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Compositional Characteristics of Geophagic Clays in Parts of Southern Nigeria

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Abstract

Geophagy is the practice of deliberate consumption of soil and clay deposits by humans, birds and other animals in the wild. It is closely related to pica, a classified eating disorder characterized by abnormal cravings for non-food items. The focus of this work is to determine the compositional characteristics of the geophagic clays consumed around Asaba, Benin, Ibadan and Aramoko-Ekiti areas in southern Nigeria in order to get an insight into the role these clay constituents play in geophagy. This study includes XRD aided mineralogical determination, chemical analysis of major and trace elements using ICP-MS instrumentation, physical tests including determination of Atterberg limits. Biological parameters such as the bacteriological content and nutritional value were also determined from in situ samples of geophagic clays. X-ray diffraction analysis of ten representative samples collected from these areas show mineralogical composition of predominantly kaolinite with minor palygorskite, nontronite, illite, K-feldspar and halloysite, while the nonclay fraction is mainly quartz.. The relatively high percentage of fine grained kaolinite content in the geophagic clays is similar to that in kaolinite-based western medicines that are marketed for the purpose of alleviating gastrointestinal upsets. This characteristic is also revealed in the chemical analysis of the study samples which show average values of major elements such $Si0_2$ (50.9%), Al_2O_3 (25.4%) and Fe_2O_3 (2.9%); while MgO, P_2O_5 and Ba are all below 0.5%. The bacteriological analysis shows high total bacteria count of 9.8×10^4 – 11.4×10^4 cfu/gm for the Asaba samples while the Benin and Aramoko-Ekiti samples have an average total bacterial count of 2.1×10^4. Cfu/gm The Ibadan samples have the lowest total bacteria count of 0.2×10^4. cfu/gm. The low total bacteria count of the Ibadan sample may be due to the baking of the sample before consumption as against samples from Asaba, consumed fresh. *Staphylococcus aureus* and *Micrococcus acidiophilus* are the two micro-organisms common to all samples. Analysis for nutritional value indicates that geophagic clays have little or no nutritional value for humans. Results of this study show that the rich kaolinite content of these clays could serve as an antacid, while bacteriological and trace element content reveals the harmful effect of these clays on consumers.

Keywords: geophagy, clay minerals, kaolinite, bacterial count, nutritional value

1. Introduction

Geophagy which is the practice of eating earthy or soil-like substances such as clay, and chalk, in order to obtain essential nutrients such as sulphur and phosphorus from the soil is widespread among humans, birds and animals. Recent research has highlighted the fact that geophagy is widespread throughout the animal kingdom. It has been reported for reptiles (Marlow and Tollestrup, 1982), birds (Diamond et al.,1999; Gilardi et al., 1999), mammals, particularly certain herbivores (Kerulen and Jager, 1984; Kreulen, 1985) and many primates (Krishnamani and Mahaney, 2000). Human geophagy is closely related to pica, a classified eating disorder characterized by abnormal cravings for non food items. As such, it is lumped with aberrant behaviours like the consumption of starch, ice, paint, cigarette butts, and burnt matches. (Johns and Duquette 1991). Geophagy is most often seen in rural or pre-industrial societies among children and pregnant women. Some reasons have been proposed forthis practice in both humans and animals. For example, Kreulen (1985) pointed out that geophagic constituents could act as a lubricant for fibrous forages, provide extra minerals and stimulate the flow of saliva, which contain high concentration of Na and P, and could thus relieve a mineral shortage in the rumen. Historically, and today in Nigeria, geophagy is almost synonymous with clay consumption and is regarded as normal. The main aim of this study therefore, is to determine the compositional features of the clay consumed by humans in the study areas, with a view to getting an insight to the role the clay composition plays in this phenomenon. This involves the determination of the mineralogical and chemical composition of these rocks, the physical properties, the microbial (bacterial) constituents and their nutritional characteristics. The study location is southern Nigeria. Samples were obtained from four local markets: Aleshinloye market, Ibadan, Oyo state; Ogbogonogo market, Asaba, Delta state; new Benin market, Benin -city, Edo state; Elewe-omo store, Aramoko-Ekiti, Ekiti state. The market samples were traced to their geological locations where they occur as ‘in situ’ primary derived and secondary clays and also sampled,

In Nigeria, a dearth of information exists on the compositional characteristics of geophagic clays. One notable study done on geophagia in Nigeria dealt with the role of minerals on the aetiology of geophagia in periurban dairy cattle in the derived savannah of Nigeria, (Smith et al., 2000). Also, the studies of McDowell et al. (1993) and Okaeme and Akerejola, (1985) studies show the relationship between the deficiency of P in blood samples and the low levels of P in forage and soil samples are worthy of note.

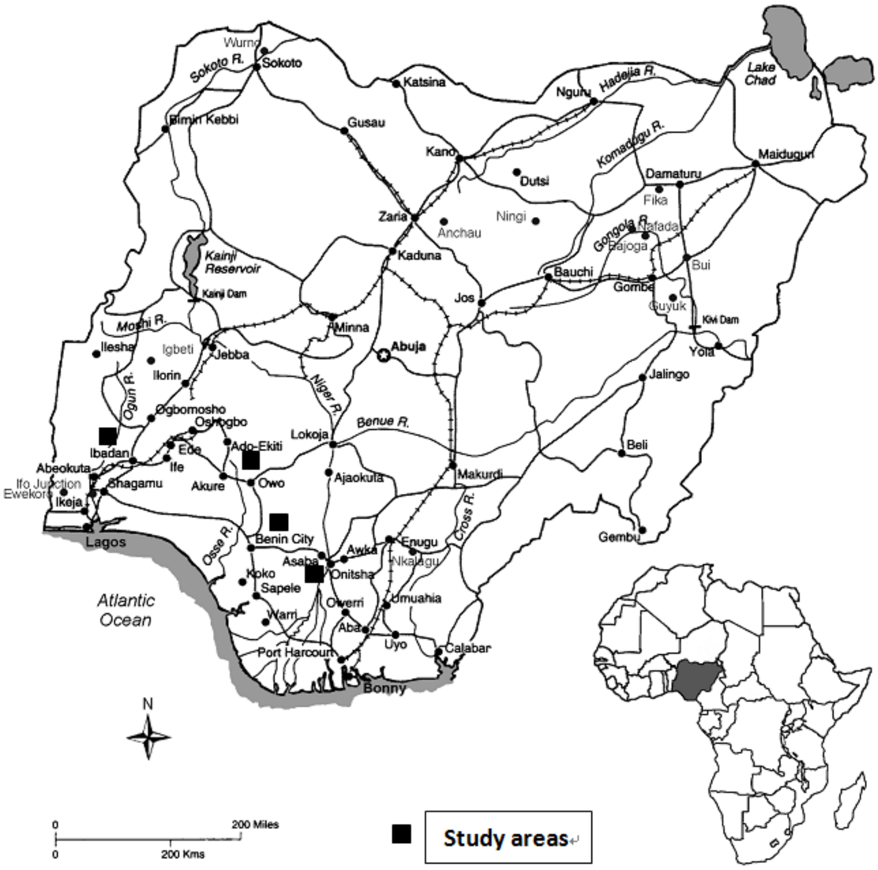

Figure 1. Map showing locations of Ibadan, Asaba, Ekiti and Benin in southern Nigeria

2. Materials and Methods

Twenty samples were collected for this study from eight different locations. Ten samples were collected from markets where geophagic materials are sold for consumption. The markets are the Aleshinloye market, Ibadan; Ogbogonogo market, Asaba; new Benin market, Benin City; and Elewe omo store, Aramoko Ekiti. Four samples were collected from Asaba, three samples from Ibadan, one sample from Aramoko Ekiti and two samples from Benin. Three of the samples from Asaba are clay lumps, while one is a light grey fissile shale. The market samples were traced to their geological locations where they occur as *in situ* as primary and secondary clays. Ten fresh samples similar to the market samples were taken. Four samples were taken from Ubulu-Uku near Asaba, three samples were taken from Omi-Adio on the outskirts of Ibadan, two samples were taken from a circular road at an exposed roadside excavation in Benin-city and one sample was taken from Ijero Ekiti.

