# Mineralogical Characteristics of Consumed Earth Materials from Vhembe District, Limpopo Province, South Africa

**Momoh A[a*], Davies TC[a], Akinsola HA[b] and Akinyemi O[c]**

[a]Department of Mining and Environmental Geology, University of Venda, Private Bag X5050, Thohoyandou, 0950, South Africa.
[b]Department of Public Health, University of Venda, Private Bag X5050, Thohoyandou, 0950, South Africa.
[c]Department of Mathematical Sciences, University of Ado-Ekiti, Nigeria.

**Corresponding Email Address: abkenomai@yahoo.com; Tel: +27720433833*

## Abstract

Deliberate consumption or involuntary ingestion of Earth materials such as clays, sands, anthills, termite mounds and sediments from dried up ponds is referred to as geophagy or geophagia. The practice is very common amongst children, women of child bearing age and lactating mothers in this locality. They indulge in geophagic practice for wide varieties of reasons, which includes; cleaning out and purifying intestinal tract, as a source of antacid to relieve excess acidity in the digestive tract, detoxification of unpalatable foods, as a means of relieving nausea and excess salivation in pregnant women. Studies providing a link between mineralogical characteristics of consumed Earth materials and the above mentioned reasons are relatively scarce in South Africa. This study was undertaken to assess mineralogical features of geophagic materials from Vhembe District for human geophagic practice. 20 consumed Earth materials were collected from local mining sites, retail outlets in shops and local markets in the area for analyses. The mineralogical characteristics of Earth materials were determined by X-ray diffraction (XRD) method. The results of mineralogical analyses indicate the following range in weight percent (wt. %) for each respective mineral in the sample: Kaolinite (14.88 % to 77.35 %); smectite (2.99 % to 10.15 %); muscovite (17.77 % to 56.03 %); quartz (4.50 % to 49.40 %); albite (4.99 % to 9.38 %); orthoclase (4.38 % to 6.66 %); goethite (1.86 % to 11.21 %); hematite (3.07 % to 9.49 %); microcline (4.95 % to 6.04 %) and anatase (1.01 % to 4.13 %). Results of Tukey's post hoc test mineralogy showed that only kaolinite has a significant percentage with respect to all other minerals. The consumed Earth materials are made of variable minerals, with some having a mixture of kaolinite smectite microcline muscovite and others with a complex mixture of kaolinite smectite quartz or orthoclase. Qualitative description of XRD fitting pattern yielded results that were consistent with quantitative description except one sample whose silica content was dominant. Kaolin is the dominant mineral of interest in the consumed Earth materials. It's calm soothing sour taste due to acidic to weakly nature, ability to coat and adherence to intestinal membrane of geophagists could suggests that pregnant women, lactating mothers and children indulge in geophagic practice to alleviate gastrointestinal problems and protection against toxins.

***Keywords**: Antacid, earth materials, geophagia, intestinal membrane, lactating mothers, mineralogy, nausea, South Africa*

## 1. Introduction

Geophagy or geophagia is the deliberate consumption or involuntary ingestion of Earth materials such as clays, sands, anthills, termite mounds and sediments from dried up ponds. The practice is common amongst children, women of child bearing age and lactating mothers in Vhembe District of Limpopo Province. Research conducted by Jones and Hanson, (1985); Kruelen, (1985); Krishnamani et al. (2000); Young et al. (2010); revealed that geophagy is a common practice throughout the animal kingdom. This practice is virtually found in all continents of the globe, but most prevalent in sub-Sahara Africa (Abraham, 2002; 2005; Wilson, 2003).

The causative reasons for consumption of Earth materials are many, some of which includes; food detoxifier to counteract toxins and poisons (Houston et al. 2001; Shinondo and Mwikuma, 2009); for pharmaceutical reasons, kaopectate a form of clay material, is used to treat diarrhoea and stomach upset (Vermeer and Ferrel, 1985); to supplement intake of available copper, iron and manganese by rural communities (Mills, 1996; Davies, 2008); to alleviate gastrointestinal disorders (Chandrajith et al. 2009). Till date, there is so much confusion about the entire practice, though, it has been reported that it is thought to have both beneficial and harmful effects on man. The potential medical implications of the practice include excessive tooth wear, enamel damage and erosion of the mucosal surfaces of the stomach (Barker, 2005). Geophagia is a major factor for transmission of *Ascaris lumbricoides*, *Trichuris trichuria* and other parasitic infections among children (Saathoff et al. 2000). Obstruction and perforation of the colon may result following the internal accumulation of soil (Abraham, 2002).

