Comparison of Chemical and Mineralogical Properties of Geophagic Materials from Taita and Mombasa, Kenya

Gichumbi, JM[1*], Maghanga JK[2], Cheshari, E.C[3], Ongulu, RO [4], Gichuki, JG[5]

Abstract— Geophagy is the deliberate consumption of soil and clay deposits by animals including man. The practice is widespread particularly in pregnant women in Africa. This study of geophagic soil from coast province in Kenya had its primary objectives in analyzing the geochemical and mineralogy of the geophagic material sold in open air markets in Taita and Mombasa Districts. The elemental analysis and major oxides was carried out using AAS and Energy dispersive X-ray fluorescence. Elemental analysis showed that silica (SiO_2) and alumina (Al_2O_3) were the main oxides present in the materials. The transition metals Cd and Co were not detected, while the concentration of Cu, Zn, and Pb was low. The mineralogy studies using Fourier transform infrared spectroscopy showed that the samples were mainly siliceous with quartz being the dominant mineral and kaolin and calcite being present.

Index Terms— Geophagy, geochemical, mineralogy, Pregnancy, Atomic Absorption Spectrometry, Xray fluorescence Spectroscopy, Fourier transform infrared spectroscopy

——————————— ◆ ———————————

1 INTRODUCTION

Geophagy is a specific type of pica. Pica is the persistent eating of non nutritive substances or the tendency or craving to eat substances other than the normal foodstuffs [16]. Geophagy is defined as the craving and subsequent consumption of non-food substances [15].Geophagy is common in both human cultures and animal kingdom [2]

Young and coworkers proposed three major hypotheses concerning the physiological courses of pica: hunger, micronutrient deficiency and protection from toxins and pathogens [2].

————————————————

• [1] *Chuka University College, Kenya, P.O.Box 109-60400-Chuka. E-mail: jsmwangi2003@yahoo.co.uk*
• [2] *Pwani University College, P.O, Box 195-80108, Kilifi,Kenya*
• [3]*Laikipia University College, P.O.Box P.O,.Box 1100-20300, Nyahururu*
• [4]*Masinde Muliro University of Science and Technology, , P.O.Box 190-50100, Kakamega*

The practice of Geophagy is widespread among pregnant and breast feeding women in sub-Saharan Africa. The practice cuts across social status, with pregnant women of low social status and affluent backgrounds consuming the materials [4]. Southern Africa women and children in both urban and rural setting were found to engage in geophagia. The women surveyed by Woywodt and Kiss believed that the consumption of earthy materials including oils and clays enhance their beauty [17].

In some communities like the Chagga of Tanzania, geophagia is considered to be sacred to women [3]. Red soil is ingested in many communities to prevent and alleviate symptoms of iron deficiency anemia because of its inferred high Fe content [7].

The consumption of geophagic materials have been found to have drawbacks which impact negatively on human health and some of which include anemia, microbial infections, helminthiasis, intestinal obstruction, dental abrasion and heavy metal poisoning [4], [8], [11].The effects of ingesting geophagic soils on the consumer depends on the physico-chemistry, mineralogy and geochemistry of the ingested soils which to a large extent are influenced by the soils pedogenetic development and the quantity of soil ingested.

Research on Geophagy in Kenya by [6], [5], [15], have shown that the materials consist mainly of silica and alumina. The aim of this research was therefore to study the geochemistry and mineralogy of the geophagic materials from Taita and Mombasa in coastal Kenya. This was necessary in order to ascertain their elemental composition particularly the presence or absence of heavy metals.

2 MATERIALS AND METHODS

2.1 Sampling sites

Taita Taveta district is in Coast province of Kenya. The district lies between 2˚46 ′ south and 4˚1′ South and longitudes 37˚36′East and 30 ˚ 14′ east. The samples from Taita were collected from Wundanyi, Taveta and Voi towns and were labeled T1, T2 and T3 respectively.

Mombasa is in the South –Eastern part of coast province. The district lies between latitudes 3˚-80˚ and 4-10˚ South of the Equator and between longitudes 39-80 ˚ East of the Greenwich Meridian. The samples were collected from Kilifi, Malindi and Mombasa town open air markets. The samples were labeled M1, M2 and M3 respectively.