The samples were pulverised and sieved at the Department of Geology laboratory of the University of Ibadan. XRD analysis of ten representative samples was carried out at Acme Analytical Laboratories Ltd, Vancouver, Canada. 0.5g_of powdered sample was mixed with acetone to produce thin slurry. The mixture was then transferred onto a glass slide which was scanned, and the mineralogy determined by XRD. Chemical analysis was performed on twenty clay/shale samples at the same laboratory using the ICP-MS technique (Perkin-Elmer Elan 6000).

Geotechnical tests were also carried out on twenty samples. These tests include Atterberg limit tests (liquid limit, plastic limit and plasticity index) and 'Water Absorption Capacity' test. The tests were carried out at Welaf laboratory, Surulere, Lagos. The Atterberg limit tests were carried out in accordance with the British Standard Institute Code of Practice BS 1377: part 2, clause 4:3 on material passing sieve 425 micron. While the 'Water Absorption Capacity' test was carried out in accordance with ASTM designation C 128.

3. Geological Setting

Half of Nigeria is underlain by Precambrian Basement Complex rocks. The Basement rocks of Nigeria form part of the extensive Pan- African province of West Africa and are delimited in the west by the West African Craton and east by the Congo Craton. Basement complex rocks are subdivided into Migmatite-gneiss Complexes; the Older metasediments; the younger metasediments; the Older Granites; The Younger Granite Alkaline Ring Complexes and volcanic rocks represent a Cainozoic anorogenic phase. Between these massifs are sedimentary basins which include the Calabar Flank, the Benue Trough, the Chad Basin, Nupe Basin, SE lullemmenden (Sokoto) Basin, the Dahomey Basin, and the Niger Delta Basin.

The local geological setting of Aramoko-Ekiti, Ibadan, Asaba and Benin clays, (Fig 2-5) the locations from which the in situ samples were taken, is briefly described below.