Three major hypotheses were advanced for human geophagic practice: hunger, micronutrient deficiency and protection from toxins and pathogens (Wilson, 2003; Young et al. 2010). The hunger hypothesis says that people consume Earth materials because they do not have anything else to eat (Laufer, 1930). The micronutrient deficiency hypothesis posits that people with micronutrient deficiencies eat Earth materials in order to increase micronutrient intake of iron (Hunter, 1973). The practice of geophagy has been shown to supply 17% to 55% of recommended pregnancy supplementation of calcium, magnesium, zinc, iron, copper, manganese, selenium, potassium and cobalt (Hunter, 1984; Brand et al. 2009).

The protection hypothesis states that geophagic practice is motivated by an attempt to mitigate the harmful effects of plant chemicals or microbes (John, 1986; Profet, 1992). It was proposed that geophagic soils protect by either adsorbing pathogens or toxins within the gut lumen or coating the surface of intestinal endothelium, thereby rendering it less permeable to toxins and pathogens (Young et al. 2010).

These hypotheses that were postulated in favour of geophagic practice reflect the nature, behaviour and properties of clay minerals in the geophagic materials; hence clay mineralogy could be a factor in the assessment of these hypotheses (Wilson, 2003).

According to Ferrel et al. (1985), geophagy provides a link between environmental geochemistry and human health. They urged research to answer several questions, which include;

(i) Why do humans and animals consume soil?
(ii) Could it be that inorganic nutrients in soil supplement our dietary intake of essential trace elements?
(iii) Does the ingestion of soil cause detoxification of noxious or unpalatable compounds present in the diet?
(iv) Do these soil elements alleviate gastro intestinal ailments?

More research is needed to evaluate the risks and benefits of geophagy (Dissayanke, 2005; Ferrel, 2008).This paper thus, attempts to characterise the mineralogy of Earth materials that are consumed by women and children in order to test some of the hypotheses concerning human geophagic practice. The mineralogical data obtained from this study may assists researchers in answering some of the questions which border on the reasons for Earth eating. Also, it would aid in identification of suitable Earth materials for geophagic purposes.

### *1.1 Location and socio-economic conditions of Vhembe District*

Vhembe District lies at the north-western tip of South Africa in Limpopo Province (Fig 1). Majority of the District's population is female. Most of these women are engaged in agriculture and retail trade as a source of livelihood. Geophagic practice is common with people of low socio-economic status that lives in the rural areas. Though, some affluent members of the society are also involved in Earth eating. The area is characterized by a sub-tropical climate that is greatly influenced by the Soutpansberg mountain range (Munyati and Kabanda, 2009). The area experiences cold winters and hot summer, which is the rainy season. Geologically, the area is underlain by Archean granulite gneiss and pink massive quartzite typified by siltstone, gravelly sand, silts and sandstones of Karoo sediments (Taylor, 1986).

## 2. Materials and sampling methods

### *2.1 Sample collection*

Twenty (20) samples of consumed Earth materials were collected from local mining sites and retail outlets in local markets and shops across the entire District. These are Type A reddish brown termite mound found on bark of tree (Fig 2). Type B is a yellowish silty sandy material found in horizon A soil profile (Fig 3), and type C is grey smooth natural clays available in retail outlets sold in markets and shops in the area (Fig 4). The clays are mined around Johannesburg and transported to other parts of South Africa.

