ELEMENTAL COMPOSITION AND PHYSICOCHEMICAL PROPERTIES OF GEOPHAGIC CLAY (‘EKO’), FROM UBIAJA IN EDO STATE, NIGERIA.

1Edene, O. A. & 2Aghedo, O. N.

1Department of Environmental Management and Toxicology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria.
2Department of Science Laboratory Technology, Faculty of Life Sciences, University of Benin, Benin City, Nigeria.

*Corresponding Author Email: osemudiamen.anao@uniben.edu; Phone no.: +2347061857637

ABSTRACT

In Edo State, Nigeria, geophagia (‘Eko’) is highly prevalent, and men and women, especially pregnant women, are believed to indulge in its consumption as a remedy for vomiting (nausea) and some other related inconveniences in pregnancy. Others are due to a natural craving. These practices are associated with varying health complications; as such, it is pertinent that the physical and chemical composition of the clay be known. In this study, we assessed the levels of heavy metals and trace elements of clinical importance in ‘Eko’, as well as their physical and chemical properties using standard protocols. Tests conducted include: colour, pH, electrical conductivity (EC), cation exchange capacity (CEC), total dissolved solids (TDS), particle density, and concentrations of metals [chloride (Cl), sulphate (S), calcium (Ca), sodium (Na), magnesium (Mg), potassium (K), aluminium (Al), iron (Fe), copper (Cu), manganese (Mn), zinc (Zn), chromium (Cr), lead (Pb) and cadmium (Cd)]. The results obtained showed that some of the elements (Cl, Ca, Na and Mg) are present in moderate concentrations (353.33, 182.33, 216, 111.33 mg/kg) respectively. However, concentrations of some of the heavy metals [(Cd, Pb and Cr) (0.30, 0.26, 0.42 mg/kg) respectively], were higher than the permissible limits (65, 35, 25 µg/kg) set by WHO. Though some of the moderately present trace metals may play important biological roles, the high concentrations of some heavy metals could have detrimental health effects. Results from this study suggest that ‘Eko’ can predispose consumers to health hazards. As such, the continuous consumption of “Eko” should be discouraged.

Keywords: Eko, Geophagia, Heavy metals, Trace metals

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INTRODUCTION

Eating abnormality - pica is a recurrent practice in many parts of the world and across different races. Pica describes this habit of eating non-food substances or items - clay soil, for example (Vignando et al., 2020). When clay materials are consumed in the form of eating disability, it is known as geophagy. Chalk, charcoal, wallboard, ice, foam, hair, and even toilet paper are other forms of materials that can be consumed in pica (Young, 2010).

![Geophagic clay from Ubiaja, Edo State](image)

**Figure 1:** Geophagic clay from Ubiaja, Edo State

In Nigeria specifically, some natives, such as the Igbo and Tiv women, have certain weird beliefs which propel them to consume ‘Eko’, especially pregnant women. One of which is that geophagic clay contributes to the overall nutritional status of pregnant women (Davies, 2023). Traditional doctors known as “dibias” in the Igbo-speaking part of Nigeria also make use of this clay in the treatment and cure of different diseases (Izugbara, 2003). Due to the inability of some pregnant women to obtain proper medical treatment and malnutrition, they tend to search for alternative means to stay healthy. Hence, they engage in geophagy to get some necessary elemental nutrients (for example, Mg, Fe, Cu, Mn, Ca, Zn, and Se) (Asowata, 2021), believed to be present in these earth materials. They opined that these metals are beneficial for the development of their unborn babies and their well-being, as modern literature has shown that human health is ultimately linked to diet and healthy eating (Orisakwe et al., 2020; Asowata, 2021; Banerjee & van der Heijden, 2023). In the course of the study, verbal questioning of the residents revealed some reasons these locals are intentional in their consumption of clay. They included: the reduction of the nauseating feeling during pregnancy, a successful pregnancy, ease of placenta delivery, and role played in aiding conception. These responses were similar to those of some other authors whose respondents had similar reasons for geophagic clay consumption (Gomes, 2018; Iron-Segev et al., 2018).

