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Physico Chemical Investigations and Health Implications of Geophagial Clays of Edo State, Mid-Western Nigeria

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Abstract

Geophagy is the habitual and intentional consumption of earth and clay deposits by animals and humans. This research investigates the physical, chemical and the mineralogical composition of some selected clay samples collected across the three political zones of Edo state, in order to ascertain claims about their effectiveness in curing certain ailments. Among the properties investigated are: texture, pH, Electrical Conductivity (EC), Water Retention Capacity (WRC), Organic Matter Content (OM) and Cation Exchange Capacity (CEC). Results show that the pH values range from 5.22 to 6.46. EC values are generally high but those of OM are low (0.13 to 0.75%). The WRC values are generally very high (above 50%) except for the Auchi-Jattu clay whose value is 42.83.The samples were observed to have low CEC, ranging from 2.76 to 3.07. Results of the AAS analysis show that major and minor elements range from 1.0 mg to the limit of delectability 0.0001mg/g. Results of XRD analysis for mineralogical investigation reveal that the samples are dominantly composed of quartz, kaolinite, halloysite, illite, mica and feldspar. SiO_2 values range between 54.85 and 63.1wt%, whereas Al_2O_3 values range from 12.63 to 26.78%. The present studies have shown that the high clay content and the high water retention capacity may help to alleviate the symptoms of diarrhea because of its absorption ability. The acidity of the soil impacts sour taste on the soil hence its effectiveness in overcoming nausea and excessive salivation. Because of the low CEC of the soils, adsorption of cations from the gastrointestinal tract may not be possible. But from results of available elements, there is tendency for some of the cations to be released and absorbed into the gastrointestinal tract. Possible human health shortcoming in the ingestion of the geophagic clayey soils would include dental enamel damage and perforation of the sigmoid colon.

Keywords: Geophagy; Diarrhea; Gastrointestines; Dental disorder; Bioavailability

Introduction

Geophagy is the purposeful or deliberate consumption of earthy materials, including clays by animals and man [1,2] by Ngole et al. [3]. It is an age-long practice that dates back to the prehistoric times. Vermeer [4], for example, noted geophagy in East Africa some 40,000 years ago. The practice of geophagy has been reported in several countries across continents of the world including Africa; (South Africa, Democratic Republic of Congo (DRC), Edo State of Nigeria); Swaziland, Tanzania and Uganda). Asia (China, India, Guatemala, Thailand, Philippines) and the Americas [1,4]. Several reasons have been advanced to justify geophagial behavior; some of which are cultural, others medicinal and nutritional [5,6]. Consumers of clays/soils believe that clay consumption prevents excessive secretion of saliva and reduces nausea, provides them with micronutrients, which help them during pregnancy and in turn helps in the physiological development of their fetus. They emphasize that a child whose mother consumed clay during her pregnancy tends to have natural beauty and well developed skin. It has also been noted that kaolin minerals have long been used in pharmaceutical formulations to both treat the causes and symptoms of gastrointestinal distress [5,7,8] as reported by Sera LY, by having the effect of adsorbing toxins and thus preventing their absorption by the G.I.T.

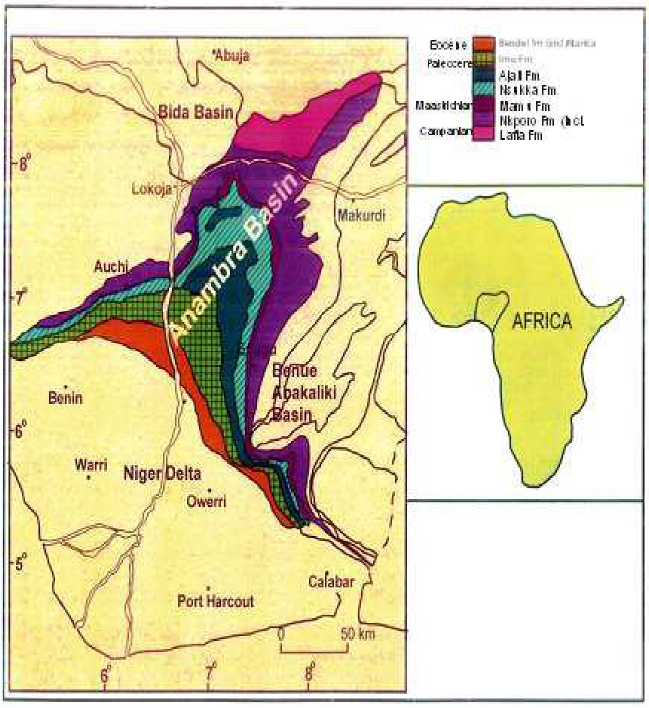

Figure 1: Anambra Basin Showing the Extension of Ajali Sandstone within Auchi Environs. Inset is map of Africa. (Drawn from Geological Map of Nigeria, GSN1994).