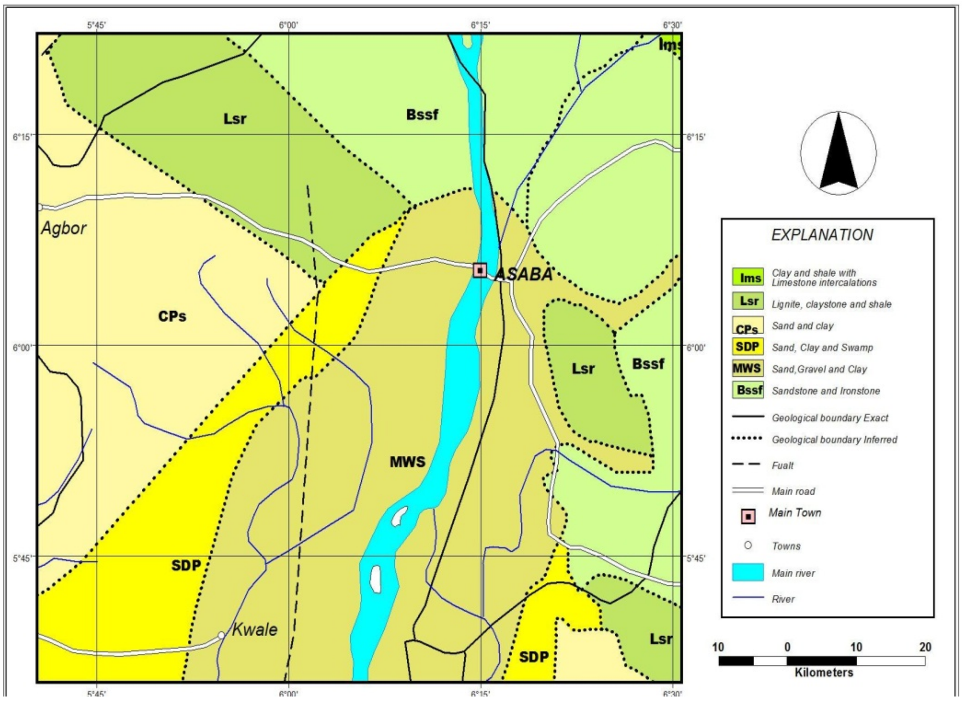

Figure 2. Geological Map of Asaba Area

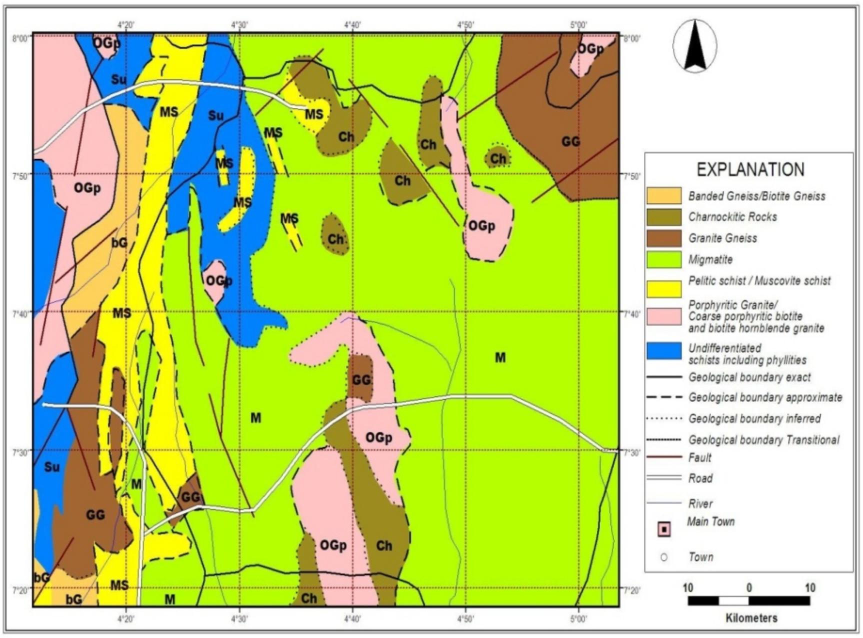

Figure 3. Geological map of Aramoko-Ekiti area

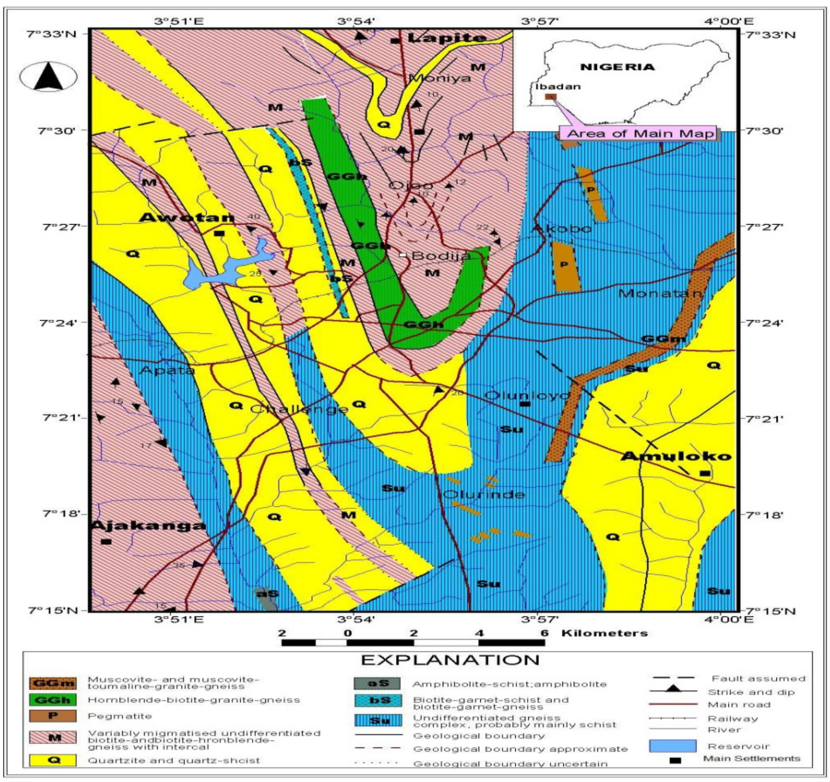

Figure 4. Geological Map of Ibadan Area

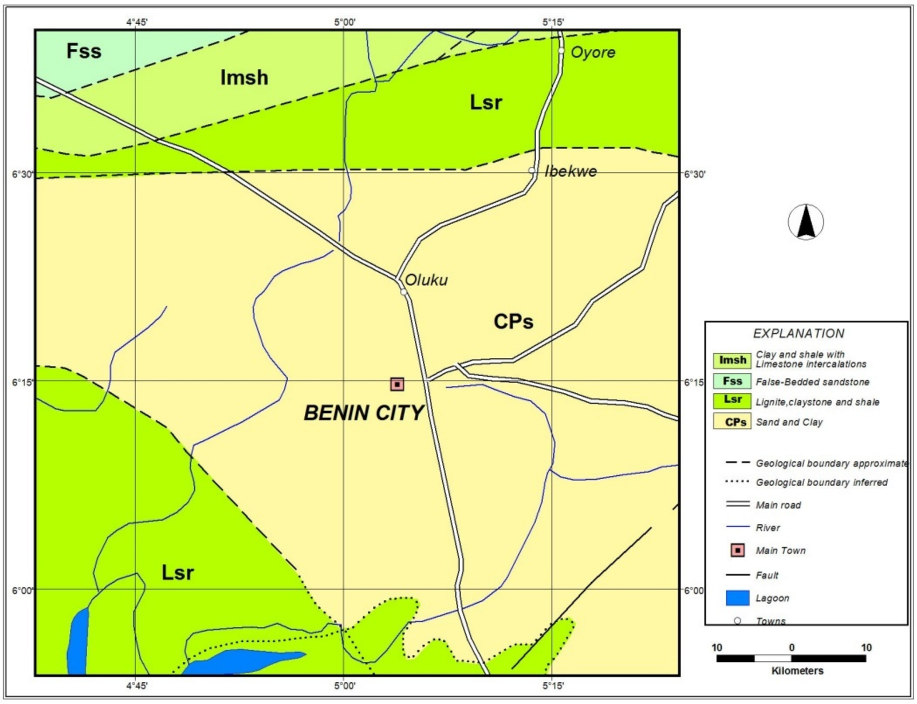

Figure 5. Geological Map of Benin Area

3.1Aramoko- Ekiti Area

Aramoko-Ekiti clay is associated with the Ijero–Aramoko pegmatite lithology (Fig 3). They are weathered products of the pegmatite. This pegmatite which forms intrusions into the older lithology of biotite schist that occupies the central part of the area (Okunlola and Akinola, 2010). Occurs as fine–medium grained tabular bodies comprising mainly quartz and microcline, with garnet and tourmaline as accessories. Around Ijero, the outcrops are coarse-grained, and extensive, with prominent graphic textures (Okunlola and Jimba, 2006).

3.2 Ibadan Area

The Ibadan clays around Omi-Adio area occurs within the ancient Migmatite-Gneiss-Quartzite Complex, and the Pan African Granitic Series (Fig4) .The Migmatite Granite suites are mainly ca. 2.8 to 2.0 Ga. in age. The rocks of these suites comprise mostly a sedimentary series with associated minor igneous rocks which have been variably altered by metamorphic, magmatic and granitic processes (Oyawoye,1972; Rahaman et al., 1988; Okunlola, 2005; and Okunlola et al., 2009).

3.3 Asaba Area

The study area is underlain in most parts by the Ogwashi- Asaba Formation comprising essentially clays and lignite (Fig.5) In places, the formation is mostly continental cross-bedded sandstone and grits. Carbonaceous mudstone and shale also occur. The clays are mostly mottled, white, bluish or pink in colour and vary from sandy to plastic in nature. Outcrops are relatively scarce, but good exposures have been found along river valleys, especially along the Mgbiligba stream in Asaba, and oboshi and Atakpo river valleys in Ibusa and Okpanam . Good exposures of clays associated with the Ogwashi-Asaba formation are found in Isho valley at ubulu-Uku as well as along the Ago-Uku stream.

3.4 Benin Area

Benin clays constitute a member of the Benin Formation.The Benin Formation is the youngest Formation of the Niger Delta Basin which includes two other formations, the Akata and Agbada Formations. Benin Formation represents the continental unit overlying Agbada Formation (Fig. 8). It consists of over 90% sand and gravels, with minor shale intercalations which were laid down in continental-fluviatile environments. Various structural units like point bars, channel fills, natural levees, back swamp deposits, and oxbow fills are identifiable within the formation indicating shallow water depositional environments (Kogbe, 1975) . The Benin Formation comprises unconsolidated white to yellowish sands that become pebbly in some horizons. Clay samples were obtained from the clay-rich bands

4. Results and Discussions

4.1 Mineralogical Characteristics

X-ray Diffraction patterns were obtained for representative samples (Fig 6-7; Tables1-2). Results show that kaolinite is the dominant clay mineral in all samples but one (Asaba 4), which has nontronite (34%) and Palygorskite (35%) as dominant clay minerals. Other clay minerals present in the samples are halloysite, illite and K-Feldspar. These are found in trace to only a few percent. The major non-clay mineral constituent in all samples is quartz. The percentage composition of quartz in all the samples ranges from 8% to 40% . Kaolinite makes up the major mineral constituent of all the samples except Asaba 4. The percentage composition of kaolinite in nine samples ranges from 38% in Ibadan to 72% in Asaba 1 indicating that the geophagic clays are kaolin rich. K-feldspar is present in minor amounts in some samples, especially those from Benin; palygorskite is present in all samples, and ranges from 4% in Ibadan 1 to 35% in Asaba 4