Some studies have shown that in African regions where geophagia occurs, the percentage of women who regularly consume soil ranges from 46 to 73% of pregnant or breastfeeding women. The amounts consumed differ significantly, as an average value of 1 to 100 grams per day (and more) is being reported (Sackey et al., 2018;
Kambunga et al., 2019). Of note is the deep rootedness of this practice in cultural beliefs, and the highly psychosocial embracement.

This practice may be a major contributory factor to some of the health challenges faced by pregnant and nursing mothers and their unborn babies, especially when consumed at high concentrations. It is difficult to assess the proper dosage of the different components in geophagic materials; as a result, it is easy to consume excessive quantities of valuable minerals as well as dangerously large amounts of harmful or toxic materials, resulting in electrolyte imbalances and toxicity (Chamy et al., 2022). For example, one of the consequences of lead exposure, which has been found in some geophagic clay, is intelligence decline in exposed children, while in adults it can cause cancer over time (Kalgum et al., 2019; Olajide-Kayode et al., 2023). Another element of interest is zinc (Zn), which is generally considered non-toxic, but exposure to high concentrations can cause detrimental health effects such as growth retardation in infants, abdominal pain, diarrhea, and electrolyte imbalance (Ncube et al., 2020). The etiology of geophagia remains vague. Several factors contribute to geophagia which includes psychosocial, neuropsychiatric, nutritional, sensory, physiological, and cultural factors (Duncan & Croft, 2018). The geophagic clay used in this study is shown in Figure 1.

Different clay materials sourced from different locations will vary in elemental composition due to differences in the geology, and geochemical makeup of the different earth materials. The presence of a particular heavy metal in a defined geographical area will be different from that in another by different contributory physical and chemical factors. Many works of literature have reported on different clays from different locations, but not in Ubiaja, Edo State, Nigeria. Hence, this study was carried out to assess and ascertain heavy metals, trace elements, and physicochemical properties of geophagic clay obtained from this location.

**MATERIALS AND METHODS**

**Chemicals and reagents**

Reagents of standard and analytical grade used in this study were purchased from the British Drug House (BDH) Chemicals Limited, Poole, England.

**Sampling**

The geophagic clay used in this study was obtained from Ubiaja, the capital of Esan South East Local Government Area, Edo State, Nigeria, and it was ascertained to be similar to the type of clay consumed by pregnant women. Three locations were sampled, and two (2) replicates of the geophagic clay were purchased from each, and placed in zip-lock bags. This measure was taken to prevent the introduction of other contaminants. They were pulverized into a fine powder with a mortar and pestle; a composite sample was made and analyzed in the laboratory. GPS coordinates were taken at the various sampling locations with the following coordinates: 6° 6501803N 6° 3902683E, 5° 468798N 6° 3327434E6°, and 6° 5972N 6° 38222E. A sampling map was plotted using these coordinates, to represent the sampling locations as shown in Figure 2.
The sampling locations represented in the map are market stores around the Ubiaja correctional facility, Ebhohimi Market and Ewato Market.

**Physicochemical parameters**

**Determination of pH**

A multifunction pH meter, model number EZ-9901 was used. It was standardized with a known buffer solution and temperature adjusted over a range of 0 °C to 100 °C. To get rid of the coarse fraction, the sample was made dry by the process of air drying. It was then passed through a mesh sieve of 2mm diameter. The sample was dried by air and then passed through a mesh sieve measuring 2mm in diameter to remove the coarser fraction. From the sieved sample, 5 g was poured into a glass container containing 10 ml of distilled water. It was mixed thoroughly and placed in a still position for an hour. The standard buffer was matched with the suspended sample in terms of temperature to ensure their similarity. The temperature of the suspended sample was checked and set to match that of the buffer. Condensed water was used to rinse the probes and dried them using a paper blot. After switching on the meter, the pH reading was taken by placing the electrode into the sample suspension. The reading was displayed on the screen of the pH meter and recorded after the stabilization of the meter (ASTM, 2011).