Materials and Methods

The local geology of the study area

The study area is located in Edo State, Mid-Western Nigeria,

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within coordinates N06°27' 06°80'67" and E005°43' - 006°21' (Figure 1). Edo State is geologically characterized by rocks, whose ages range from Tertiary to Cretaceous [9]. The geologic formations that underlie Edo State include; Benin, Ameki, Ogwashi-Asaba, Imo and Nsukka Formation and Ajali Sandstone. The study area thus is partly within both the Anambra and the Niger Delta basins. The clays within Uzalla-Benin and Ohordua-Ewatto, for example, belong to the Ogwashi-Asaba Formation. Field relationship suggests that, the clays within Auchi-Jattu belong to the Ajali Sandstone [10] (Table 1).

Methodology

Five clay samples were collected from three mining sites; Auchi-Jattu (Edo North), Ewatto-Ohordua (Edo Central) to Uzalla-Benin (Edo South), as shown in Plates 1-4. The sampling location map is shown in Figure 2.

All samples were then packaged in airtight plastic bags, labeled and transported to the laboratory for physico-chemical and mineralogical analyses.

Physico-chemical analyses

The samples were air-dried after collection, according to the methods of Tan, 1996 and Van Reeuwijk, 2002. They were then gently disaggregated using an agate mortar and pestle. Analyses for colour, particle size distribution/specific surface area, pH, Water Retention Capacity (WRC), Electrical Conductivity (EC), Organic Matter contents (OM) and Cation Exchange Capacity (CEC) was determined on all the samples. Colour determination was done by visually comparing the sample colour with those in the Munsell soil colour charts to obtain the hue, value, chroma and colour of the samples [11-13].

Age	Formation	Lithology	Thickness (m)
Miocene-Recent	Benin Formation	Unconsolidated sandstone with lenses of clay	200
Oligocene-Miocene	Ogwashi-Asaba Formation	Unconsolidated sandstone clays with lignite seam	84
Eocene	Imo Formation (Imo Shale)	Blue to gray dark shales and sandstone member	314
Maastrichtian	Nsukka Formation	Sandstones and Shales with coal seam	233
Lower Maastrichtian	Ajali	Friable sandstone bioturbated shale and ferruginised sandstone	450

Table 1: Stratigraphic sequence of sediments in the Anambra Basin (Kogbe et al., 1976; Reyment 1965).

Plate 1: Auchi-Jattu geophagic clays mines located in Aforwa community, N06° 80' 067" and 005° 53' 08"E.

Plate 2: Ohordua-Ewatto clay deposit mine located at N06° 31' 38" /006° 21 39".

Plate 3: Uzalla geophagic clays deposits Uzalla located within coordinates N06° 27 068"; 005° 43 08".

The particle size distribution and specific surface area of the geophagic soil samples were determined by the hydrometer method as described by Van Reevwijk [14]. With the aid of a texture auto look up software package (TAL version 4.2), the results obtained were used to determined the texture of each sample. The pH of the clayey soil samples was determined both in a 1:2.5 clayey soil-water suspension ratio according to the methods advanced by Van Reevwijk [14] and Palombo, et al. [15]. Electrical Conductivity (EC) of samples was measured on the saturated paste extract of each sample as described in the United States Soil Survey Laboratory Manual (1996). Water Retention Capacity (WRC) of the samples was determined using the methods advanced by Forster. Organic Matter content (OM) of the clay was analysed using the modified Walkley Black wet combustion method

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Plate 4: Samples being air dried.

Figure 2: Political map of Edo state showing the different sample locations (shown by arrows).

as described by Van Reeuwijk [14]. The Barium chloride compulsive exchange method of Cation Exchange Capacity (CEC) determination as described by Gilman and Sumpler was employed for all the samples.

Geochemical analyses

To ascertain the medicinal and nutritional hypothesis of geophagy, geochemical analyses were carried out on the samples to determine both the major and minor elements present in the soils samples using Atomic Absorption Spectrometry (210VEP AAS model), following the procedures developed by Norrish and Hutton [16]. The uniqueness of this work involved carrying out a partial digestion using a simulated stomach acid extract of 0.12MHCl varied from1.0mg/g to the limit of detectability, 0.0001 mg/g. This is used to determine the bioavailability of some elements of geophagic soils.

Results

Physico-chemical properties

The results of grain size, pH, electrical conductivity, organic matter, water retention capacity, cation exchange, bulk elements and bio available elements are presented in Figures 3-10 respectively. While the results of colour, bulk chemical analyses and bio available elements are presented in Tables 2-4 respectively. Results of colour analysis show that the samples from the Ohordua - Ewatto are light gray to grayish colour, samples from Auchi-Jattu range from reddish brown to red, while those from Uzalla sample are white to grayish in colour.