### *2.2 Sample preparation and analyses:*

Air dried samples were crushed and milled to < 2 mm size fraction for analyses. The mineralogy of consumed Earth materials was determined by X-ray diffraction (XRD) method. The powder was packed in a sample holder by back loading methods for determination of the mineral content of the whole consumed Earth materials. The XRD analyses of samples was performed in Geology Department, University of Pretoria, South Africa using a Pan analytical X'-Pert Pro Powder diffractometer with an X' Celerator position sensitive detector and variable divergence and receiving slits with Fe filtered Co-K radiation. The phases were identified using X' Pert High score plus software. The relative phase amounts (weight %) was estimated using the Rietveld method (Autoquan programme). Identification of certain clay minerals required the use of supplementary treatments. Ethylene glycol tests were performed on selected samples to verify the presence of swelling clay minerals represented by smectite, while the presence of kaolinite was verified by treating selected samples to $550^0$C for 2.5 hours (Wilson, 1987).

*Statistical analyses:* Statistical analyses of mineralogical data were performed using Analyses of variance (ANOVA) and Tukey test to obtain minerals with most significant level of concentration with respect to other minerals.

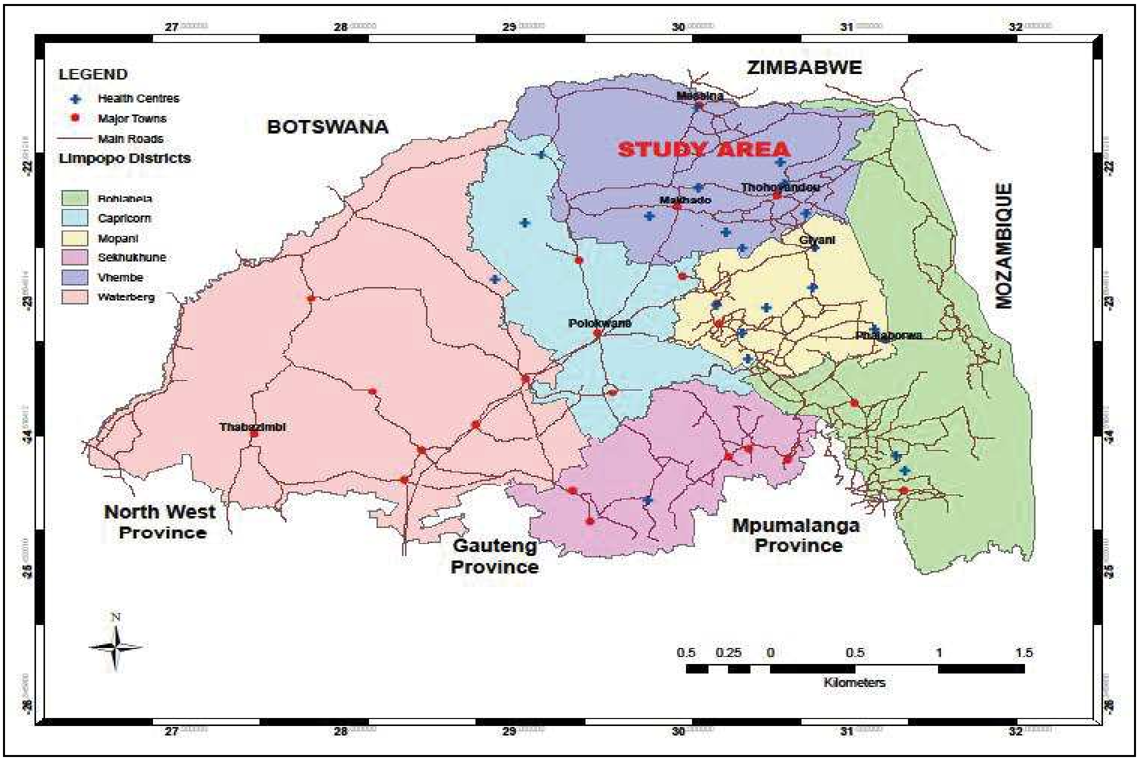


Figure 1. Location map of the study area. (Source: Municipal Demarcation Board, 2006).