The geophagic samples were randomly selected and were purchased from vendors who were selling them in open air markets. The purchased samples were in the state in which they were consumed.

.

2.2 Sample preparation and Pretreatment

The samples were dried in an oven at 105˚ C and then placed in a dessicator to cool and then weighed until a constant weight is obtained. The dried samples for mineralogical and chemical analyses were ground in a pulverizer prior to analyses.

2.3 Sample Analyses

Preliminary Elemental analysis was performed by Energy Dispersive X-ray fluorescence (XRF) using PANanalytical Minipal QC model and Atomic Absorption Spectrometry (AAS) using A Varian Spectra AA-10 Model.

XRF was performed on pressed disks and involves no pre-treatment other than simple crushing and milling procedures. The mineralogy of the geophagic samples was determined by Fourier transform infrared (FT-IR) spectroscopy using Shimadzu 800 instrument.

Fourier transform infrared spectrometry was done using a modified procedure employed by [3], [14]. The sample was dried in an oven at 105˚C for 12 hours. The mineral sample of about 2 mg was then mixed with 40 mg of spectroscopic KBr in the ratio 1:20 using a clean mortar and pestle to prepare a sample pellet. The ratio of sample to KBr was varied in the ratio 1:100 and 1:200 to avoid overlap of the peaks. Before mixing of the sample with KBr, the KBr was dried at 120˚ C for six hours in an oven to avoid the broad spectral peak due to free OH which would seriously affect the interpretation of the bound hydroxyls associated with the minerals. A pellet of about 1 mm thickness and 12 mm in diameter was prepared by pressing. The prepared pellet was placed in a suitable sample holder immediately after preparation and introduced in the infrared beam for analysis. Peaks were reported based on percentage transmittance to given wavelength, recorded in the range 4000-200 cm^{-1}.

Elemental analysis was performed using atomic absorption spectrometry (AAS). Standard procedures for digestion of the samples were followed and standard solutions of the elements were used in calibrating the AAS. The elements determined were chosen because of their possible association with this materials and their toxicity potential.

3.0 RESULTS AND DISCUSSION

3.1 Elemental analysis - major oxides

The results for major oxides (full assay) from Mombasa and Taita district are shown in Table 1.0 and 1.1.The samples from Mombasa had SiO_2values ranging from 61.45 to 53.16 with an average of 57.31. The samples from Taita also had SiO_2 having the highest values as compared with the other oxides,with

values ranging from 58.23 and 60.48% and an average value of 59.59%.This shows that silica is the main oxide in all the studied geophagic samples and this is in agreement with values reported by [6], [12], [2].

The levels of Al_2O_3 oxide were the second highest with values ranging from 30.8% to 33.60% for Mombasa with an average of 31.76%.The Al_2O_3 values of samples from Taita had an average of 31.16% with values ranging from 30.0% to 31.9%.

The values for the alkali and alkaline earth elemental oxides CaO, MgO, Na_2O and K_2O were generally low. The transition metal oxides were lowest for MnO with an average value of 0.01% for both Mombasa and Taita. Titanium ranged between 3.46% to 4.63% and 3.50% to 4.06 % for Mombasa and Taita respectively.

The values for transition metal oxide Fe_2O_3 had an average of 3.49% and 2.59% for Mombasa and Taita respectively which were low compared to those reported by [6]

Table 1.0: Bulk chemical (major Element) analyses in geophagic samples from Mombasa and Taita Open Air markets.

Sample	SiO_2	Al_2O_3	CaO	MgO	Na_2O
M 1	53.16	33.60	0.08	0.15	0.07
M 2	60.45	30.90	0.07	0.21	0.40
M 3	57.32	30.80	0.08	0.19	0.39
T 1	60.48	30.00	0.08	0.31	0.19
T2	58.23	31.60	0.04	0.30	0.71
Taita 3	60.08	31.90	0.07	0.37	0.53

Table 1.1: Bulk chemical (major Element) analyses in geophagic samples from Mombasa and Taita Open Air markets.

