were incubated for 24 – 48 hrs at 35^0 C and examined for gas production. Tubes that produced gas after incubation were recorded as positive for total coliforms. Using a transferring loop, the solution in the positive tubes was transferred onto a plate with Eosin-Methylene Blue-Lactose agar (EMB agar) using the streak plate method and incubated for 24hr. After 24hr, colonies nucleated with metallic sheen were recognised as confirmation test for the presence of *E. coli* bacteria. The coliform count was calculated using the reference most probable number table (MICR 213 Water Practice Manual, 2011).

5.2.5 Heavy metals determination through diethylenetriamine penta acetic acid extraction

About 1.97 g of diethylene triamine penta acetic acid (DTPA), 1.47 g calcium chloride ($CaCl_2.2H_2O$), and 13.3 ml Triethanolamine were dissolved in distilled water. The initial pH was 7.8 then adjusted to 7.3 using concentrated hydrochloric acid and made up to 1L with distilled water. About 12.5 g of soil was weighed then 25 ml of the DTPA extraction solution was added to a centrifuge tube. The solution was shaken for 2 hours using a horizontal shaker, then filtered using Whatman No.1 filter paper (Kulikov, 2016). Multi-element calibration standards were prepared at the following concentrations 0, 1, 2, 5, and 10mg/L. An atomic absorption spectrophotometer (AAS) was used to determine the concentration of metals. The wavelength was set at 342.7nm for copper, 248.3nm for iron, 297.5nm for manganese, 213.9nm for zinc (Zn), 232 nm for nickel (Ni), 228.8nm for cadmium (Cd) and 217 nm for lead (Pb).

5.2.6 Statistical analysis

Results from microbial and heavy metal analysis were subjected to were subjected to one way analysis of variance (ANOVA) unbalance design using GenStat 18th edition. The treatment factor was/site area. The area means were separated using the least significant difference (Bonferroni at $p < 0.05$).

5.3 Results

5.3.1 The bacterial and fungal count of soil used for cosmetics and medicinal purposes

Table 5.1 presents the bacterial colony count of soil used for cosmetics and medicinal purposes. The majority of soil samples were not significantly different except for an Elandskop Hillside$_4$ and PMB (Roadside and Mountain$_2$) soil that had high bacterial counts. Overall, PMB had the highest mean bacterial numbers while Willowfontein had lowest. Area and source factors also did not have a significant impact on fungal numbers though there were a few samples in KwaNxamalala and Willowfontein with higher fungal counts. There were no significant differences among mean fungal counts across areas.

Table 5.1: Bacterial and fungal colony counts of cosmetic & medicinal soil

Area	Source	Bacteria count (CFU/ml) x 1000	Fungal count (CFU/ml) x 1000
Elandskop	Hillside$_1$	126.5	501
	Roadside	775	6.25
	Hillside$_2$	32.25	27.75
	Hillside$_3$	647.5	65.5
	Hillside$_4$	7607.5	11175
Mean		**1837.75**	**2355.1**
KwaNxamalala	Roadside$_1$	1937.5	589.5
	Mountain$_1$	4282.5	1117.75
	Mountain$_2$	410	617.5
	Mountain$_3$	1545	11312.5
	Roadside$_2$	1312.5	6800
Mean		**1823.7**	**4087.45**
Willowfontein	Hillside	430.25	23.5
	Roadside$_1$	56.5	6.25

	$Roadside_2$	14.5	28
	$Roadside_3$	3980	12180
	Mountain	1567.5	5570
Mean		**1209.75**	**3561.55**
PMB central	$Mountain_1$	3175	3361.25
	Roadside	13137.5	3155.75
	$Mountain_2$	13862.5	3061.25
	$Mountain_3$	2865	728
	$Mountain_4$	2390.5	1528.5
Mean		**7086.1**	**2366.95**
	LSD	**4745.826**	**5915.792**

5.3.2 The bacterial and fungal count of soil used for geophagia

The area sampled did not have a significant impact on bacterial or fungal counts of geophagic soils, with only a few samples in Willowfontein and PMB having significantly higher bacterial numbers (Table 5.2). The standard regulation for food safety in South Africa stipulates that colony counts for bacteria and fungi should not exceed $1x10^5$ CFU/ml if analysed using plated agar (Health, 2000). In both the bacterial and fungal counts, 14 out of 20 soil samples were above this count, thereby compromising their safety.

Table 5.2: The bacterial and fungal count of soil used for geophagia

Area	Source	Bacteria count (CFU/ml) x 1000	Fungal count (CFU/m[soil) x 1000
Elandskop	$Roadside_1$	270	0.5
	$Roadside_2$	97.5	0.5
	Yard	415	537.5
	$Roadside_3$	40	2.5
	$Roadside_4$	4545	20225
Mean		**1073.5**	**4153.2**
KwaNxamalala	$Roadside_1$	1227.5	673.25
	$Roadside_2$	1910	199.75
	$Roadside_3$	91	60
	$Roadside_4$	372.25	11.25
	$Roadside_5$	1507.5	946.25
Mean		**1021.65**	**378.1**
Willowfontein	Yard	9.5	297
	$Hillside_1$	69.5	30.5
	$Roadside_1$	59	286.75
	$Hillside_2$	12050	3350
	$Roadside_2$	9970	3572.5
Mean		**4431.6**	**1507.35**
PMB	$Mountain_1$	1357.5	2366.5
	$Mountain_2$	1357.5	122.5
	$Roadside_1$	757.5	2369.25
	$Roadside_2$	14475	2113.75
	$Roadside_3$	2880	3338.5
Mean		**4165.5**	**2062.1**
	LSD(Area)	**5798.295**	**6200.031**

5.3.3 Total coliforms counts and *E. coli* identification of cosmetics and medicinal soil

Overall, there were no significant differences in total coliform bacterial numbers among areas, while some differences were picked within each area among sources, although there were no clear patterns (Table 5.3). At Elandskop, coliform numbers ranged from 22 (for a $Hillside_3$ soil) -743 ($Hillside_2$ soil) with a mean count of 342 CFU/ml. Ranges were 203 – 528 with mean of 398 CFU/ml at KwaNxamalala, while it was 366 – 451 with a mean of 394 CFU/ml at Willofontein; and 30 – 741 CFU/ml with a mean of 396 in Pietermaritzburg central.