Results of geochemical Analyses

Major element concentration of the geophagic clayey soil samples as compared to Average Upper Continental Crust (UC) and average Post Archean Australian Shale (PAAS) are presented in Table 4. The SiO_2 concentration in the geophagic clayey soils ranges from 54.85 to 63.1 wt% with a mean a of 59.25wt%, whereas Al_2O_3 values are 12.63 to26.78wt% with mean being 22.30wt%. Other low concentrations of oxides of major elements in the samples are those of CaO, Na_2O, and MgO. Similar enrichment and depletion have been recorded for kaolinitic soils and sediments [17]. The geophagic clays were generally much depleted of Na, Ca and K relative to their concentrations in PAAS and UC. This depletion is indicative of intense chemical weathering with amounts lost being proportional to degree of weathering.

Discussions

Texture of clays

Textural analyses results show that the soil samples were texturally dominated by clay size particle with grain sizes ranging from 81.58-91.05% with some silt and very fine sand particles. These results thus

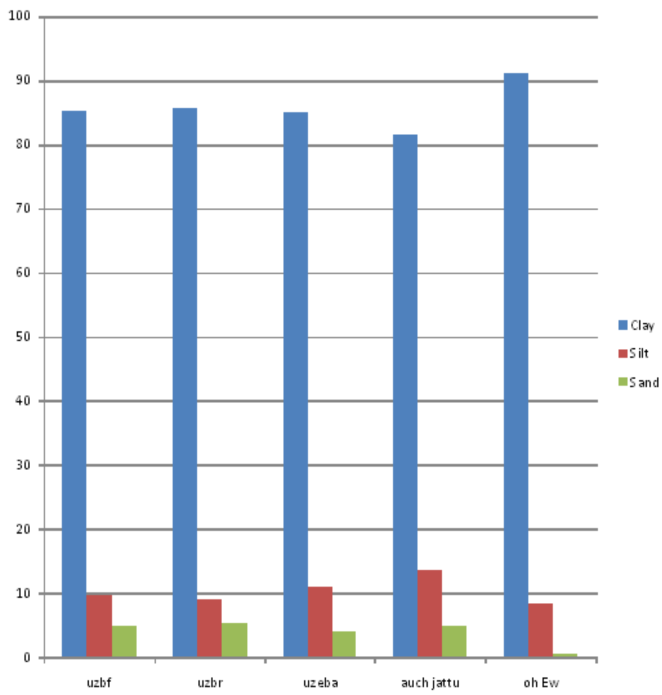

Figure 3: Grain Sizes of the different geophagic samples.

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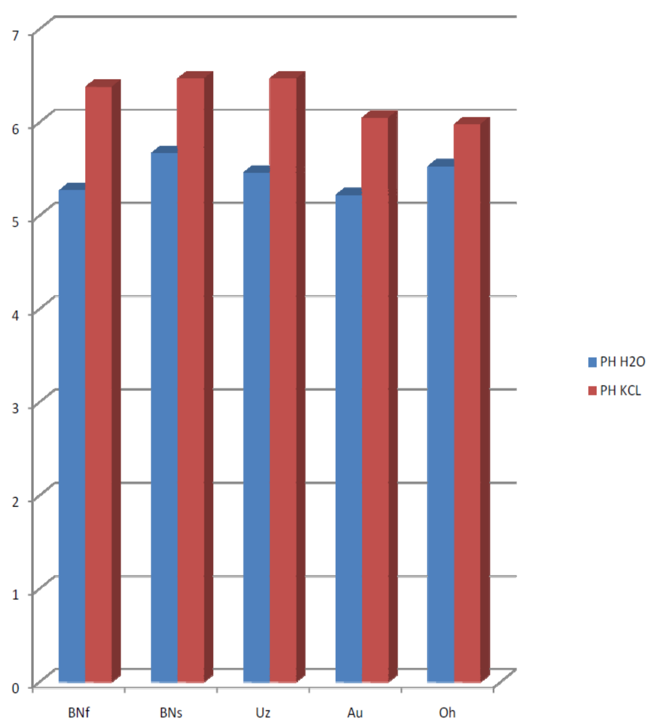

Figure 4: pH of geophagic clayey soil samples from the different location.