## 3. Results

The quantitative result of all the mineralogical characteristics of samples shows the following minerals and each of their respective concentrations (Table 1). The result revealed that the concentration of kaolinite ranges from 14.88 % to 77.35 %; muscovite (17.77 % to 56.03 %); smectite (2.99 % to 10.15 %); quartz (4.50 % to 49.40 %); albite (4.99 % to 9.38 %); orthoclase (4.38 % to 6.66 %); goethite (1.86 % to 11.21 %); hematite (3.07 % to 9.49 %); microcline (4.95 % to 6.04 %) and anatase (1.01 % to 4.13 %).

The kaolin content of most samples was greater than 50% (Fig. 5). Each of the consumed Earth materials was accompanied by a certain fraction of quartz as reflected in the results of X-ray diffraction (Table 1).Other detrital minerals such as albite and anatase were present in the samples, most especially samples 2 and 4 which had the presence of anatase in them. Muscovite was present in the entire sample except sample 2 which was muscovite free. Plagioclase albite was present in the entire sample except sample 2 to 6. Microcline was only noticeable in very few samples namely; 7, 14 and 16 respectively. Iron oxides, goethite and hematite were present in samples 2 to 6 respectively. Orthoclase was determined in all the samples except samples 2 to 8, 14 and 16 respectively. The most common clay mineral was kaolinite, closely accompanied by muscovite. The exceptions were samples 3, 5 and 6 which had higher percentage of muscovite closely accompanied by quartz. Smectite was equally present in virtually all the samples except samples 2 to 6 and sample 19. The percentage composition was less than 10% of the entire sample in which it was present. Sample 2 was a highly siliceous earthy material, 3, 5 and 6 were muscovite rich while the rest were kaolinitic in nature. Abundant quartz was identified by high peak intensities at $31^{0}$ 2Ø (Fig 6a) in sample 2, while significant amount of quartz in sample 3 was reflected in the peak intensities at $10^{0}$ 2Ø and $30^{0}$ 2Ø respectively (Fig. 6b). Goethite and hematite were noticeable in few samples but goethite was more profound in sample 5 with a peak intensity at $54^{0}$ 2Ø (Fig. 6c).

Qualitative results of some selected Earth materials were reflected in the XRD patterns. Figures 6d and 6e show the variable nature of the clay mineralogy. Kaolinite was the predominant mineral of interest as reflected in the XRD pattern except in sample 2 which quartz was the predominant mineral with a very high peak intensity at $31^{0}$ 2Ø.

Mean and standard deviation for minerals in the analysed samples are shown in (Table 2). The Analysis of variance (ANOVA) test (Table 3) shows that the average percentage of minerals in the consumed earth materials was highly significant P ≤ 0.001. This further compels the use of Tukey's post hoc test to identify the homogeneous groups (pairs with no significant mean differences) among the minerals. Results of Tukey's post hoc test (Table 4) showed that only kaolinite had a significant percentage with respect to all other minerals.

Figure 2. Earth material mining site within the District from

Figure 3: A geophagist collecting Earth material preferred soil horizon

Figure 4. Earth materials on display in a retail outlet

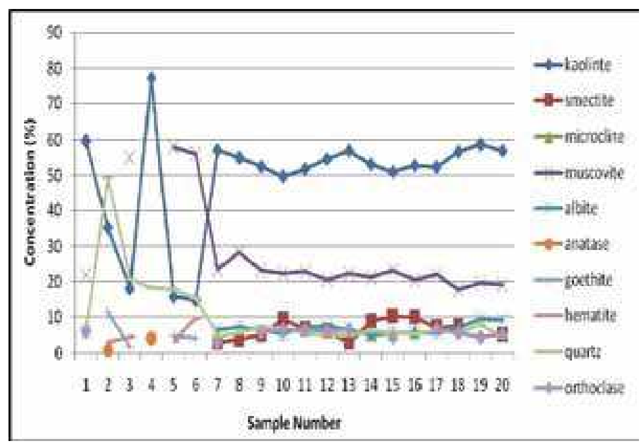


Figure 5.Clay mineralogy of the samples studied.