Escherichia coli bacteria were present in 3 out of 5 samples each at Elandskop and KwaNxamalala, while only 1 sample tested positive at Willowfontein, and none were detected in Pietermaritzburg central.

Table 5.3: Total coliform bacteria and E. coli for cosmetics and medicinal soil

Area	**Source**	**Total coliform (CFU/ml)**	***E. coli***
Elandskop	$Hillside_1$	450	ND
	Roadside	448	Present
	$Hillside_2$	743	Present
	$Hillside_3$	22	Present
	$Hillside_4$	48	ND
	Mean	**342**	
KwaNxamalala	$Roadside_1$	528	ND
	$Mountain_1$	374	Present
	$Mountain_2$	442	ND
	$Mountain_3$	442	Present
	$Roadside_2$	203	Present
	Mean	**398**	
Willowfontein	Hillside	391	ND
	$Roadside_1$	451	Present
	$Roadside_2$	381	ND
	$Roadside_3$	366	ND
	Mountain	382	ND
	Mean	**394**	
PMB central	$Mountain_1$	30	ND
	Roadside	382	ND
	$Mountain_2$	738	ND

	$Mountain_3$	89	ND
	$Mountain_4$	741	ND
	Mean	**396**	
	LSD	**318.1**	

ND =Not detected

5.3.4 The total coliform and *E.coli* of soil used for geophagia

There was no significant effect of area on mean total coliform counts, though a few source differences were picked in each area for geophagic soil samples (Table 5.4). Nine out of the 20 samples studied also had total coliform counts that were below the recommended safe limit for food (i.e. < 200 CFU/ml) in South Africa, with KwaNxamalala having more samples (4), while Elandskop and PMB central had the least number of samples (2 each) above the safe limit. *E. coli* bacteria was however mostly detected in the Willowfontein soil samples, while none was detected in PMB central samples as with cosmetic soil (Table 5.4).

Table 5.4: The total faecal coliform and E.coli bacteria in soil used for geophagia

Area	Source	Total coliform (CFU/ml)	*E.coli*
Elandskop	$Roadside_1$	30	ND
	$Roadside_2$	34	ND
	Yard	72	Present
	$Roadside_3$	423	ND
	$Roadside_4$	423	Present
	Mean	**196**	
KwaNxamalala	$Roadside_1$	528	ND
	$Roadside_2$	412	ND
	$Roadside_3$	387	ND
	$Roadside_4$	47	ND
	$Roadside_5$	382	Present
	Mean	**351**	
Willowfontein	Yard	130	ND
	$Hillside_1$	418	Present

	$Roadside_1$	29	ND
	$Hillside_2$	399	Present
	$Roadside_2$	741	Present
	Mean	**343**	
PMB Central	$Mountain_1$	65	ND
	$Mountain_2$	60	ND
	$Roadside_1$	454	ND
	$Roadside_2$	395	ND
	$Roadside_3$	47	ND
	Mean	**204**	
	LSD	295.4	

ND = Not detected

5.3.4 Heavy metal concentration in soil used for cosmetics and medicinal purposes.

Table 5.5 presents concentrations of trace metals in soil used for cosmetics and medicinal purposes. Iron concentrations ranged from -3.99-13.53mg/kg. The Willowfontein samples however generally had higher Fe amounts while those from Elandskop had the lowest mean concentrations.

Most of the samples collected (except for a few) had Nickel (Ni) below the critical safe limit of 0.5 mg/kg, with at least one sample from each area being above the safe level (Table 5.5). There were however no significant differences in Ni among sites.

PMB central samples exhibited the lowest copper amounts (mean = -0.017 mg/kg) with a number of the samples in the undetectable range, while Willowfontein soils had higher Cu amounts (mean = 0.295 mg/kg). Most roadside soils also generally had lower Cu amounts than hillside or mountain soils across sites (Table 5.5).

PMB central soils generally had the highest manganese concentration ($p < 0.001$), while KwaNxamalala soils had the least (Table 5.5).

All samples collected had lead (Pb) below the WHO recommended safe limit for skin products of 10 mg/kg, with the PMB central samples having the lowest Pb values that did not significantly differ, while KwaNxamalala soils had among the higher Pb ranges ($p < 0.001$). (Table 5.5).

The recommended safe concentration of zinc (Zn) for skin products is 40mg/kg and all studied samples were below this (Table 5.5). All the samples had quite low concentrations of Zn below 1mg/kg thus no harm could occur if applied onto the skin. Again, samples from PMB had among the lowest Zn levels with some samples being below detection level, while Elandskop soils had higher values ($p < 0.001$).

The Cd recommended safety concentration for cosmetics is 3 mg/kg and all the soil samples were below this (Table 5.5). The Cd concentration was low in most samples (< 1 mg/kg), with a few samples below the detection limit. The PMB soils had extremely low Cd levels, while the Elandskop soils were higher ($p < 0.001$).