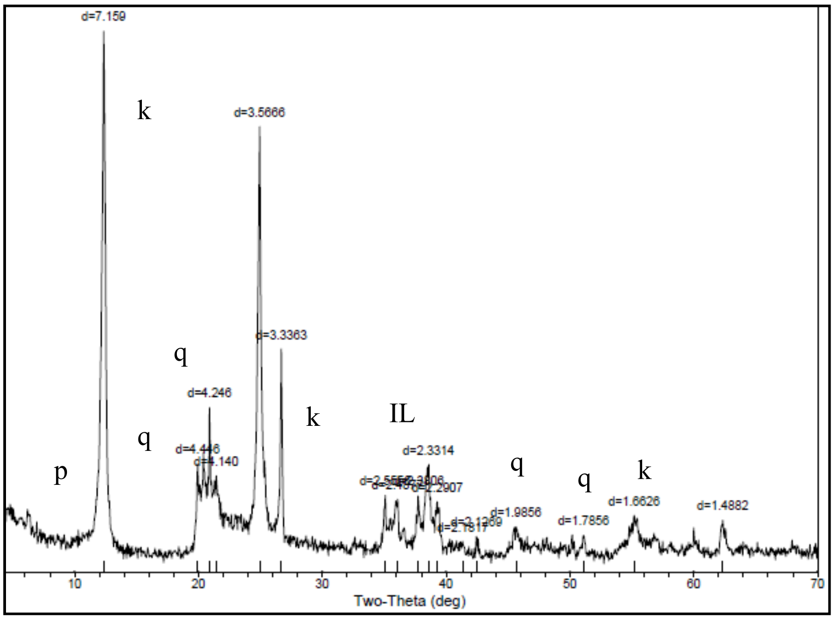

Figure 6. X-ray diffractogram of Asaba sample 1 (k-kaolinite; q-quartz; p-palygorskite; IL-Illite)

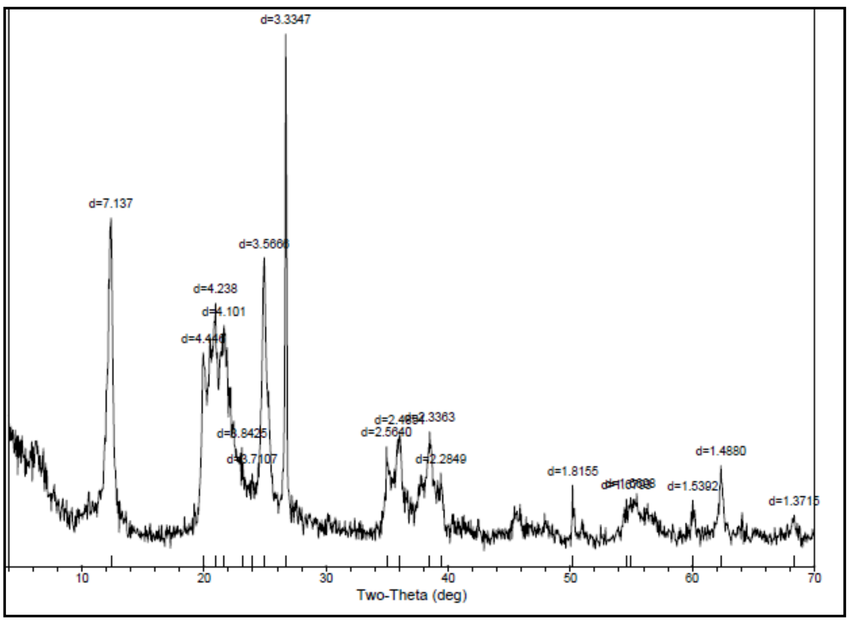

Figure 7. X-ray diffractogram of Benin sample1(K – kaolinite; p – palygorskite; q – quartz;

Nontronite is present only in Asaba 4 and makes up 34% of the sam sample. Halloysite is present as a trace mineral in only one sample . Illite is also present in five samples as trace mineral (Table 1).

From the above, the sampled clays are rich in kaolin. Kaolin has been used in the preparation of medication to alleviate diarrhoea and mild intestinal upsets (Wilson, 2003; Vermeer and Ferrell, 1985). However, these clay samples are consumed in their raw and unprocessed state, which has long-term health implications. The claimed detoxification effect of geophagic clays when consumed with wild potatoes or other foods could not be confirmed for the studied localities, because the consumption of geophagic clays with other foods is not a known or is not a common practice in the study area.

Table 1. Mineralogical composition of geophagic clays of southern Nigeria

Mineral	Asaba1 %	Asaba2 %	Asaba3 %	Asaba4 %	Ekiti1 %	Ibadan1 %	Ibadan2 %	Ibadan3 %	Benin1 %	Benin2 %
Kaolinite	72	54	61	18	53	40	63	38	50	49
Quartz	16	29	31	8	38	40	21	34	36	22
K- Feldspar	2			4		1		4		9
Palygorskite	5	6	5	35	6	4	10	5	7	5
Nontronite				34						
					2					
Illite	3	3				1		2		3
Others	2	8	3	1	1	4	6	17	7	12
Total	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	

When compared with geophagic clays consumed by humans in other parts of the world, geophagic clays of southern Nigeria show some similarities with those of China, Zimbabwe, Uganda and Indonesia (Table 2) which all have kaolinite as a dominant constituent. The samples studied show marked compositional differences from geophagic materials from other parts of the world; for example, smectite is dominant in some of the geophagic clays of China and Indonesia, while halloysite is the dominant clay mineral in geophagic materials of USA and Indonesia; illite is present in subordinate percentages in geophagic clays of USA and Indonesia, while it is found in southern Nigeria geophagic clays only in trace percentages

Table 2. Comparison of the clay mineralogical composition of geophagic clays in other parts of the world (Wilson2003) with that of Southern Nigeria geophagic clays

	Asaba	Ekiti	Ibadan	Benin	1	2	3	4	5
Kaolinite	Dorm	Abunt	Abunt	Abunt	Abunt		Abunt	Dorm	Sub
Smectite					Dorm	Sub		Sub	Dorm
Halloysite		Tr			Sub	Dorm	Sub		Dorm
Nontronite	Abunt								
Palygorskite	Abunt	Sub	Sub	Sub					
Illite	Tr		Tr	Tr		Sub			
K Feldspar	Tr		Tr	Sub					Sub

Dorm-Dominant (>50%), Abunt-Abundant (25-50%), Sub-Subordinate (5-25%), Tr-Trace (<5%)

1-Aufreiter et al (1997) China 2-U S A

3-Zimbabwe 4-Abraham (1997) Uganda

5-Mahaney (2000) Indonesia

4.2 Chemical Characteristics

Results of major element analysis (Table3,4,5) show that the average SiO_2 values range from 47.2% -53.2% with the Asaba samples recording the highest value and the Ibadan samples, the lowest. However these values are lower than most clay samples from other parts of Nigeria (Table 5) Mean Al_2O_3 values also range from 24.94%

in the Asaba samples to 28.31 % in the Benin samples. These values are comparable to those obtained for residual and secondary clays from other parts of Nigeria. On the other hand Na_2O, K_2O, and CaO concentrations are all less than 0.4%, and are lower than those of other clays in Nigeria. Similarly, values of Fe_2O_3 which range from 2.53 to 4.10 are lower than the clays of Itakpe (Okunlola, 2006), Itu and Isan clays (Elueze and Bolarinwa,1995).