Sample	K_2O	TiO_2	MnO	Fe_2O_3	LOI
M 1	1.80	4.63	0.01	4.24	2.25
M 2	1.20	3.46	0.01	3.23	1.00
M 3	0.80	3.52	0.01	3.00	3.80
T 1	1.90	4.06	0.01	2.37	0.58
T2	0.60	3.50	0.01	3.09	1.82
Taita 3	1.10	3.51	0.01	2.30	0.12

3.2 Elemental analysis for heavy metals

The trace elements analyzed were; Cu, Zn, Cr, Pb, Sb, Co, Cd. Sr, B, V and Mo. The results were obtained from both AAS and XRF data and are represented in figure 2-5. The Energy dispersive XRF was used for preliminary investigations while quantitative analysis was carried out using AAS. The levels of Cu ranged from 4.0 to 9 ppm while Zn levels ranged from 27.5 ppm to 58.0 ppm. These values were lower as compared to those reported by [2] for geophagic clay samples from Cameroon and Nigeria.

The levels of Cr, Pb and Co were low ranging from 0.5 ppm to 9.0 ppm, 0.68 ppm to 1.54 ppm and 1.5 ppm to 5.5 ppm respectively. Molybdenum ranged from 30 ppm to 52.0 ppm. Cad-

mium, boron and vanadium were not detected in all the samples. A representative XRF spectra for samples collected from Mombasa is shown in Figure 1.
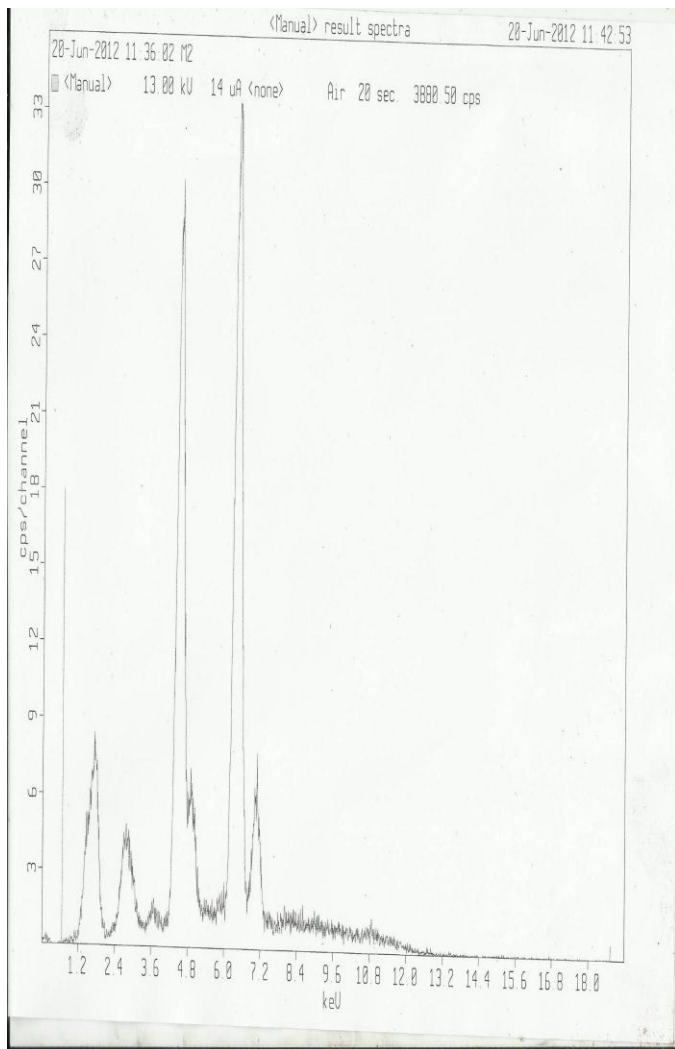