Table 5.5 Heavy metal concentrations in soil used for medicinal and cosmetic purposes

Area	Source	Fe (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Mn(mg/kg)	Pb (mg/kg)	Zn(mg/kg)	Cd(mg/kg)
Elandskop	$Hillside_1$	0.13	-0.46	0.073	2.37	3.20_b	0.35	0.19_c
	Roadside	0.05	-0.13	-0.11	5.95	4.60	0.65	0.34_d
	$Hillside_2$	0.07	0.00	0.41	20.04	5.47	0.82	0.25_{dc}
	$Hillside_3$	0.016	0.51	0.08	4.43	3.40	0.87	0.27_{dc}
	$Hillside_4$	0.43	0.033	0.17	0.88	1.00	0.54	0.04_{ba}
	Mean	**0.14**	**-0.009**	**0.123**	**6.74**	**3.53**	**0.65**	**0.22**
KwaNxamalala	$Roadside_1$	0.08	0.13	-0.25	2.01	4.40	0.62	0.33_d
	$Mountain_1$	0.11	0.90	-0.21	0.62	6.67	0.49	0.30_d
	$Mountain_2$	0.03	0.11	0.43	3.85	6.00	0.77	0.33_d
	$Mountain_3$	1.62	0.29	0.03	0.44	1.27	0.40	0.02_{ab}
	$Roadside_2$	1.46	0.55	0.15	0.89	1.47	0.26	-0.04_a
	Mean	**0.66**	**0.395**	**0.028**	**1.56**	**3.96**	**0.51**	**0.19**
Willowfontein	Hillside	2.11	0.54	0.76	3.95	2.33	0.55	0.087_b
	$Roadside_1$	0.84	0.107	0.30	6.43	4.07	0.24	0.20_c
	$Roadside_2$	13.53	-0.15	0.22	6.13	5.40	0.71	0.20_c
	$Roadside_3$	1.88	0.15	0.09	0.81	0.80	0.40	0.033_{ba}
	Mountain	0.90	0.0067	0.10	6.33	1.00	0.54	-0.007_{ab}
	Mean	**3.85**	**0.131**	**0.295**	**4.73**	**2.72**	**0.49**	**0.10**
PMB central	$Mountain_1$	-2.36	0.53	0.24	17.42	0.27	0.053	0.005_{ab}
	Roadside	-0.32	0.37	-0.37	30.33	0.53	0.26	0.0018_{ab}
	$Mountain_2$	-3.99	0.38	0.11	8.58	0.13	-0.14	0.01_{ab}
	$Mountain_3$	5.64	-0.35	-0.24	33.07	0.27	-0.003	0.0014_{ab}
	$Mountain_4$	3.51_c	-0.067	0.17	1.67	0.33	-0.10	0.0013_{ab}
	Mean	**0.50**	**0.173**	**-0.017**	**18.21**	**0.31**	**0.01**	**0.01**
	Safety limits		**0.5**			**10**	**40**	**3**
	LSD(Area)	**2.959**	**0.336**	**0.3002**	**5.69**	**1.345**	**0.152**	**0.0873**

5.3.5 The trace and heavy metals of soil used for geophagia

The WHO permissible limits sourced from Moraa (2014) were used in this section. Table 5.6 presents the heavy metal loads of soils used for geophagia. The recommended safety limit for iron in food is 15 mg/kg, and most samples examined were below this except for one sample from PMB central. A few of the samples were below detection, with PMB soils having generally higher Fe levels, while KwaNxamalala soils had the least ($p = 0.006$).

The recommended Ni concentration limit in food is 1 mg/kg. Most soil samples (except for 1 at KwaNxamalala) were below this (Table 5.6). Most soil samples from PMB had Ni below detection levels while those from KwaNxamalala had higher values ($p = 0.024$).

All soil samples had low copper concentration below 2 mg/kg, which is way below the recommended safe level of 10 mg/kg for food, while others were below the detection limit (Table 5.6).
The recommended concentration of Mn for food is 5 mg/kg and most of the sols studied were below this. A few samples from PMB and Willowfontein were above this limit and thus might cause danger if consumed (Table 5.6). The area of samples had no overall significant effect on Mn levels in the soils.

Most soil samples were above the recommended safe limit for Pb in food of 0.3 mg/kg, thus posing a danger to humans consuming this soil (Table 5.6). Moreover, soils in KwaNxamalala had very high Pb levels (average 4.59 mg/kg), while those in PMB had the least Pb amounts ($p < 0.001$).

All soil samples were below the Zn safe limit of 20 mg/kg in food products, and there was also no significant overall impact of area on Zn amounts (Table 5.6).

All soil samples had Cd amounts below the critical safe limit of 0.3 mg/kg (Table 5.6). There was a very wide Cd range of -0.0067 to 0.31 mg/kg in the Willowfontein soils giving a high average of 0.096 mg/kg, while the PMB samples recorded the lowest mean Cd concentration of 0.015 mg/kg ($p < 0.05$).