Table 3. Chemical composition of geophagic clays of Asaba, Ekiti, Ibadan and Benin in southern Nigeria

Oxides	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
SiO_2	*47.1*	*47.6*	*36.9*	*39.5*	*54.9*	*52.9*	*50.0*	*48.6*	*55.2*	*57.2*	*52.0*	*52.0*	*55.1*	*51.1*	*55.0*	*54.0*	*56.0*	*57.0*	*49.0*	*49.0*
Al_2O	*33.5*	*30.1*	*21.0*	*22.1*	*26.1*	*28.1*	*17.6*	*20.6*	*26.1*	*27.1*	*24.0*	*22.1*	*24.2*	*24.4*	*27.5*	*30.3*	*24.2*	*25.2*	*32.3*	*31.4*
$_3Fe_2$	*92.3*	*52.5*	*95.5*	*5.00*	*72.3*	*82.5*	*16.2*	*16.4*	*72.2*	*72.0*	*92.0*	*02.1*	*12.5*	*02.4*	*21.4*	*1.86*	*92.5*	*03.1*	*42.2*	*02.2*
O_3C	*1<0.*	*2<0.*	*00.0*	*0.03*	*10.0*	*20.0*	*30.6*	*00.0*	*10.0*	*00.0*	*50.0*	*10.0*	*80.0*	*60.0*	*9<0.*	*<0.0*	*50.0*	*00.0*	*60.0*	*00.0*
aOM	*010.*	*010.*	*20.0*	*0.06*	*40.1*	*40.1*	*03.4*	*63.8*	*60.1*	*40.2*	*10.1*	*10.1*	*40.1*	*40.1*	*010.*	*10.0*	*40.1*	*60.2*	*20.1*	*20.1*
gON	*07<0*	*06<0*	*6<0.*	*<0.0*	*70.0*	*50.0*	*70.0*	*60.0*	*7<0.*	*0<0.*	*30.0*	*40.0*	*70.0*	*70.0*	*080.*	*80.8*	*80.0*	*00.0*	*10.0*	*10.0*
a_2O	*.010.*	*.010.*	*010.*	*10.1*	*10.3*	*10.4*	*70.8*	*50.7*	*010.*	*010.*	*30.5*	*20.5*	*10.3*	*10.4*	*720.*	*80.2*	*10.3*	*10.3*	*40.3*	*50.3*
K_2O	*13<0*	*15<0*	*150.*	*50.0*	*60.0*	*00.0*	*30.0*	*50.0*	*360.*	*360.*	*00.0*	*00.0*	*6<0.*	*6<0.*	*30<*	*8<0.*	*70.0*	*70.0*	*1<0.*	*1<0.*
MnO	*.012.*	*.012.*	*041.*	*22.0*	*11.4*	*21.3*	*60.9*	*60.9*	*011.*	*011.*	*12.2*	*12.2*	*011.*	*011.*	*0.01*	*011.*	*11.3*	*11.3*	*011.*	*011.*
TiO_2	*000.*	*260.*	*350.*	*00.0*	*70.0*	*50.0*	*80.0*	*80.0*	*530.*	*470.*	*60.1*	*00.1*	*400.*	*350.*	*1.93*	*880.*	*50.0*	*50.0*	*810.*	*810.*
P_2O_5	*070.*	*060.*	*060.*	*70.0*	*70.0*	*70.0*	*60.0*	*70.0*	*070.*	*060.*	*10.0*	*00.0*	*070.*	*080.*	*0.09*	*090.*	*70.0*	*70.0*	*080.*	*080.*
Cr_2O	*0290*	*0280*	*0180*	*160.*	*210.*	*310.*	*190.*	*180.*	*0200*	*0180*	*200.*	*200.*	*0170*	*0180*	*0.01*	*0190*	*190.*	*170.*	*0240*	*0200*
$_3BaL$	*.021*	*.021*	*.033*	*0230*	*0313*	*0313*	*0219*	*0218*	*.031*	*.021*	*0518*	*0318*	*.031*	*.051*	*90.0*	*.021*	*0314*	*0315*	*.031*	*.031*
OI	*3.74*	*2.70*	*4.38*	*.40*	*.85*	*.65*	*.43*	*.40*	*3.51*	*3.41*	*.30*	*.85*	*4.61*	*4.41*	*312. 29*	*3.20*	*.79*	*.00*	*3.51*	*3.41*

Table 4. Chemical composition of geophagic clays of southern Nigeria compared to some other clays in Nigeria.

Oxides	Geophagia clays of Southern Nigeria			%								
	As	Ek	Ib	B	1(%)	2 (%)	3(%)	4(%)	5(%)	6(%)	7(%)	8(%)
SiO_2	47.2	56.2	53.2	52.8	52.65	55.49	60.47	60.70	70.82	50.74	51.25	57.65
Al_2O_3	24.94	26.07	25.44	28.01	27.24	18.63	17.77	17.75	13.11	32.70	32.32	25.10
Fe_2O_3	4.10	2.11	2.09	2.53	3.01	9.67	8.18	6.04	2.81	2.59	2.21	3.20
Na_2O	0.02	<0.01	0.28	0.03	0.37	0.46	0.44	0.23	0.07	0.06	0.06	0.27
K_2O	0.37	0.36	0.4	0.34	1.44	1.84	1.17	1.40	0.34	0.37	0.27	0.49
CaO	0.03	0.05	0.02	0.04	0.19	0.77	0.47	0.83	0.64	Tr	Tr	Tr
MgO	1.0	0.19	0.13	0.15	0.38	1.25	1.26	1.22	0.16	0.15	0.12	0.39
MnO	0.03	0.01	<0.01	<0.01		0.04	0.03	0.03		0.006	0.005	0.01
TiO_2	1.55	1.50	1.84	1.58						1.99	1.20	2.47
P_2O_5	0.27	0.20	0.95	0.35	6.35	6.50	6.40	6.33	5.6			
LOI	19.57	13.46	15.28	14.18						11.41	12.25	10.43
Total	99.78	100.16	99.64	100.02						100.01	99.68	100.02

1 - Itakpe (Okunlola,2008), 2 - Isan(brown), 3 - Isan(red), 4 - Ara-Ijero (Elueze and Bolarinwa,1995)
5 - Itu area clays (Elueze, et al.,1998); 6 – Ubulu-Uku, 7 – Awo-Omama, 8 – Buan (Emofuriefa et al., 1992)
As- Asaba – ave of 8 samples; Ek- Ekiti – ave of 2 samples; Ib- Ibadan – ave of 6 samples; B- Benin – ave of 4 samples