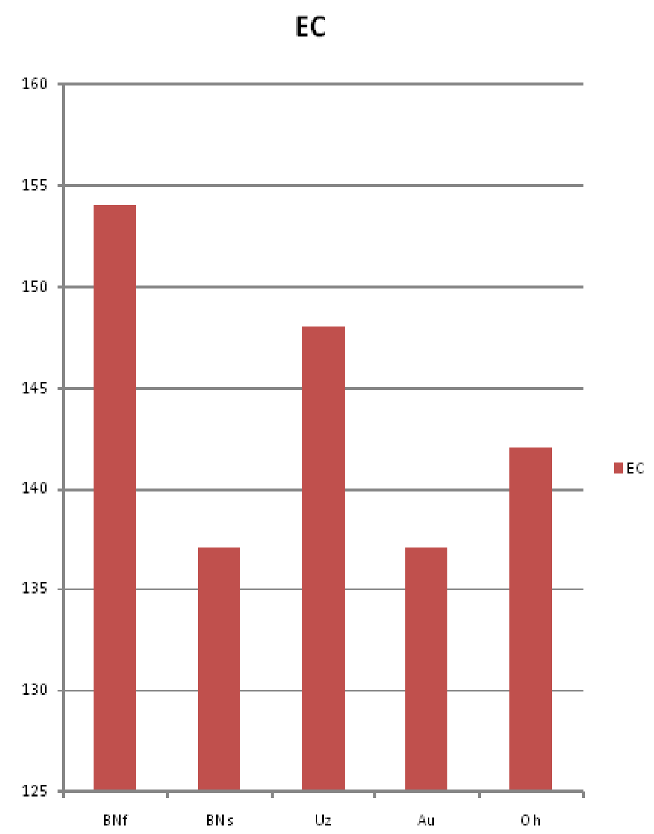

Figure 5: Electrical conductivity of geophagic clay of the samples.

suggest that these geophagic soils have large and high surface area, which enable them to adsorb much more water; since adsorption is a function surface area. This property therefore supports the medicinal hypotheses as they tend to curb diarrhea and other gastrointestinal ailments especially those infected with diarrhea-causing pathogens. Consumers of geophagic clays prefer those that are soft, silky and powdery. Geophagic clays that are gritty contain silt and fine sand particles of quartz and feldspars which may negatively affect dental enamels of its consumers,(through grinding, cracking, splitting and breakage during masticulation); since quartz (harness 7) scratches the dental enamel, which is the main inorganic component of the human tooth and dominated by hydroxyl apatite ($Ca_5(PO_4)_3(OH)$, (a calcium phosphate mineral), of hardness 5 on the Mohr's scale. Studies carried out by King, et al. indicate that medium sized sand (250-500 µm) cause severe dental damage in hominid species. Perforation of the sigmoid colon has been reported in some geophagic individuals [1]. According to Lohn, et al. foreign bodies in the small intestines can cause perforation and the most important considerations of these bodies are the size, shape and nature of the object.

pH

The pH values of all the samples were generally lower than 7 indicating that they are slightly acidic thereby imparting a sour taste to the soil, as reported by Abrahams and Parsons. This sour taste is one main reason why people, especially the pregnant women crave for this clay. Consumption of clay is reported to control excessive secretion of saliva and reduce nausea; Ibeanu, et al. [18]. The values of the pH (KCl) of all the samples were significantly higher than those of pH (H_2O) indicating that the samples were all positively charged. Possible chemical reactions involving clay minerals and organic matter in the geophagic soil could

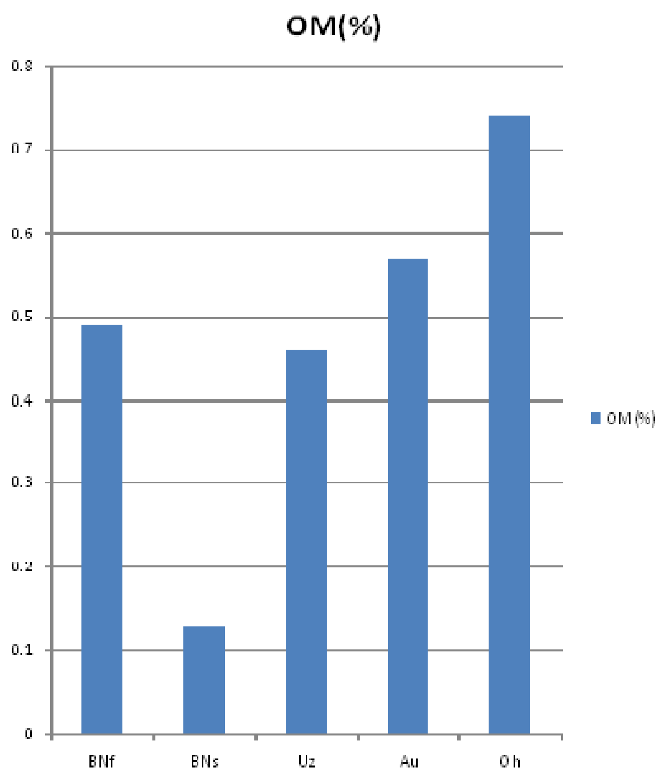

Figure 6: Organic matter contents of the geophagic clayey samples.