Table 5.6: Heavy metal load of soil used for geophagia

Area	Source	Fe (mg/kg)	Ni (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Cd (mg/kg)
Elandskop	$Roadside_1$	1.45_{bc}	0.19_{b}	-0.073a	0.51_{ab}	4.20_{cb}	0.43_{c}	0.013_{a}
	$Roadside_2$	2.34_{cb}	0.24_{bc}	-0.093_{a}	4.70_{c}	4.33_{cb}	0.67_{d}	0.016_{a}
	Yard	1.91_{bc}	-0.24_{a}	-0.10_{ab}	1.02_{ab}	4.87_{cd}	0.46_{c}	0.011_{a}
	$Roadside_3$	0.85_{bc}	0.31_{bc}	0.053_{b}	1.25_{ba}	5.87_{d}	0.70_{d}	0.015_{a}
	$Roadside_4$	1.86_{bc}	0.67_{c}	0.21_{ab}	2.00_{b}	1.13_{a}	0.50_{c}	0.17_{c}
	Mean	**1.68**	**0.24**	**0.00**	**1.90**	**4.08**	**0.55**	**0.046**
KwaNxamalala	$Roadside_1$	0.42_{b}	0.41_{cb}	-0.42_{ab}	1.87_{ba}	4.60_{c}	0.59_{c}	0.016_{ab}
	$Roadside_2$	1.51_{bc}	-0.033_{a}	-0.586_{a}	0.26_{ab}	4.67_{c}	0.66_{d}	0.014_{a}
	$Roadside_3$	-2.69_{a}	0.00_{a}	-0.013_{ab}	1.77_{ba}	5.60_{dc}	0.84_{d}	0.017_{ab}
	$Roadside_4$	-2.51_{a}	0.85_{cd}	-0180_{ab}	3.12_{bc}	4.33_{cb}	0.61_{d}	0.017_{ab}
	$Roadside_5$	1.57_{bc}	1.27_{d}	-0.453_{ab}	1.29_{ba}	3.73_{bc}	0.72_{d}	0.015_{a}
	Mean	**-0.34**	**0.5**	**-0.331**	**1.66**	**4.59**	**0.68**	**0.016**
Willowfontein	Yard	3.99_{c}	0.11_{b}	1.113_{d}	1.33_{ba}	3.40_{b}	1.15_{e}	0.31_{d}
	$Hillside_1$	0.61_{bc}	-0.19_{a}	0.106c	1.78_{ba}	3.93_{bc}	0.48_{c}	0.073_{b}
	$Roadside_1$	5.44_{c}	-0.28_{a}	0.06_{b}	8.35_{d}	5.93_{d}	0.73_{d}	0.087_{b}
	$Hillside_2$	3.21_{cb}	0.11_{b}	0.12_{b}	2.53_{b}	0.87_{a}	0.34_{c}	0.02_{ab}
	$Roadside_2$	4.21_{c}	-0.28_{a}	0.173_{b}	3.87_{cb}	1.20_{a}	0.36_{c}	-0.0067_{a}
	Mean	**3.49**	**-0.107**	**0.315**	**3.57**	**3.07**	**0.61**	**0.096**
PMB	$Mountain_1$	15.85_{d}	0.83_{c}	1.50e	9.56_{d}	0.80_{a}	1.12_{e}	0.006_{a}
	$Mountain_2$	-3.58_{a}	-0.23_{a}	-0.20_{ab}	-0.19_{a}	0.27_{a}	-0.31_{a}	0.01_{a}
	$Roadside_1$	6.51_{c}	-0.39_{a}	0.446_{c}	7.40_{d}	1.40_{a}	0.84_{d}	0.022_{a}
	$Roadside_2$	6.91_{c}	-0.35_{a}	-0.88_{ab}	1.08_{ab}	0.47_{a}	0.34_{c}	0.017_{ab}
	$Roadside_3$	3.56_{b}	-0.16_{a}	0.313_{c}	0.71_{ab}	1.20_{a}	0.075_{b}	0.018_{ab}
	Mean	**5.85**	**-0.06**	**0.236**	**3.71**	**0.83**	**0.46**	**0.015**
	Critical safe limit	**15**	**1**	**10**	**5**	**0.3**	**20**	**0.3**
	LSD	**3.446**	**0.4344**	**0.3002**	**2.162**	**1.144**	**0.2577**	**0.0578**

Means followed by a different subscript are significantly different ($p < 0.05$)

5.4 Discussion

5.4.1 Microbial Load Determination

The bacterial colony count for cosmetics and medicinal soil was found to range from $1.45x10^4$-$1.39x10^7$ CFU/ml. This was much higher than that found by Ogamaka, (2015) in a study in Western Nigeria (with 10^3-10^5 bacterial CFU/ml). The fungal colony count range for cosmetics and medicinal soil was $2.65x10^3$-$1.22x10^7$CFU/ml. Currently there are no internationally standardised safety limits in cosmetic soil, (Kim et al., 2020). The mean bacterial count for geophagic soils in the four studied areas ($1.02x10^6$- $4.58x10^6$CFU/ml) was also higher than geophagia soil samples from markets in Nigeria that ranged from 2.1 - $6.9x10^2$ CFU/ml (Ogomaka, 2015). The fungal count for geophagia was $5x10^2$-$2.02x10^7$CFU/ml. The reason for the high bacterial and fungal counts for both cosmetics and geophagic soil samples is that soil provides excellent substrates for various organisms due to nutrient, water and organic matter availability (Bisi-Johnson et al., 2013). The studied soil were collected in top soil which contains high organic matter content that serves as a source of carbon and energy for microorganisms (Bhattarai et al., 2015).

The total coliform of soil used for cosmetics and medicinal soil range was 22-743 CFU/ml. While the *E.coli* presence in 7 out of 20 soil samples was an indication of pathogenic microorganism. The US FDA mandates that cosmetics should not be sterile but must not be contaminated with pathogenic microorganisms, and the level of non pathogenic microorganisms should be minimal (Kim et al., 2020). Geophagic soils had a total faecal coliform bacteria count mean range of 29 – 741CFU/ml. The South African health guidelines propose a total coliform count of < 200 CFU/ml in fresh vegetables and raw fruits (Health, 2000). Some of the geophagic samples (across all sites) were above this limit; thus indicating that pathogens may be present in the soil. Possible sources of soil contamination with coliform bacteria could be the pit latrines used in these areas. *E.coli* was also identified in some of the studied soils. Originally *E.coli* counts in water and food were used as an indicator of faecal contamination (Ishii et al., 2006). The absence of *E.coli* in the PMB soil may be due to the influence of heat treatments such as boiling used by PMB vendors that decreased bacterial contaminants. Studies show that *E.coli* bacteria denatures at temperatures above 94°C (Lee et al., 2002). While the normal boiling point of pure liquid water is 100°C (Andrade-Gamboa and Donati, 2021), thus exposing the soil to such heat treatments (boiling) may be effective in eliminating pathogenic organisms like *E.coli.*