Table 5. Chemical composition of geophagic clays of southern Nigeria compared to some industrial specification of clays

	Geophagic clays of southern Nigeria				Some Industrial Specification							
Oxides	Asaba	Ekiti	Ibadan	Benin	A	B	C	D	E	F	G	H
SiO_2	47.2	56.2	53.2	52.8	48.67	67.50	51.00	45.78	44.90	46.07	49.88	47
Al_2O_3	24.94	26.07	25.44	28.01	9.45	26.50	25.44	36.46	32.35	38.07	37.65	40
Fe_2O_3	4.10	2.11	2.09	2.53	2.70	0.50-1.20	0.5-2.4	0.28	0.43	0.33	0.88	
MgO	1.0	0.19	0.13	0.15	8.50	0.1- 0.19	0.2-0.7	0.04	Tr	0.01	0.13	
CaO	0.03	0.05	0.02	0.04	15.84	0.18-0.30	0.1-0.2	0.50	Tr	0.38	0.03	
Na_2O	0.02	<0.1	0.28	0.03	2.76	0.2- 1.5	0.8-3.5	0.25	0.14	0.27	0.21	
K_2O	0.37	0.36	0.4	0.34	2.76	1.1- 3.10		0.25	0.28	0.43	1.60	
TiO_2	1.55	1.5	1.84	1.85		0.1- 1.0	1.0-2.		1.80	0.50	0.09	

H_2O/ LOI	19.57	13.46	15.28	14.18	3.04	12.00		13.40	14.20	13.47	12.43	13
MnO	0.03	0.01	<0.01	<0.01						0.01		
Total	99.78	100.16	99.64	100.02	93.72			96.96	94.1	99.53	102.87	

A=Brick clay (Murray, 1960)

B = Ceramics (Singer and Sonja, 1971)

C = Refractory bricks (Parker, 1967)

D = Plastics (Frados, 1965)
E = Rubber (Keller,1964)
F = Fertilizer (NAFCON, 1985)
G = Agricultural (Huber, 1985)
H = Pharmaceutical (Todd, 1973)

Various explanations have been suggested to relate the favourable chemical composition of geophagic clays, and value as nutritional supplement, as the reason for its consumption. It was established from examination of four different geophagic clays consumed by Indians from Bolivia, Peru, and Arizona, dominated by interstratified illite-smectite, sometimes with subsidiary amounts of other clay minerals like kaolinite and chlorite, that geophagy functions as a detoxification process to enable consumption of wild potato species free from toxins. In fact, this is the specific reason for geophagy given by these Indians. Eating clay with potatoes is thought to be effective in eliminating the bitterness of food, and in preventing stomach pains and vomiting. All the clays were effective in absorbing the glycoalkaloid tomatine over a range of simulated physiological conditions. (Johns, 1986).

In addition to the fact that geophagic clays are consumed by humans for nutritional supplement or pharmaceutical purposes, these clays from chemical analytical results are also suitable for other industrial uses For instance the average SiO_2 content of geophagia clays of southern Nigeria is comparable with industrial brick clay of Murray (1960). And for the manufacture of fertilizers, agricultural and pharmaceutical uses respectively (NAFCON, 1985) (Table 5).

4. 2. 1 Trace Element Content

When compared to the adequate daily intake of trace elements in the human body, the trace element content of the geophagic clays of southern Nigeria is relatively high. (Tables 6 and 7) For example the Cu content in the geophagic clays of southern Nigeria have a range of 18.56-26.89ppm, while daily intake necessary for human body functions is only 1.0 – 1.5 mg/kg /day. Average Mn content has a range of 43.17-200.13ppm, but only 2 – 5 mg/kg /day is required for body functions. The average Co content in these geophagic clays has a range of 4.9 - 21.57ppm, while the body requirement for this element daily is 0.002 – 0.1 mg/kg. However geophagic clay content for Zn with a range of 29.1- 42.3ppm is consistent with the human body content of 33mg/kg body weight (Table 7). This means that apart from Zn, most trace metals in the sampled clays occur in excess of required for the proper functioning of the human body.

Table 6. Trace element content of Southern Nigeria geophagia clays

Elements	Asaba								Ekiti		Ibadan					Benin				
Ppm	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mo	1.40	1.56	2.30	1.40	1.55	2.44	0.77	0.98	1.23	1.33	2.05	1.14	1.12	2.27	2.47	2.05	1.12	1.14	2.36	2.24
Cu	5.76	11.77	15.35	14.30	42.73	40.80	14.15	14.17	19.06	18.06	30.60	35.35	23.49	24.39	8.29	10.11	25.35	24.45	29.37	28.40
Pb	56.19	55.18	39.67	40.11	56.51	50.41	36.68	35.68	40.64	38.42	48.32	46.50	39.44	40.12	63.37	60.40	35.36	32.36	96.33	94.44
Zn	18.5	20.4	21.3	22.4	40.2	38.6	89.4	72.4	43.8	40.8	35.3	40.4	70.0	58.8	13.8	11.6	32.1	30.1	27.7	26.5
Ag	95	90	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	131	135
Ni	17.9	16.8	56.6	54.2	22.3	20.4	38.5	38.6	23.3	20.4	70.2	70.4	26.3	26.3	17.2	18.4	27.4	25.6	21.5	21.8
Co	3.1	3.0	31.8	28.0	5.0	7.2	15.8	14.6	5.0	4.8	57.9	47.9	8.7	8.8	2.9	3.2	9.8	10.0	3.2	3.2
Mn	40	45	278	256	58	60	442	422	53	50	54	48	50	48	31	28	60	60	34	36
As	3.3	3.4	9.1	9.2	3.7	3.6	2.1	2.0	1.7	2.0	2.3	2.0	2.5	2.3	2.1	2.0	2.1	2.1	5.1	5.1
U	3.5	3.1	3.1	3.4	5.9	3.5	1.4	5.8	4.8	4.6	6.8	6.6	3.8	3.6	5.0	4.8	3.1	3.6	3.4	3.6
Au	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Th	14.3	15.0	15.0	14.6	12.7	14.3	9.3	12.6	13.5	12.8	19.2	19.0	12.5	13.5	16.8	18.6	11.7	11.8	19.8	20.0
Sr	69	69	69	65	65	69	111	124	63	65	99	89	56	58	93	90	63	60	88	84
Cd	0.08	0.06	0.27	0.25	0.07	0.06	0.05	0.06	0.06	0.05	0.01	0.02	0.19	0.19	0.05	0.06	0.06	0.06	0.09	0.08

Sb	0.22	0.21	0.21	0.21	0.29	0.26	0.22	0.22	0.24	0.24	0.19	0.18	0.20	0.20	0.81	0.80	0.20	0.14	0.48	0.46
Bi	0.41	0.44	0.46	0.44	0.56	0.46	0.71	0.77	0.43	0.56	0.58	0.43	0.36	0.36	0.93	0.71	0.48	0.48	3.32	3.22
V	91	88	84	86	101	91	136	130	94	96	107	110	92	106	142	136	83	91	115	101
Mg(%)	0.03	0.04	0.03	0.33	0.09	0.08	1.92	1.80	0.09	0.08	0.07	0.07	0.09	0.08	0.04	0.04	0.09	0.09	0.06	0.06
Ba	123	133	133	133	261	251	99	111	239	227	272	272	218	200	200	211	208	200	183	218