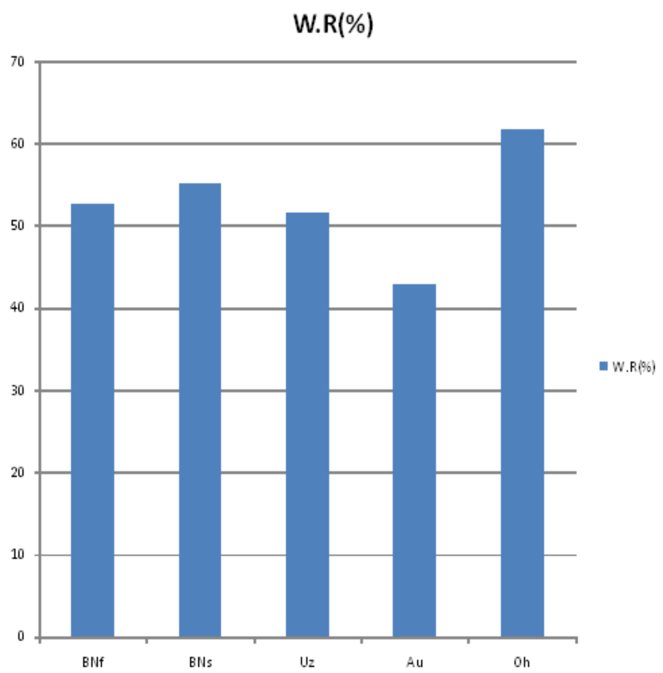

Figure 7: Water retention capacity of the geophagic clayey samples.

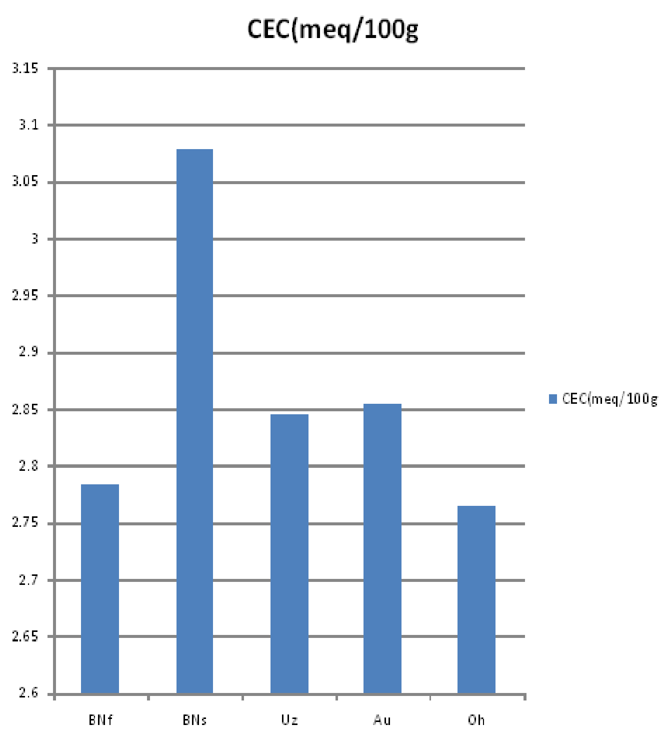

Figure 8: Cation exchange capacity of geophagic clayey samples.

occur in the stomach because of the acidity (pH = 2) [19] of its gastric juice. However, residence time of ingested material in the stomach, being approximately 2 hours, is inadequate for any significant reaction to occur. The low pH of the intestines would result in the release of cations that may have been adsorbed on the exchange sites of the ingested soil. In the duodenal and intestinal section of the GI where the pH is about 8 [19], some of the clay-size particles may undergo chemical reactions, but the silt and sand-sized particles dominated mostly by silica may not be altered. The unaltered particles would pass through the GI and most likely be lodged in the diverticulitis of the sigmoid colon. Similar observations have been reported by Jahanshahee, et al. [20] in a boy after prolonged consumption of sandy material. Due to the abrasive nature of these silica-rich particles, possible lacerations, and eventual rupturing of the colon may occur; (perforation of the sigmoid colon). The studied geophagic clayey samples have reasonable pH buffering capacity as indicated by the values of pH (KCl). When ingested, the pH of these soils is not likely to drop to the pH of the stomach because of this buffering capacity. According to Young, et al. [2], solubility of Fe and other cations in the GI increases with a decrease in pH. Ingestion of any of these soils may prevent the stomach pH from dropping to levels that are favorable for Fe dissolution thereby reducing their bioavailability to the geophagic individual even where the Fe concentration in the ingested soil is high.