5.4.2 Heavy metal load of cosmetics and medicinal soil

The heavy metal load was determined to test safety of soil samples applied on the skin or ingested by humans. Iron concentration ranged from -3.99 - 13.53 mg/kg across sites. This was lower compared to other studied cosmetic soils in South Africa. Morekhure-Mphahlele et al., (2017) found Fe ranges of 0.05 - 19.27 mg/kg in Qwa-Qwa, then 0.25-17 mg/kg in Harrismith. Iron is considered to be a metal with minimal toxicological effects in the short term, but long exposure from cosmetic application with high Fe levels may induce cellular death or colorectal cancer as a result of cumulative effects (Moraa, 2014). The studied soils had Ni concentration ranges of -0.46 - 0.9 mg/kg; which is lower than soil sampled from KZN and Limpopo (31-133 mg/kg) by Morekhure-Mphahlele et al., (2017). A Ni concentration of 0.5 mg/kg is adequate to cause dermatitis in the skin, so since most of the soils (except for four) had concentrations below that, they can be rendered safe for use. Copper concentration levels ranged from -0.37-0.76 mg/kg. It is an active ingredient used in cosmetics products through its role in skin toning, wound healing, and UV protection (Borkow, 2014). Neutrogena Visibly Firm® Face Lotion SPF 20 is a cosmetic facial cream that contains copper as its active ingredient (Borkow, 2014). The studied samples Cu concentrations were below 1mg/kg (way below the recommended safe level of 5mg /kg) and are thus safe for use.

The Manganese ranges across sites were 0.44 - 33.07 mg/kg in cosmetic soil. Most of these soils (except for a few) had pH below 5.5, which could explain the high Mn levels. Lead levels in all cosmetic and medicinal soils (0.13 - 6.67mg/kg) on the other hand were much lower than the WHO maximum recommended safety limit of 10 mg/kg (Moraa, 2014), with PMB central soils that were bought processed having the lowest Pb. This means these soils are safe for use in terms of their Pb amounts. Zinc amounts (-0.14 - 0.87 mg/kg) were also quite safe since they were much lower than the recommended safe limit of 40 mg/kg. This means zinc acts as an essential nutrient rather than a toxin in these soils. It is essential as a cofactor for nearly 300 enzymes involved in DNA creation, cell growth, protein building, tissue healing and immune system support (Hussain et al., 2022). Cadmium levels in cosmetics soils (-0.04 - 0.34 mg/kg) were quite safe since they were below the WHO recommended safety limit of 3 mg/kg.

5.4.3 Trace elements and heavy metals in geophagic soils.

Most geophagic soils (range of -3.58 to 15.85 mg/kg) were below the recommended maximum limit for iron in food of 15 mg/kg (Balayneh et al., 2015), with only one soil sample from PMB central slightly higher than this. Other studies of geophagic soils in South Africa found much higher Fe ranges of 24.7 - 87.3 mg/kg (Olowoyo and Macheka, 2013). Nickel concentration levels (-0.39 - 1.27mg/kg) for most geophagic soils (except for 1) were also below the recommended safety limit of 1 mg/kg in food (Balayneh et al., 2015), meaning these soils were relatively safe from Ni toxicity. Copper amounts (-0.88.-1.50 mg/kg) were also much lower than the WHO/FAO safety limit of 10 mg/kg (Balayneh et al., 2015), and thus do not pose a danger to human health. Manganese mean concentrations of -0.19-9.56 mg/kg, were much lower than the WHO/FAO safety guide of 5mg/kg, although a few samples from Willowfontein and PMB central were above this recommended limit and could pose a danger to consumers. Mn exposures can occur in various environments, including food, water, soil, and air. It has a short half-life in blood but long in tissues. Mn accumulates in bones and is associated with dopaminergic dysfunction. Individual factors like age, gender, ethnicity, genetics, and pre-existing medical conditions can significantly impact Mn toxicities (O'Neal and Zheng, 2015).

All but one sample from PMB central had lead concentrations (range of 0.27-5.93 mg/kg) that were way above the recommended Pb safety level in food of 0.3 mg/kg. This is expected because of high pollution levels due to use of leaded fuel. Lead is quite dangerous even in low concentrations to the human body, as it can result in permanent damage including reduced IQ, learning disabilities, nervous system problems, and shortened attention span (Balayneh et al., 2015). Zinc amounts were below the 20 mg/kg safety in all soil samples analysed and so quite safe for use. Most soils (except for one) also had cadmium amounts (-0.0067-0.31 mg/kg) below the WHO/FAO recommended limit for human consumption of 0.3 mg/kg (Balayneh et al., 2015). Olowoyo and Macheka, (2013) also found cadmium to be very low in soils consumed by pregnant women in South Africa. This is ideal since Cd is toxic at intense levels in the long term, with high exposure to humans causing renal dysfunction, obstructive lung disease, Cd pneumonitis, bone defects and increased blood pressure (Tateo and Summa, 2007).

5.5 Conclusion

Generally, bacterial, and fungal populations were high in all soils studied, with the pathogenic bacteria *E.coli* identified in some samples from Elandskop, KwaNxamalala and Willowfontein, but not in soil samples from PMB central. This might be because vendors in PMB central heat treat (through boiling) their soils before selling, which could help kill pathogenic bacteria. Total coliform counts in some geophagic samples were also above the stipulated limit for fresh vegetables in the South African food standard of 200 CFU/ml meaning they pose a danger of causing pathogen diseases. This means users from the other three areas could also try heat-treating the soil before use (as does PMB vendors) to minimise pathogenic contamination of samples they consume or apply. Trace metal elements for cosmetic soil in all areas generally had lower concentrations compared to those found in other similar studies done in South Africa. Ni, Pb, Zn and Cd concentrations in particular were below the safe limits in all cosmetic soils; and thus, regarded as safe from toxicity problems. Geophagic soils mostly had safe levels of Fe, Ni, Cu, Mn, Zn and Cd and hence are safe for use in this regard and could actually serve as sources of these nutrients, while Pb was above the WHO/FAO safety limit in food of 0.3 mg/kg for all geophagic samples but one. This is not ideal as exposure to lead can cause permanent damage, including reduced IQ, learning disabilities, nervous system problems, and shortened attention span. Thus, it is not recommended for people in the Umsunduzi district to consume some of the high lead geophagic soils to avoid such complications.