## 4. Discussion

All the studied Earth materials were dominated by kaolinite except one sample whose silica content was fairly greater than kaolinite (Table 1). Chandrajith et al. (2009), revealed that in humid tropical environments, smectite clays are present in partly weathered soil profile and degrade further to form kaolin. The higher content of kaolinite in analysed Earth materials of the area showed that they were highly weathered products. The mineralogical analyses as reported in this study also support the work of Diko and Ekosse, (2011), which showed kaolinite as the major phyllosilicate in geophagic samples from South Africa. The clays contain abundant kaolinite with subsidiary amounts of smectite (John and Duquette, 1991a). These clays were able to reduce the tannic acid content of acorn meal by up to 77%, thus providing a rationale for their consumption (Wilson, 2003).

This mineralogical characteristic was consistent with the protection hypothesis being canvassed for human geophagic practice. Kaolinite is used in production of pharmaceutical drugs such as kaopectate, which helps to cure or alleviate diarrhoea and gastrointestinal upsets (Vermeer and Ferrel, 1985; Wilson, 2003; Young et al. 2010). Kaolin has the ability to coat and adhere to the gastric and intestinal mucus membrane, thus protecting against toxins, bacteria and adsorbing excess water in the faeces (Gonzalez et al. 2004). Another reason for human geophagic practice is that consumed Earth materials act as a natural antacid by reducing excess acidity in the digestive tract. This is dependent on the mineralogical characteristics of these materials and the pH values (Wilson, 2003). The pH values of the consumed Earth materials are weakly acidic to neutral and would impart a sour taste to Earth materials on consumption. The sour taste could be beneficial to pregnant women in reduction of nauseates feeling and prevention of excess salivation

(Ngole et al. 2010). Geophagic clays studied by Diko and Ekosse (2011), showed remarkable traces of goethite and hematite minerals, similar to the soils in this study, whose reddish colouration indicate the presence of goethite and hematite in them. Though, the reddish colour may not be an indication of bioavailability of iron to geophagists who may assume that they could supplement their iron intake by consuming such Earthy materials (Fontes et al. 2005; Ngole et al. 2010). The silica content of sample 2 was relatively high compared to other consumed Earth materials.

According to the work of Barker, (2005), ingestion of siliceous Earth materials could damage the dental organ of geophagists and erosion of the mucosal surface of the stomach. Considering the attendant health risks that are associated with geophagic practice, only sample 2 could pose danger to these geophagic women and children.