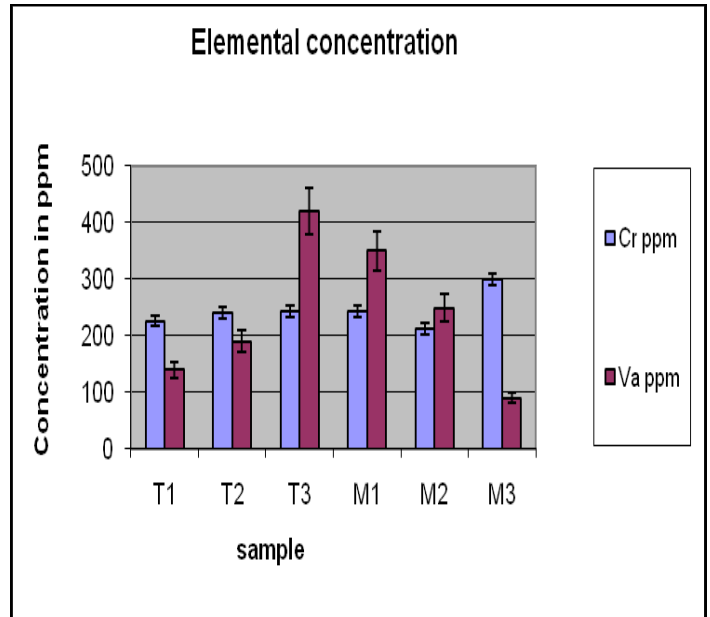Figure 1: XRF spectra for samples collected from Mombasa
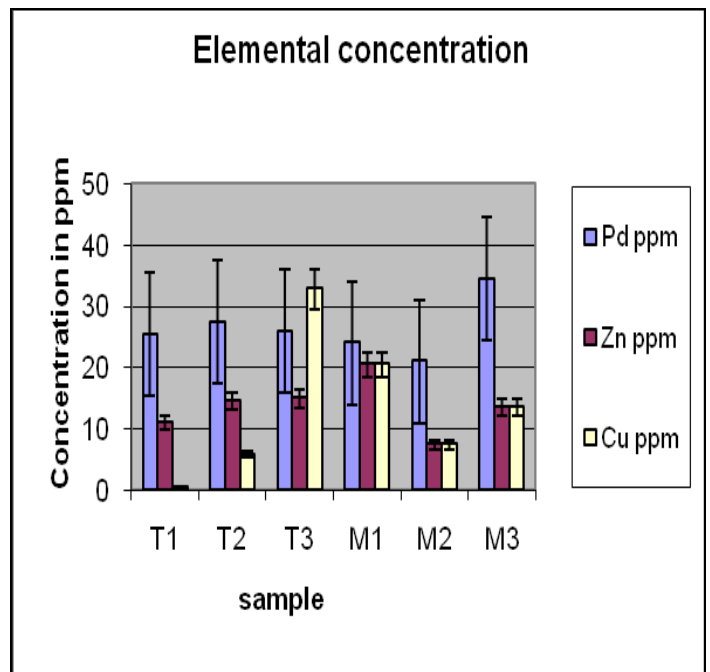

Figure 2: Cr and Va concentrations in ppm
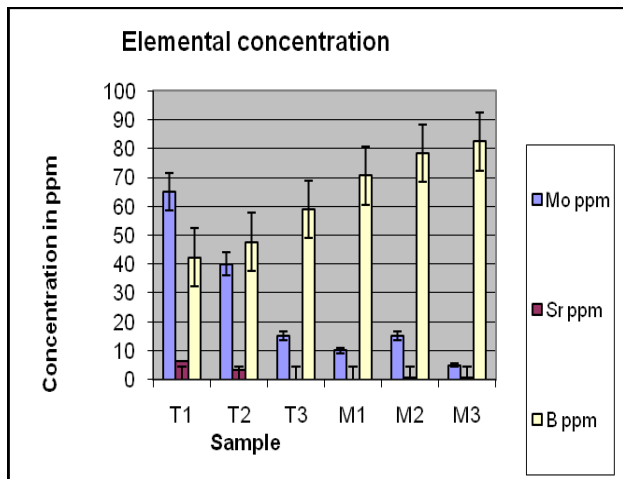

Figure 3: Pb, Zn and Cu concentrations in p

Figure 4: Mo, Sr and B concentrations in ppm
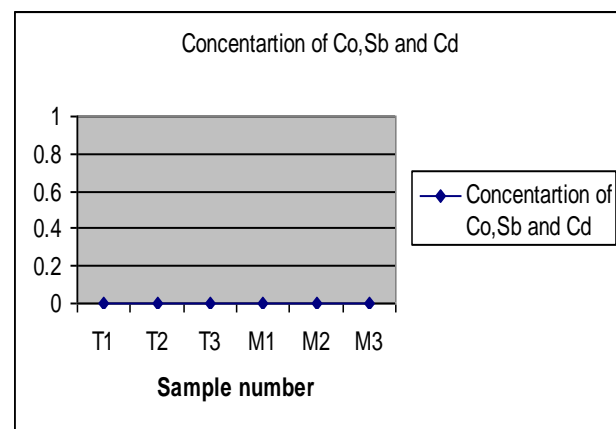