CHAPTER 6

6.1 GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

This chapter covers the main findings, conclusion and recommendations drawn from the study. It gives an overview of the main soil uses from the selected areas and illustrates how the soils' physical and chemical properties are related to their uses. An evaluation of how safe it is for soil to be used for cosmetics, medicinal and geophagic purposes was also done.

The questionnaire results showed there were more female than male respondents that participated in the survey, with men believing that women were more knowledge on non-agricultural soil uses as these practises are mostly done by women. The common soil uses identified were cosmetics, geophagia, medicinal purposes and construction. Pottery was not practised in all areas since the selected sites were mostly peri - urban. People apply cosmetic soil as a paste onto their skin, in an attempt to cleanse it from impurities and shield them from the sun. Users stated the side effects of this practice included skin blemishes, irritation and drying, depending on the user's skin sensitivity. Skin drying often occurs when the soil paste is not mixed with body lotion. Geophagia is another soil use practised in these areas to satisfy cravings and for enjoyment. The respondents' observation about geophagia side effects on users were constipation, development of gull stones and appendix infection. Cosmetic soil however undergoes heat treatment after collection that includes boiling with water, baking, or direct heat treatments. Users believe that such treatment is effective in reducing contamination by pathogens. This assertion was actually proved correct through biological analyses of some processed soil samples from Pietermaritzburg that had undergone heat treatment and did not have *E. coli* bacteria present in them, unlike soils from the other 3 sites that had not received similar treatment.

The survey also revealed that individuals in various areas collected soil from diverse locations, with cosmetic soil primarily sourced from mountains or purchased already processed from street vendors. Some individuals also collected it from hillsides and roadsides. Matike et al. (2011a) also observed that individuals collected soil samples from roadsides for cosmetic purposes. Soil used for geophagia in particular was predominantly collected from roadside excavations during road construction and mountains, while a small number of participants procured it directly from suppliers. In a study in Limpopo, Mpanama respondents also sourced geophagic soil from mountains (Phakoago, 2017). Most users sampled geophagic soils with tools such as knives, spades, hand-hoes, or selective handpicking across sites. Research conducted by Msibi (2014) revealed a similar finding where most individuals gathered soil by digging with a knife.

Physico-chemical analysis revealed that cosmetic and medicinal soils were in the acidic pH range (4.7 - 6.07). Since normal skin pH skin is around 5 - 7; the observed soil pHs would thus have no significant impact when soil is applied onto the skin. Geophagic soil pH (3.73 - 5.79), also complements that of saliva (5 - 8) and thus would not pose harm to users. The CEC of cosmetics and medicinal soils however was below 15 $Cmol_c$/kg which meant these soils had low ability as cleansers, to absorb impurities and toxins from the skin when applied. Few soils samples that had CEC > 15 $Cmol_c$/kg can be potentially used as effective skin cleanser. Cosmetic soil texture varied from silty clay to sandy loam across sites. The soil samples with sandy loam texture had high sand content. This was also supported by mineralogical analysis which showed the dominance of quartz and haematite in all samples. This is problematic to users since sand particles bruise the skin when applied, as well as damage the teeth and stomach lining when ingested since quartz particles could scratch the walls of the intestines due to its high hardness (Georges-Ivo and Stella, 2012). The light red to red colour of cosmetic soil was also confirmed by high presence of haematite through XRD analysis. Users feel these colours are effective for sun-screening, a notion shared by Hoang-Minh (2010) who reported goethite and haematite to have low UV radiation transmission due to their high refractive indices, making red-coloured soils to be effective sunscreens. Geophagic soils users however selected from a wider colour range of white through pale yellow, reddish yellow, yellow brown to light grey. Other studies also revealed most geophagic soils from South Africa to be whitish, grey or khaki as a result of kaolin, smectite and calcite (George and Ndip, 2011, Georges-Ivo and Stella, 2012). The CEC of most sampled soils also supported this as they were in the kaolinitic range of CEC (i.e. 3-15 $Cmol_c$/kg) with low adsorption capacity. Quartz is typically a colourless or milky white substance that is frequently adorned with a layer of red or yellow iron oxide, thereby enhancing the soil's colour (Silva et al., 2023). The mineralogy of cosmetic soil, however, did not match that used in the cosmetic industry as most commercial sunscreen products contain metalloids such as zinc and titanium oxide, indicating that these soils might not be as effective as commercial sunscreen. The high presence of quartz would also cause skin abrasion if such soil were applied due to the hardness of quartz, thus users are advised to choose finer textures. The presence of haematite in geophagic soil is quite beneficial to users as it can serve as a source of iron to supplement iron deficiency in the body. In the survey, most users stated they consumed soil as a source of nutrient supplements, though some were not too sure of the nutrients supplied. This implies that users have some idea of the scientific benefits of consuming soil.

The bacterial colony count for cosmetics and medicinal soil was high, ranging from 1.45×10^4 to 1.39×10^7 CFU/ml, and so was the fungal count (2.65×10^3 to 1.22×10^7 CFU/ml). This means these soils had favourable conditions (nutrients, water, and organic matter etc.) that favoured proliferation of microbes. Safety guidelines in Europe, USA and South Korea recommend total aerobic counts in cosmetics to be below 1 000 CFU/g or ml (Kim et al., 2020). The examined microbial counts however did not distinguish between aerobes and anaerobic organisms, so no clear conclusion could be drawn on their safety based on this. Generally, safety regulations set forth by the United States Food and Drug Administration require that cosmetic products maintain a sterile status that is free from contamination by pathogenic microorganisms, such as *E.coli*. Additionally, the presence of non-pathogenic microorganisms in cosmetics should be kept at a minimal (Kim et al., 2020). *E.coli* was however detected in a few cosmetic soil samples making them unsafe for use.