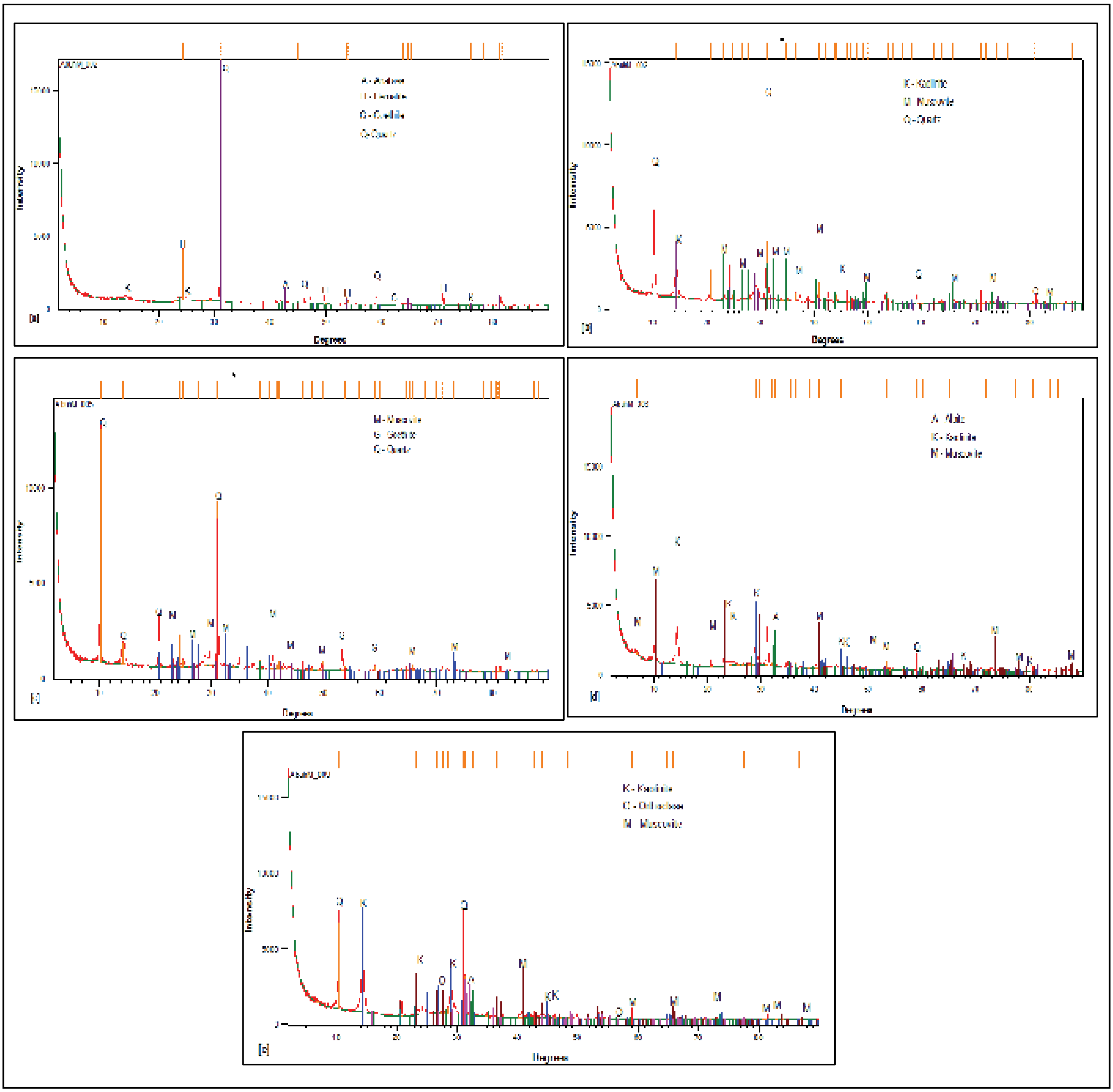


Figure 6. XRD patterns of ethylene glycol saturated samples illustrating the variable clays used for geophagic practice; a&b - quartz rich geophagic materials; c - goethite rich geophagic material; d&e - variable clay mineralogy of geophagic materials.

Table 1. Full pattern fitting mineral analyses (wt. %) of bulk consumed Earth materials from Vhembe District

| Sample No. | Kaolinite | Smectite | Microcline | Muscovite | Albite | Anatase | Goethite | Hematite | Quartz | Orthoclase |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 59.75 | | | 21.9 | 5.99 | | | | 6.41 | 5.94 |
| 2 | 35.29 | | | | | 1.01 | 11.21 | 3.07 | 49.42 | |
| 3 | 18.1 | | | 55.07 | | | 1.86 | 4.29 | 20.68 | |
| 4 | 77.35 | | | | | 4.13 | | | 18.53 | |
| 5 | 15.89 | | | 58 | | | 4.91 | 3.44 | 17.77 | |
| 6 | 14.88 | | | 56.03 | | | 4.14 | 9.49 | 15.46 | |
| 7 | 57.23 | 3.07 | 4.95 | 23.51 | 6.42 | | | | 4.82 | |
| 8 | 55.09 | 3.92 | | 28.26 | 7.19 | | | | 5.54 | |
| 9 | 52.59 | 5.17 | | 23.17 | 6.28 | | | | 7.08 | 5.72 |
| 10 | 49.86 | 9.39 | | 22.42 | 5.28 | | | | 6.62 | 6.44 |
| 11 | 51.87 | 6.7 | | 22.76 | 7.21 | | | | 5.62 | 6.43 |
| 12 | 54.71 | 6.17 | | 20.55 | 7.33 | | | | 5.11 | 6.15 |
| 13 | 57.06 | 2.99 | | 22.2 | 6.37 | | | | 4.96 | 6.43 |
| 14 | 53.26 | 8.81 | 5.54 | 21.31 | 4.99 | | | | 6.09 | |
| 15 | 51.11 | 10.15 | | 23.13 | 5.65 | | | | 5.59 | 4.38 |
| 16 | 52.87 | 9.94 | 6.04 | 20.35 | 5.58 | | | | 5.21 | |
| 17 | 52.46 | 7.07 | | 21.97 | 5.41 | | | | 6.42 | 6.66 |
| 18 | 56.77 | 7.44 | | 17.77 | 6.95 | | | | 5.63 | 5.44 |
| 19 | 58.74 | | | 19.78 | 9.38 | | | | 7.67 | 4.43 |
| 20 | 57 | 5.08 | | 19.2 | 9.1 | | | | 4.5 | 5.13 |