Electrical Conductivity (EC)

Electrical conductivity is used to indicate the amount of dissolved salts in clays and soils. High electric conductivity of geophagic clays is indicative of high amounts of dissolved salts. According to Goldberg and Foster [21] and Kolyer, et al., there exists a relationship between flocculation, soil pH and salts. The flocculation of geophagic clay may influence their ability to coat and create a shield in intestinal mucosa thereby protecting the intestines from the acidic gastric juice. The high dissolved salts in the geophagic soil are however, likely to influence the degree of flocculation that may occur.

Organic Matter (OM)

The organic matter content in the samples were generally very low, suggesting that the pathogen load is low, hence, the risk of bacterial infection including those like *E. coli*, *E. histolytica*, *S. typhi* and helminthes infection such as those of *A. lumbricoides, T. trichiura* and *S. stercoralis* as a result of consuming clay is slim. Because of low organic matter, the diarrhea-causing pathogen will not survive because of low nutrients.

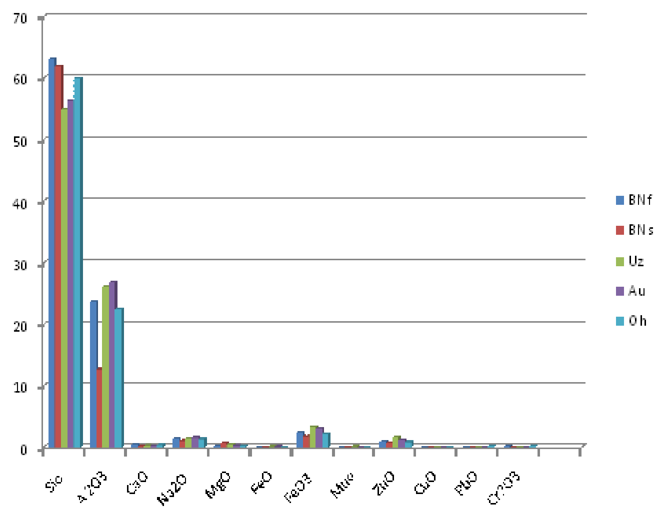

Figure 9: Bulk elements in oxides forms in the samples.

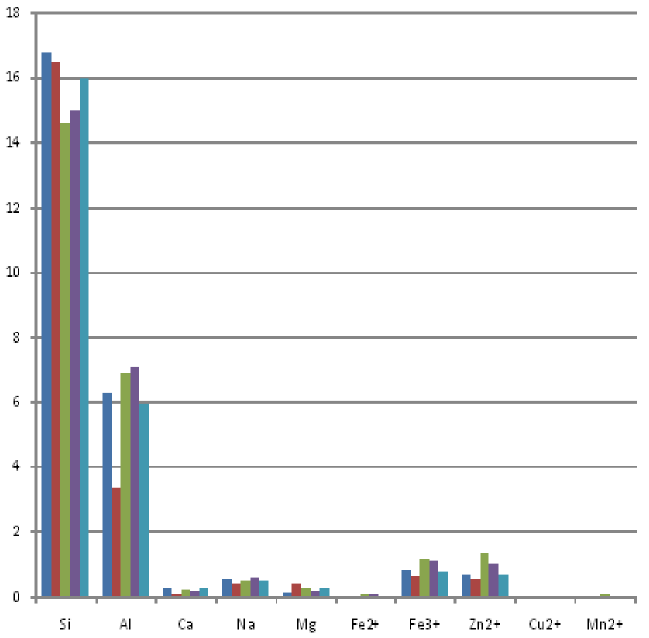

Figure 10: Bio-available elements in the samples.

Country/state	Sample No./ Code	Source	Geographic coordinate
Nigeria/Edo (south)	UZ1 (fresh)	Uzalla-Benin	N06o27 06.8", E 005043'08"
Nigeria/Edo (north)	AJ 2 (fresh)	Auchi-Jattu	N06080'67"/ E005o43'08"
Nigeria/Edo (central)	OH 3 (fresh)	Ohordua-Ewatto	N06o31' 38" /006o 21 39"
Nigeria/Edo (north)	UZB4 (fresh) (control)	Uzebba	Satellite not receivable
Nigeria/Edo (south)	UZ 5 (roasted)	Uzalla-Benin	N06o270.68" , E005o43".07

Table 2: Source of Geophagic clayey soil sample from Edo Nigeria.

Water Retention Capacity (WRC)

Water retention is the ability of soils to take in and hold large amounts of water [22]. Geophagic clays differ in terms of their WRC. Those with high clay content tend to have higher WRC compared to those with high sand content [22]. This property has been gainfully exploited in medicinal and pharmaceutical sciences where clays like kaolin have been used to prepare formulations that treat stomach upsets such as diarrhea and other GI related ailments. The studied samples generally have high water retention capacity. This property also acts by having numerous micro pores that tend to inhibit diarrhea pathogen. The survival rate of these pathogens in these geophagic soils would however be low because of low amounts of nutrients as indicated by the low levels of OM. These clayey soils also have considerable WRC and therefore have the ability to absorb water from the GI if at all it is infected with diarrhea-causing pathogens. An inferred role of these clayey soils in the control of diarrhea is thus suggested.