Bacterial and fungal counts for geophagic soils were also high (bacteria: 4×10^4 - 1.45×10^7 and fungal: 5×10^2 - 2.02×10^7 CFU/ml) compared to the limits for microbial counts recommended by the South African food standards (1×10^5 CFU/ml), meaning these soils had favourable properties for microbial proliferation. The total coliform count of geophagic soils had 11 out 20 soil samples that were above the South African guidelines of microbial analysis of food, i.e. < 200 CFU/ml for fresh food like vegetables and raw fruits (Health, 2000), indicating presence of potential pathogens. The *E.coli* bacteria was sometimes present in soils that were freshly sampled from Elandskop, KwaNxamalala and Willowfontein, but not from those bought from street vendors in PMB central. This might be due to the influence of heat treatment that the PMB vendors subjected their soils to before selling, which might have decreased the bacteria loads. The *E.coli* bacteria denatures at temperatures above 94ºC (Lee et al., 2002). This means users from other areas could also try heat-treating the soil before use to minimise pathogenic bacterial contamination of samples they consume or apply.

Most trace and heavy metals in soils used for cosmetics and medicinal purposes were below the limits used by commercial products set by the World Health Organisation (WHO). Elements such as Zn, Cd, Pb and Ni (except for two soil) were below the safety limit and thus would not cause harm to the user. Instead, this soil would be a good source of Zn for human nutrition. The few soils with Ni slightly above the safety limit (0.5 mg/kg) might cause bad skin reaction due to dermatitis that is expressed as a rash (Gates et al., 2023). The studied geophagic soils showed safe levels by WHO/FAO standards for Cu, Zn, Fe, Ni and Cd making them good sources of trace elements. The high Pb concentration (above the 0.3 mg/kg limit) of geophagic soils could be problematic to consumers as lead can lead to reduced IQ, learning disabilities, nervous system problems, and shortened attention span (Balayneh et al., 2015) making the soils risky in this regard.

6.2 Conclusion and Recommendations

The most frequent non-agricultural soil use was ranked to be cosmetics. Mineralogical analysis and colour identification proved high haematite presence (red and yellow-red colours) in cosmetic soil which is an effective sunscreen to support the choice of soils by users. The studied areas can be categorised as semi-rural, where women do chores that expose them to the sun like gardening and they do not have the capital to purchase commercial sunscreen. Thus, their use of soil as sunscreen is understandable. The high presence of quartz would cause skin abrasion if such soil were applied due to the hardness of quartz, thus users are advised to choose finer textures.

Though cosmetic soils had pHs that fall within the normal acidic skin pH, their mineralogy (dominated by quartz and haematite) however differed from that of commercial sunscreen products such as titanium dioxide or zinc oxide as the active ingredient, making them inferior in this regard. The potential for heavy metal contaminants in cosmetic soil was low, as safety limits for Zn, Cd, and Pb were below the recommended WHO limits for commercial cosmetics products. Nickel was slightly higher than the recommended safety limit (0.5 mg/kg) in 3 out 20 samples which might pose a danger of dermatitis.

Geophagia was also a common practise mostly because of cravings and enjoyment. In conclusion, geophagic soils present a mixed profile of potential benefits and risks. While their dominance in haematite and quartz provides a source of nutritional iron, the hardness of quartz can lead to dental abrasions and gastrointestinal irritation. This underscores the importance of selecting finer soil textures to minimize mechanical harm. Furthermore, although the pH of geophagic soils is generally compatible with human saliva, indicating low pH-related health risks, the presence of coliform bacteria in some samples exceeds recommended safety levels, indicating possible pathogenic contamination. The boiling methods used by vendors appear effective in reducing pathogen risks, as indicated by the absence of *E. coli* in boiled samples, suggesting heat-treatment as a recommended practice to contaminant health risks.

Additionally, most trace and heavy metal concentrations in geophagic soils are below the FAO safety limits, except for lead, which presents a significant health concern due to its potential neurotoxic effects, including impacts on the central nervous system and cognitive function. Therefore, while geophagic soils may serve as beneficial sources of trace elements like Cu, Zn, Fe, Ni, and Mn, users should exercise caution and avoid sources with elevated lead levels to reduce the risk of lead toxicity.

Future studies could focus on mapping the soil types, to further classify these soils, and more detailed analysis of other soil chemical and biological properties (especially of more pathogenic organisms) to ascertain safety of these soils for use. More areas (other than the peri-urban areas) in deeper rural areas could also be included to explore more diverse soil uses such as pottery and traditional construction of huts that was not identified in this study. Collaboration with other stakeholders such as the Department of Health and other academic disciplines e.g. Microbiology could help further probe the impact of soils on human health and levels of pathogenic contamination in these soils. There is also needed to give feedback to communities who are users so that they are aware of the potential risks of soil use.

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APPENDICES

Appendices A: Questionnaire used in survey conducted in ELandskop, KwaNxamalala and Willowfontein

Questionnaire

Objective: To identify the indigenous non-agricultural uses of soil by communities, its safety for use and understanding the underlying soil properties that govern these uses.

Enumerator Name …………………… Date of interview……………………….

District Name……………………...... Ward Name ……………………..........

Village name……………………….. Suburb Name……………………………..