Table 7. Trace elements in the human body and their daily intake compared to trace element content of geophagic clays of southern Nigeria

Element	Geophagic clays of Southern Nigeria (ppm)				*Human body content mg/kg body weight	*Adequate intake mg/day
	Asaba	Ekiti	Ibadan	Benin		
Mo	1.55	1.28	1.85	1.72	0.1	0.05-0.1
Cu	19.88	18.56	22.04	26.89	1.0	1.0-1.5
Pb	46.30	39.53	49.69	64.62	NA	NA
Zn	40.4	42.3	38.32	29.1	33	10-15
Ni	33.16	21.85	38.13	24.08	0.1	0.025-0.03
Co	13.56	4.9	21.57	6.55	0.02	0.002-0.1
Mn	200.13	51.5	43.17	47.5	0.2	2-5
As	4.55	1.85	2.2	3.6	NA	NA
U	3.71	4.7	5.1	3.43	NA	NA
Th	13.9	13.15	16.6	15.83	NA	NA
Sr	80.13	64	80.83	73.75	NA	NA
Cd	0.11	0.055	0.087	0.07	NA	NA

Belitz et al., (2009).

4. 3 Physical Properties

The results obtained for the determination of the physical properties of the geophagic clays of southern Nigeria are presented in Table 8. The colours of hand specimens of geophagic clays from China, Zimbabwe, Uganda and Indonesia are pale yellow to yellow, with some red, while that of Southern Nigeria which are greyish white to light brown are similar to geophagic clays of United States of America (Table 9).

Table 8. Physical parameters of geophagic clays of southern Nigeria

	Asaba				**Ekiti**	**Ibadan**			**Benin city**	
Property	**1**	**2**	**3**	**4**	**1**	**1**	**2**	**3**	**1**	**2**
Liquid Limit(%)	68	48	55	50	60	56	52	72	49	53
Plastic Limit (%)	29	22	26	24	27	25	24	30	23	25
PlasticityIndex(%)	39	26	29	26	33	31	28	42	26	28
Water Absorption(%)	2.5	1.8	2.1	1.9	2.3	2.0	2.0	3.0	1.8	1.9
pH	4.76	2.76	4.33	5.21	5.20	3.15	4.17	4.54	4.13	4.57
LOI	13.7	34.4	13.8	19.4	13.5	18.3	14.6	12.3	14.8	13.5
Compressibility	High	Med	High	High	High	High	High	High	Med	High

Plasticity Index (PI) values show the clays to be highly plastic with values for Asaba clays ranging from 26% to39%. Ekiti also has an average PI value of 33%, while the PI values for Ibadan geophagic clays range from 28% to 42%, and those for Benin clays from 26%-28%. A plot of the relationship between liquid limit and the plasticity index for these clays (Fig 8) shows that southern Nigeria geophagic clays are highly compressible except for two representative samples from Asaba and Benin with medium values. The pH values of these geophagia clays (2.76-7.2) reveals they are acidic to moderately acidic . High acidity value of 2.76 is close to acidity of the stomach in humans. When compared to geophagic clays from Uganda with values ranging from 4.6-7.2 and that of Indonesia with pH value range of 6.0-8.1, geophagic clays of southern Nigeria are more acidic (Table 9). Geophagic soils have been known to act as a natural antacid, helping to alleviate discomfort brought about by excess acidity in the digestive tract (Abrahams and Parsons, 1997; Abrahams, 1999). Wilson (2003) had posited that acidic soils could be effective in alleviating excess acidity in the digestive tract because of the aluminous minerals that they contain. Reactive aluminum hydroxide is used in many pharmaceutical antacid preparations.

Table 9. Some physical properties of Southern Nigeria geophagic clays compared with those of geophagic clays from other parts of the world

Property	Southern Nigeria geophagic clays				Aufreiter et al (1997) China	USA	Zimbabwe	Abraham (1997) Uganda	Mahaney (2000) Indonesia
	Asaba	**Ekiti**	**Ibadan**	**Benin**					
Source	Street market	Street market	Street market	Street market	Weathered roc	Clayey subsoil	Termite mould	Street market	Soil from Leucite lava and sediment
Colour	Light brown	Light brown	Grey-light brown	Light brown-white	Pale yellow	Light brown	Red-yellow	Dark grey-red, yellow	Pale yellow, brown
pH	2.76-5.21	5.20	3.15-4.54	4.13-4.57	Not tested	Not tested	Not tested	4.6-7.2	6.0-8.1

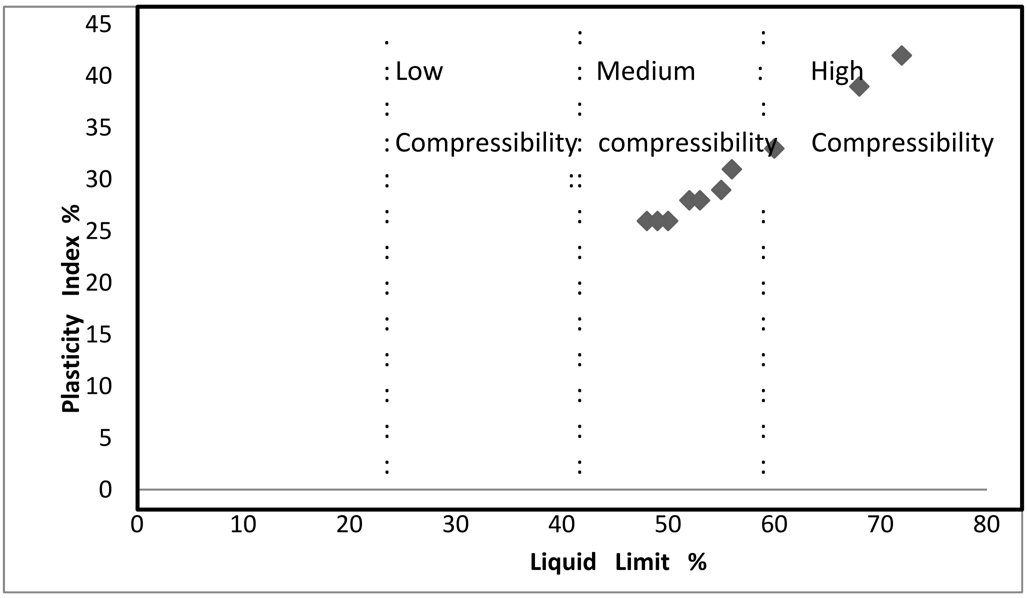

Figure 8. Relationship between Liquid limit and plasticity index for geophagic clays of Southern Nigeria (after Casagrande, 1948)

4.4 Bacteriological Constituents

Result of bacteriological analysis carried out on ten representative samples show relatively high bacteria population with samples from Asaba having the highest total bacteria count ranging from 1.0 x 10^4 to 10.4 x 10^4, and samples from Ibadan having the lowest total bacteria count ranging from 0.2 – 0.3 x 10^4. Total coliform count is nil in five samples, but ranges from 0.1 – 1.2 x 10^4 in Asaba samples, 0.3 – 0.6 x 10^4 in Benin samples, while one Ibadan sample has a coliform count of 0.1 x 10^4 (Table 10).