Cation Exchange Capacity (CEC)

For soils to serve as supplements for any one nutrient, the nutrient must be sufficiently present in the available form in the soil. Availability of the nutrient in the soil and eventually in the stomach is influenced by the soil texture and mineralogy; OM and pH also influence soil CEC [22]. The cation exchange capacity of the geophagic clayey soils from the different location were generally low as compared to those reported by Abrahams and parsons, hence, the adsorption capacity of these soils could be classified as low and their ingestion is not likely to result in adsorption of cations from the GI. The ability of these soils to supply cations including Iron (Fe) to those who consume it depends on the concentration of the cation as well as its bioavailabity within two hours of its resident time in the stomach.

Bio-available elements

One of the objectives of this study is to investigate the presence of micronutrients and their medicinal/protective work in clays by considering the extent to which these elements are biologically available in clays. The ability of elements to be absorbed into the human system is dependent on the concentration of the elements as well as the cation exchange capacity and the absorption tendency.

Trace elements

Total trace element contents of the geophagic soils usually were lower than the range of values found for mineral soils with <5% organic matter derived from all types of parent materials, as assessed by Mitchell [23]. Not all trace elements analyzed are of biological significance from either a nutritional or toxicity point of view, but for the sake of completeness all results are shown. Trace elements of interest in the context of human nutrition, Cu, Mn, Pb and Zn, are all in the low to normal range when compared with the usual range in mineral soils. The same is true of trace elements such as Cr and Pb, which are associated with toxicity. The level of zinc was highest in Uzebba with 1.323 ppm and lowest in samples from Uzalla smoked with 0.508 ppm.The level of copper, lead and cadmium were lower than the values found for mineral soils as assessed by Mitchell [23].The amount of Pb in all the samples did not exceed the recommended EPA (Environmental Protection Agency) standard levels of about 0.01 mg/l except that of the Ohordua clays that is about 0.111 mg/l.

Mineralogical characteristics of the clay samples

Mineral analyses of the bulk soils (Table 4) were reasonably consistent with the results of the bulk chemical analysis. Series of minerals were identified from all of five samples analysed; the primary minerals are quartz, (SiO_2), Feldspar (orthoclase and Albite) $KAlSi_3O_8$ and $NaAlSi_3O_8$, mica (possibly muscovite), $KAlSiO_3O_8$ several secondary minerals were also available but the most dominant groups were the kaolinite, $Al_2SiO_5(OH)_4$; Illite $K,H_3OAl_2Si_3AlO_{10}$; montmorllonitic CaO.2 (Al, Mg) $2Si_4O_{10}(OH)2.4H_2O$. Another important clay minerals that was identified is Halloysite $Al_2Si_2O_5(OH)4.2H_2O$. Diagnostic peaks for the identification of the minerals together with the International Centre for Diffraction Data (ICDD) reference numbers and the crystals system, d-values, peak intensity of the minerals are presented the Table 4.

Sample No./Code	Locations (site) of samples	Hue value and chroma of samples	Colour
UZ1 (fresh)	Uzella-Benin	2.5Y/8/2	White
UZ2 (fresh)	Uzella-Benin	5Y/7/2	Light gray
AJ 3 (fresh)	Auchi-Jattu	5YR/5/4	Reddish brown
OH4 (fresh)	Ohordua Ewatto	2.5Y/N6/0	Gray
UZB5 (fresh)	Uzebba	2.5Y/2.5/2	Black
UZ 6(roasted)	Uzella-Benin	7.5YR/5/8	Strong brown

Table 3: Colour of the samples from the different locations.

	BNf	BNs	Uz	Au	Oh	PAAS	UC
SiO	63.1	61.98	54.85	56.37	59.95	62.8	66.0
Al_2O_3	23.62	12.63	26.04	26.78	22.44	18.9	15.2
Cao	0.35	0.11	0.27	0.23	0.33	1.3	4.2
Na_2O	1.37	1.02	1.33	1.54	1.3015	1.2	3.9
MgO	0.19	0.64	0.38	0.27	0.18	2.2	2.2
FeO	0.02	ND	0.06	0.09	0.02	-	-
FeO_3	2.31	1.75	3.33	3.14	2.19	6.5	4.5
MnO	0.04	0.04	0.08	0.04	0.04	0.11	0.08
ZnO	0.85	0.63	1.64	1.22	0.81	-	-
CuO	0.03	0.02	ND	ND	0.03	-	-
PbO	0.01	ND	ND	0.01	0.12	-	-
Cr_2O_3	0.12	ND	0.032	ND	0.12	-	-

Table 4: Bulk chemical of both major and trace elements analyses in oxides form of the sample from the different locations.