Section A: Household Details

1. Name of interviewee: ……………………………………..
2. Gender: Female ☐ Male ☐
3. Age: 18 – 30 ☐ 31 – 40 ☐ 41-50 ☐ 51-60 ☐ 61-70 ☐ > 70 ☐ Unknown ☐
4. Educational level: Primary level ☐ Secondary level ☐ Tertiary level ☐ None ☐

Section B: Soil information

5. What are the common non -agricultural uses of soil in your community?

	Mark (x)	Rank
Cosmetics		
Geophagia		
Medicinal purposes		
Construction		
Pottery		
Other please specify		

6. What are the common uses of soil that is applied onto the skin?

	Mark (x)	Rank
Sunscreen		
Skin cleanser		
Applied by traditional Trainees (Ukuthwasa)		
Applied for Rituals like (UMemulo)		
Other please specify		

7. For soils that are consumed (geophagia), what are the mains reasons for this?

	Mark	Rank
Cravings		
Nutrient supplement		
Enjoyment		
Other please specify		

8. For soil taken for medicinal use, which diseases are commonly treated?

	Mark (x)	Rank
Skin problems		
Indigestion		
Diarrhea		
To heal traditional incisions (ukugcaba)		
Other please specify		

9. Where is the soil obtained from (Also specify the name of the place)?

River	Cosmetics	Geophagia	Medicinal purposes	Construction	Pottery
Mountain					
Anthill					
Tree bark					
Vendor					
Other please specify					

10. How do you collect soil used as Geophagia?

Digging with knife ☐

Hand Hoe ☐

Spade ☐

Selective handpicking ☐

Other please specify☐………...

11. Where do you store soil after collection before consumption or use?

Plastic bags ☐

Containers ☐

Sacks ☐

Other please specify ☐…………………………………………………

12. What precautions are taken to ensure that soil the soil is hygienic and safe for use?

Baking ☐

Boiling ☐

Burning ☐

Combination specify ☐

Other please specify ☐ ………………..

13. What motivated you to eat soil (geophagia)?

Peer Group ☐

Tradition ☐

Started on your own ☐

Saw someone else ☐

Taste and smell ☐

Other please specify☐ ……………………………………………

14. What are the common soil types & local names that are used for the different uses?

14.1Sunscreen (include common and scientific name if possible in brackets):

White clays ☐

Red clays ☐

Other please specify ☐…………………………………………

14.2 Cleanser (include common and scientific name if possible name in brackets):

White clays ☐

Red clays ☐

Other please specify ☐………………………………………………

14.3 Medicinal purposes (include common and scientific if possible name in brackets):

White clays ☐

Red clays ☐

Other please specify ☐……………………………………

14.4 Geophagia (include common and scientific if possible name in brackets):

White clays ☐

Red clays ☐

Yellow brown clays ☐

Other please specify ☐……………………………………

14.5 Pottery (include common and scientific name if possible in brackets):

Brown soils ☐

Reddish ☐

Yellow brown☐

Other please specify ☐ ……………………………………………….

14.6 Construction (include common and scientific name if possible in brackets):

Pit soil ☐

River sand ☐

Clay soil ☐

Other please specify ☐…………………………..

15. What guides selection of soil for the different uses (specify what they mean in response)?

	Nutrient	Colour	Texture	Smell	Taste	Other please specify
Cosmetics						
Geophagia						
Medicinal purposes						
Construction						
Pottery						
Other please specify						

16. Do you know of any side effects of using soil for?

16.1Cosmetics:

Blemishes ☐

Skin irritation ☐

Other please specify☐……………………………………………………….

16.2 Medicine:

Nausea ☐

Constipation ☐

Diarrhea ☐

Other please specify ☐……………………………………………………...

16.3 Geophagia:

Constipation ☐

Stomach ache ☐

Other please specify☐…………………………………………………….

16.4 Construction

Dry Hands ☐

Ring worm ☐

Other please specify ☐ …………………………………………………….

16.5 Pottery

Dry Hands ☐

Bursitis (inflammation of joints) ☐

Other please specify☐ ………………………………………………………

Appendices B: The ethical clearance certificate

UNIVERSITY OF ”
KWAIULU-NATAL

INYUVESI
YAKWAZULU-NATALI

30 October 1017

Ms NI Hlatshwayo
School of SAEES
College of Agriculture Engineering and Science
213513778@stu.ukzn.ac.za

Dear Ms Hlatshwayo

Protocol: Identifying indigenous non-agricultural uses of soil by selected communities in KwaZulu-Natal their safety for use and understanding the soil properties that govern these uses
Degree: MS Agric (Soil Science). **BREC Ref No: BE582/17**

A sub-committee of the Biomedical Research Ethics Committee has considered and noted your application received on 28 August 2017.

The study was provisionally approved pending appropriate responses to queries raised. Your response received on 20 October 2017 to BREC correspondence dated 09 October 2017 have been noted by a sub-committee of the Biomedical Research Ethics Committee. The conditions have now been met and the study is given full ethics approval and may begin as from 30 October 2017.

This approval is valid for one year from 30 October 2017. To ensure uninterrupted approval of this study beyond the approval expiry date, an application for recertification must be submitted to BREC on the appropriate BREC form 2-3 months before the expiry date.

Any amendments to this study, unless urgently required to ensure safety of participants, must be approved by BREC prior to implementation.

Your acceptance of this approval denotes your compliance with South African National Research Ethics Guidelines (201 5), South African National Good Clinical Practice Guidelines (2006) (if applicable) and with UKZN BREC ethics requirements as contained in the UKZN BREC Terms of Reference and Standard Operating Procedures, all available at http://resear .ukzn.ac.za/Research-Ethics/Biomedical-Researh-Ethics.aspx

BREC is registered with the South African National Health Research Ethics Council (REC-290408-009). BREC has US Office for Human Research Protections (OHRP) Federal-wide Assurance (FWA 678).

The sub-committee's decision will be RATIFIED by a full Committee at its next meeting taking place on 12 December 2017.

We wish you well with this study. We would appreciate receiving copies of all publications arising out of this study.

Yours sincerely

Pr[redacted]
Chair: Biomedical Research Ethics Committee

cc: supervisor: zeneeni@ukzn.ac.za

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