Figure 5: Cobalt, Sb and Cd concentrations in ppm

3.3 Fourier transform infrared spectroscopy

The FT-IR peaks showed an indication of –OH Stretching bands at 3621,3624,3648,3649,3650,3692,3694 and 3695 cm^{-1} and OH deformation bands at 907,908 and 909 cm^{-1}[1].

Bands associated with SiO stretching were 692,994 and 695 cm^{-1},753 and 754 cm^{-1}, 791,795 and 796 cm^{-1}. SiO deformation bands were 1007, 1032 and 1033 cm^{-1}.The appearance of Si-O bands supports the presence of quartz. The interlayer hydrogen bonding is assigned by the characteristics band at 3622.1 cm^{-1} [12], [14].

Most of the bands such as 3695.4, 3693.4, 3622.5, 3440.8, 1016.1, 916.1, 788.8, 686.6, 547.7, 466.7 cm^{-1} shows the presence

of Kaolinite [10].The presence of Calcite (calcium carbonate) is confirmed by the presence of the absorption peaks at 875-870 cm^{-1}.This is in agreement to other workers [14].

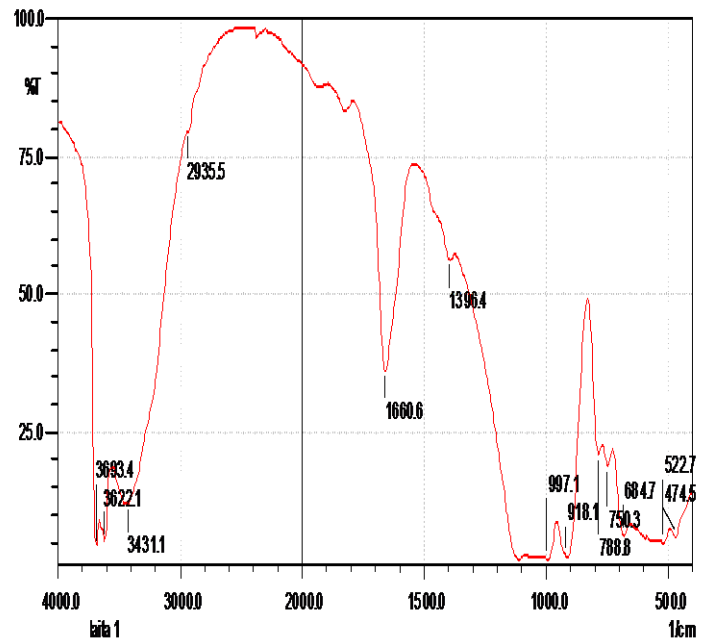A representative FT-IR spectra for a sample from Taita is shown in Figure 6

Figure 6: FTIR spectrum of geophagic material from Taita 1 sample.

3.4 Discussion

The high level of quartz in all the geophagic samples studied could have a negative effect on human health. Quartz particles are coarse, hard and angular with strong potential of damaging the dental enamel, the main inorganic component of tooth. This damage can occur through grinding, cracking, splitting and breakage during the process of consumption of geophagic materials[12].The ability of quartz to resist chemical alteration would lead to scratching and eventual perforation of the intestines and would also cause soil peritonitis due to perforation of the sigmoid colon [17].

The concentration of transition elements was generally low for the entire samples studied. The concentration of Pb, Zn, Cu and molybdenum were relatively low (< 30 ppm) while the

levels of chromium and vanadium were relatively high in all samples (> 50 ppm). However, levels of chromium were higher than those reported in geophagic samples from Nigeria and Cameroon [2].The metals Co, Sb and Cd were not detected in all the samples.

The mineralogy shows that the materials were mainly siliceous with quartz and kaolinite being the dominant phases. The presence of kaolin in the samples agrees with the protection hypothesis advanced by [15].