**Table 8. Mean and standard deviation for minerals in consumed Earth materials from Vhembe District**

| Minerals | N | Mean | Std. Deviation | Minimum | Maximum | 95% Confidence Interval for Mean | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Kaolinite | 20 | 49.10 | 15.92 | 14.88 | 77.35 | 41.64 | 56.54 |
| Smectite | 13 | 6.61 | 2.49 | 2.99 | 10.15 | 5.10 | 8.11 |
| Microline | 3 | 5.51 | 0.55 | 4.95 | 6.04 | 4.15 | 6.86 |
| Muscovite | 18 | 27.63 | 13.41 | 17.77 | 58.00 | 20.96 | 34.30 |
| Albite | 15 | 6.61 | 1.30 | 4.99 | 9.38 | 5.90 | 7.33 |
| Goethite | 4 | 5.53 | 4.00 | 1.86 | 11.21 | -0.83 | 11.90 |
| Hematite | 4 | 5.07 | 2.99 | 3.07 | 9.49 | 0.32 | 9.83 |
| Quartz | 20 | 10.46 | 10.51 | 4.50 | 49.42 | 5.54 | 15.38 |
| Orthoclase | 11 | 5.74 | 0.81 | 4.38 | 6.66 | 5.20 | 6.28 |
| Anatase | 2 | 2.57 | 2.21 | 1.01 | 4.13 | -17.25 | 22.39 |

Table 3 Table of Analysis of variance showing levels of significance

| | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 29662.414 | 9 | 3295.824 | 32.445 | 0.001 |
| Within Groups | 10158.053 | 100 | 101.581 | | |
| Total | 39820.467 | 109 | | | |

Table 4 Values of Homogeneous means of minerals using Tukey test

| Minerals | | Subset for alpha = 0.05 | | |
|---|---|---|---|---|
| | N | 1 | 2 | 3 |
| Anatase | 2 | 2.5700 | | |
| Hematite | 4 | 5.0725 | | |
| Microline | 3 | 5.5100 | | |
| Goethite | 4 | 5.5300 | | |
| Orthoclase | 11 | 5.7409 | | |
| Smectite | 13 | 6.6077 | | |
| Albite | 15 | 6.6087 | | |
| Quartz | 20 | 10.4565 | 10.4565 | |
| Muscovite | 18 | | 27.6322 | |
| Kaolinite | 20 | | | 49.0940 |
| Sig. | | 0.944 | 0.119 | 1.000 |
| Tukey HSD[a,b] | | | | |

## 5. Conclusion

The consumed Earth materials in Vhembe District of Limpopo Province have over 50% weight of kaolinite in each sample and a relatively small amount of smectite and muscovite. The plagioclase albite, anatase, orthoclase content is also small in the samples and only four of the samples have few concentration of hematite and goethite. The mineralogical characteristic varies greatly from one sample to the other. They are a mixture of kaolinite smectite microcline muscovite rich or kaolinite smectite quartz or orthoclase rich. These consumed Earth materials are weathered products which are leached from rocks under favourable weathering conditions. Significant concentration of silica could present a limited health risk to geophagists. Kaolinitic materials devoid of much silica are ideal for human consumption because the sour taste helps to quell nausea and excess salivation during pregnancy. This could be one of the reasons for human geophagic practice.


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