Summary

Geophagic soil selection based on color is not supported by our findings, because of colour variability displayed by the studied clays. The clay samples are texturally dominated by clay with grain sizes ranging from 81.58-91.05% with small quantities of silt and sand. Hence they tend to adsorb much more water, since adsorption is a function surface Area. This property therefore supports its medicinal ability to curb diarrhea and other gastrointestinal aliments and hence the cravenness of the consumer that prefers clays that are soft, silky and powdery. The pH values of all the samples were generally lower than 7 indicating that they are slightly acidic thereby imparting a sour taste to the soil. The values of the pH (KCl) of all the samples were however significantly higher than those of pH (H_2O) indicating that the samples were all positively charged. The studied geophagic clayey samples have reasonable pH buffering capacity as indicated by the values of pH (KCl). When ingested, the pH of these soils is not likely to drop to the pH of the stomach because of this buffering capacity. The survival rate of these pathogens in these geophagic soils would however be low because of low amounts of nutrients as indicated by the low levels of OM. These clayey soils also have considerable WRC and therefore have the ability to absorb water from the GI should in case it is infected with diarrhea causing pathogens. An inferred role of these clayey soils in the control of diarrhea is thus suggested. All clay fractions are dominated by a kaolin-type mineral, either kaolinite, halloysite, or a mixture of both. The clayey soil samples from the different locations are composed of all various group of clay. The Ohordua clay soil have variable clay minerals such as Hydrobiotite, Illite, Phogopite, Osumulite, Montmorillonite, Sepiolite, Muscovite and then Chlorite-Serpentine with dominant type is Kaolinite/Illite. This mineralogical similarity is consistent with the protection hypothesis, given that kaolin minerals have long been used in pharmaceutical formulations to both treat the causes and the symptoms of gastrointestinal distress. The beneficial role of the kaolin minerals is based upon their ability to coat and adhere to the gastric and intestinal mucus membrane, thus protecting against toxins, bacteria, and viruses, and adsorbing excess water in the feces. The strongest/ dominants clay mineral of the Auchi-Jattu sample include,the Nacrite-2,chloriteserpentine and phogopite. Those of the Uzalla are mainly sanidine,Halloysite a species of kaolinite group. The Uzebba clay is mainly Sepiolite, Chlorite and kaolinite. The occurrence of kaolin-type minerals in all of the geophagic soil samples serves to protect the health of the consumer. The high prevalence of geophagy during pregnancy and early childhood, the times during which individuals experience the greatest biological vulnerability, lends support to this hypothesis. No one has yet elucidated a mechanism by which humans can identify the presence of kaolin minerals in soils. One clue perhaps is the importance of smell in the selection of geophagic materials. The scent of earth, especially when wet, has been mentioned by many geophagists around the world Further study of human's capacity to identify and distinguish between odors of different clay minerals could be done easily, and may contribute further to our understanding of the selection and function of geophagy.

Conclusions

This study has established the physiochemical and mineralogical composition of the geophagic crays from different locations in Edo state. Analytical results indicate that the major constituents of the clay are quartz and kaolinite and other clay minerals like halloysite, illite, montimorillonite, mica etc. This work attempted to elucidate on reasons advanced by geophagic individuals engaged in the practice. Based on results obtained from the physiochemical analysis, the colour especially those of the Auchi –Jattu soils indicate the presence of Iron (Fe) which could be useful as source of Fe supplements. Due to their low CEC, exchangeable Fe and other related cations may not be adsorbed but can be released and absorbed in the GI tract. The slightly acidic nature of the soils gives a sour taste which is mostly coveted by pregnant women in overcoming nausea and excess salivation. Absorption of water from the Gastrointestinal (GI) is a possibility, considering their high Water Retention Capacity (WRC). The chemical analytical results indicate that the major and trace elements are uniformly low, and the bioavailability of those that are present is scanty. The palliative, protective and detoxifying properties of kaolin lend support to the hypothesis that geophagy is a protective behavior. Geophagic practice is very old, deeply rooted in several human populations all over the world, and cannot be stopped. There is thus need for concerted efforts to regulate the quality of geophagic clays. National statutory bodies, Inter-Governmental Agencies and Organizations should work collaboratively to educate geophagists on beneficiation methods that are safe and that would lead to improvement of the quality of geophagic clays especially a selective beneficiation exercise such as reduction and/or removal of sand and silt particles from the geophagic clays which could be conducted to remove non-beneficial minerals. Key health concerns should also address the reduction and/or elimination of microbial, bacterial and possible pathogen loads in the geophagic clays to levels fit for human consumption.

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