4.0 Conclusion

Geophagic materials from Mombasa and Taita have been studied and were found to contain high levels of silica and alumina. The levels of heavy metals found were generally low. Their consumption should be discouraged due to the high level of quartz which may damage the enamel and cause perforation in the large and small intestines.

The health effects on the consumers should be investigated futher,particularly the bioavailability studies of the elements in the geophagic materials consumed.

References

[1] Benedetto GED, Laviano R, Sabbatini L and Zambonin PG (2002). Infrared spectroscopy in the mineralogical characterization of ancient pottery. *J. Cul. Her*. 3, 177–186.

[2] Ekosse, G.E and Jumbam, DN (2010): Geophagic clays: Their mineralogy, chemistry and possible human health effects.*Afr.J.Biotechnol.* 9(40).6755

[3] Ekosse, G (2005). Fourier transform infrared spectrophotometry and xray powder diffractometry as complementary techniques in characterizing clay size fraction of kaolin. *J. Appl. Sci. and Environ.Manage.* 9 (2): 43-48

[4] Ekosse1, G-I. E., L de Jager and Ngole, V. (2010). Traditional mining and mineralogy of geophagic claysfrom Limpopo and Free State provinces, South Africa. *Afri. J. of Biotech.nology* 9(47), 8058-8067.

[5] Geissler PW, Mwaniki D, Thiong'o F, Friis H (1998). Geophagy as a risk factor for geohelminth infections: a longitudinal study of Kenyan primary schoolchildren. *T Roy Soc. Trop. Med. H.*, 92 (1): 7-11.

[6] Gichumbi JM and Ochieng, O (2011).Analyses of geophagic materials consumed by pregnant women in Embu, Meru and Chuka towns in Eastern Province Kenya. *J. Environ.Chem. Ecotoxicol.* 3(13), 340-344.

[7] Harvey PWJ, Dexter PB, Darton-Hill I (2000). The impact of consuming iron from non-food sources on iron status in developing countries. *J.Pub. Health. Nutr.* 3: 375-383. Campbridge university press.

[8] Kawai K, Saathoff E, Antelman G, Msamanga G, Fawzi WW (2009). Geophagy (Soil-eating) in Relation to Anemia and Helminth Infection among HIV–Infected Pregnant Women in Tanzania. Am. *J. Trop. Med. Hyg.*, 80(1): 36-43.

[9] Lohn, J.W.G., Austin, R.C.T.,Winslet, M.C., (2000). Unusual causes of small bowel obstruction. Journal of the *Roy. Soc. of Med*. 93, 365–368.

[10] Madejova and Komadel (2001). Baseline studies of the clay minerals society source clays: Infrared Methods. *Clay Minerals*. 49, 410-432.

[11] Mogongoa LF, Brand, CE; Jager, de L; Ekosse GE (2011): Hematological and iron status of Qwaqwa women in South Africa who ingest clays. Med. Tech. SA. 25 (1). 67.

[12] Ngole, VM, Ekosse, GE (2012). Physico-chemistry, mineralogy, geochemistry and nutrient bioaccessibility of geophagic soils from Eastern Cape, South Africa. *Sci. Res. and Essays 7(12) 1319 - 1331.*

[13] Njoki AN, Kiprono CK (2009). Analysis of geophagic materials consumed by pregnant women in Eldoret municipality, Kenya.J. Agric. Pure Appl. Sci.Technol., 1:18-24.

[14] Ravisankar,R;Senthikumar,G,Kiruba,S; handrasekaran,A; Jebakumar, PK (2010) Mineral analysis of coastal sediment samples of Tuna, Gujarat, India .*Ind. J. of Sc. and Techn*.Vol. 3 No. 7

[15] Young, SL, Wilson, MJ, Hillier,S E, Delbos, E ; Ali, S; Stoltzfus,JR (2010). *J Chem. Ecol.* 2010 January; 36(1): 129–140.

[16] Young SL, Wilson MJ, Miller D, Hillier S (2008) Toward a Comprehensive Approach to the Collection and Analysis of Pica Substances, with Emphasis on Geophagic Materials. *PLoS ONE* 3(9): e3147. doi:10.1371/journal.pone.0003147

[17] Woywodt A, Kiss A (2002). Geophagia: the history of earth-eating. *J. of the Royal Soc. of Med*. 95: 143-146.