Table 10. Bacteriological constituents of southern Nigeria geophagic clays (cpu/g)

	Asaba1	Asaba2	Asaba3	Asaba4	Ekiti1	Ibadan1	Ibadan2	Ibadan3	Benin1	Benin2
Total bacterial	10.4x10^4	11.4x10^4	9.8x10^4	1.0x10^4	2.1x10^4	0.3x10^4	0.2x10^4	1.8x10^4	2.3x10^4	1.9x10^4
Total coliform Count	Nil	Nil	0.1x104	1.2x104	Nil	Nil	Nil	0.1x104	0.6x104	0.3x104
E.Coli count	Nil	Nil	Nil	0.6x104	Nil	Nil	Nil	Nil	0.1x104	Nil
S-aureus count	1.1x104	0.2x104	0.6x104	0.4x104	0.8x104	Nil	Nil	0.6x104	0.8x104	0.6x104
Fungi count	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Micro-organism	Sa; Ma; Sz	Ma; Bs; Sa; Sz	Sa; Aa; Bs; Ma	Aa; Bs; Ma; Sa; Ec	Sa; Bs; Ma	Ma	Bs	Ka; Sa; Bs; Sz	Sa; Bs; Ec; Ml	Sa; Pv; Bs; Ma

Sa – *Straphylococcus aureus*; Ma – *Micrococcus acidiophilus*; Sz – *Streptococcus zymogenes*;

Bs – *Bacillius subtilis*; Aa – *Aerobacter aerogenes*; Ka – *Klebsiella aerogenes*; Ec – E. coli

Ml – *Micrococcus luteus*; Pv – *Proteus vulgaricus*

Coliform bacteria are known to be harmful to the body. They infect the digestive and excretory systems of the body and can lead to emaciation of the victim. Prolonged diarrhoea is one common symptom that shows the presence of the coliform bacteria in the digestive system (Kinyanjui, 2008).*Staphylococcus aureus* count ranges from 0.2 x 104 to 1.1 x 104 in the Asaba samples. It is present in all other samples except in two Ibadan samples. *Staphylococcus aureus* is a facultative anaerobic bacteria, Gram-positive coccus, and is the most common cause of staph infections. It is frequently part of the skin flora found in the nose and on skin. About 20% of the human population are long-term carriers of *S. aureus*. *S.aureus* can cause a range of illnesses from minor skin infections, such as pimples, impetigo, boils (furuncles), cellulitis folliculitis, carbuncles, scalded skin syndrome, and abscesses, to life-threatening diseases such as pneumonia, meningitis, osteomyelitis, endocarditis, toxic shock syndrome (TSS), chest pain, bacteremia, and sepsis

4.5 Nutritional Characteristics

The results for the analysis of micro-nutrients, Ca, P, Mg, Na and K show low values in sampled clays (Table11). This indicates that these essential elements are not available in appreciable amounts for absorption into the digestive system from consumption of the geophagic clays. However Al and Fe are available in higher percentages and so can be said to be the main elements of nutritional value derived from the samples. When compared with samples from other countries, geophagic clays of China, USA, Uganda and Indonesia all have >2% nutrient Fe content, which is similar to those of Asaba with an average Fe content of 2.82%, while that of Ekiti, Ibadan and Benin have lower average Fe content of <2%. The geophagic clays of China has Ca content of >2% as compared to Ca values of the sampled clays of southern Nigeria with Ca content of <0.1%. In comparison, the geophagic clays of USA and Zimbabwe have K content of >2%, while those of southern Nigeria have lower K contents (0.34% – 0.40%.) (Table 12).

Table 11. Nutritional elements content of Southern Nigeria geophagia clays

Element%	Asaba1	Asaba2	Asaba3	Asaba4	Ekiti1	Ibadan1	Ibadan2	Ibadan3	Benin1	Benin2
Ca	<0.02	0.04	0.04	0.045	<0.02	0.03	0.04	0.02	0.04	0.03
P	0.034	0.025	0.036	0.027	0.032	0.049	0.027	0.040	0.030	0.041
Mg	0.03	0.03	0.09	1.92	0.09	0.07	0.09	0.04	0.09	0.06
Ti	1.248	0.763	0.995	0.577	0.979	1.225	0.751	1.140	0.744	1.155
Al	>20.00	10.29	17.39	9.18	15.63	10.84	10.63	13.89	10.94	>20.00
Na	0.005	0.009	0.013	0.049	0.012	0.024	0.010	0.559	0.009	0.034
K	0.11	0.12	0.32	0.62	0.32	0.38	0.28	0.26	0.28	0.28
Fe	1.77	3.59	1.77	4.5	1.65	1.31	1.70	1.04	1.65	1.65
pH	4.76	2.76	4.33	5.21	5.20	3.15	4.17	4.54	4.13	4.57

Table 12. Some nutritional elements content of geophagic clays of Southern Nigeria compared with those from other parts of the world

Nutritional Element	Southern Nigeria geophagia clays				Aufreiter et al (1997) China %	USA %	Zimbabwe %	Abraham (1997) Uganda %	Mahaney (2000) Indonesia %
	Asaba %	Ekiti %	Ibadan %	Benin %					
Fe	2.82	1.65	1.35	1.65	>2	>2	>2	>2	>2
Ca	0.03	0.05	0.02	0.04	>2	-	-	-	-
K	0.37	0.36	0.40	0.34	-	>2	>2	-	-

5. Conclusions

The result of the study of the geophagic clays of parts of southern Nigeria namely Asaba, Ibadan, Benin and Aramoko areas has shown that compositionally, the clay samples consumed in some localities of southern Nigeria are mainly kaolinitic, with subordinate halloysite and illite. Quartz is the main non clay fraction. The clays have relatively high SiO_2 and Al_2O_3 content as well as low Ca, Mg, Na and K. Trace element contents of some of the samles show comparatively higher amounts of toxic constituents such as Mn, Cr, Ni and Co, compared to global occurrences, while the nutrient elements are comparatively low. Microbial content, especially coliform bacteria and staphylococcus, is high in some of the samples and beyond tolerable limits, especially for those obtained from off the shelf. This is mainly due to relatively unhygienic handling of the samples from the excavation points in the field through the transportation and the subsequent exposure in the open stalls. On the other hand, the relatively high Al_2O_3 concentrations coupled with the relatively abundant kaolinite mineral content makes it a palliative option as a traditional antacid if the handling relatively improves. However, the presence of toxic trace elements, even though still within tolerable limits will further reduce its consumptive preference. Overall, as consumed presently, without processing or being subjected to hygienic cleansing the negative health consequences will outweigh the likely advantages.

It is therefore recommended that the current mode of handling the geophagic clays should be discouraged. Since it is difficult stopping this craving amongst users because of addictions and /or traditional beliefs, Users should be educated on the proper handling of the samples, such as proper washing, packaging in hygenic sanitised sachets and non exposure in the stalls. Since the health benefits apart from seeming psychological craving is minimal, geophagia, as it is been presently practiced in these areas should be discouraged through proper health enlightenments campaign.

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