**Measurement of electrical conductivity (EC)**

The suspension was prepared by weighing the dry sample (10 g) in a bottle, with the addition of deionised water (50 ml) at a ratio of 1:5. The mixture was then shaken mechanically at 15 rpm for one hour to allow for the proper
dissolution of the soluble salt. The calibration of the conductivity meter was done using the 1000 µS/cm conductivity standard. The displayed values were recorded in µS/cm (ASTM, 2011).

**Measurement of Cation exchange capacity (CEC)**

The barium chloride compulsive exchange method was employed in the determination of the CEC. A centrifuge tube was weighed to the nearest mg. Two grams (2 g) of the sample and 20 ml of 0.1 M BaCl$_2$.2H$_2$O were put into the centrifuge tube and shaken for 2 hours. It was then spun at about 10,000 rpm and carefully removed. 20 ml of 2 mM BaCl$_2$.2H$_2$O was added, shaken for 1 hour, spun in a centrifuge and the supernatant removed (this was repeated twice). Before the third centrifugation, a slurry of pH 7 was obtained. 5 mM MgSO$_4$ (10 ml) was added to 2 mM BaCl$_2$.2H$_2$O after separation for the third time and the mixture was shaken gently for 1 hour. The pH and conductivity of the 1.5 mM MgSO$_4$ solution were obtained. Adjustments were made until the appropriate endpoints were reached. All calculations were made where necessary following standard methods as described by the American Society for Testing and Materials (ASTM, 2011).

**Determination of total dissolved solids (TDS)**

An evaporation dish was heated for 1 hour in the muffle furnace, cooled, and stored in the desiccator. To obtain a minimum of 25 mg of the residue on evaporation, the needed volume of the soil saturation extract was measured and allowed to go through a filter paper followed concurrently by the addition of 15 ml of deionised water thrice. The evaporation dish was weighed and the filtered sample was transferred into it. The filtered sample was made to evaporate by heating the evaporating dish at a temperature that would prevent boiling and complete drying of the sample. When it was observed that the filtered sample was close to being dried, it was then transferred to a drying oven at 103 °C to completely evaporate. Subsequently, the residue and the evaporation dish were dried at a temperature of 180 ± 2 °C for 1 hour in the furnace, cooled in a desiccator, and weighed. The previous step was repeated, and a constant weight was attained. We then recorded the weight of the dried residue and the dish. The calculation was done following the standard method of calculation as described by ASTM (2011).

**Determination of bulk density and particle density**

The sample was dried in an oven. An empty calibrated beaker was weighed and the dried sieved sample (25 g) was added. The beaker and its contents were weighed, and the volume was noted. To the sample in the beaker, condensed water (50 ml) was added. It was then boiled for 10 minutes to remove air bubbles. The beaker was removed from the heat and allowed to sit for 24 hours. Thereafter, the required volume (100 ml) was obtained by the addition of condensed water and weighed (ASTM, 2011).

**Elemental analysis**

The elemental analysis was done for six metals following standard protocols using an Atomic absorption spectrophotometer (AAS), following strictly standard analytical methods as described by the United States Environmental Protection Agency (USEPA, 1998).
RESULTS

Results from physicochemical analysis, as presented in Table 1, revealed that the pH was below the World Health Organization/Food and Agriculture Organization (WHO/FAO) standard for edible substances. The moderately high EC value (657.7 µS/cm) was within the acceptable range for the EC of edible foods. The CEC (8.21 cmol/kg) was within the permissible limit for edible foods. Table 2 shows the results of the elemental analysis of the geophagic clay from Ubiaja, Edo state, in which metals that are classified as toxic [Pb, Cd, and Cr] exceeded the WHO/FAO permissible limits (WHO/FAO, 2004). Metals of importance in metabolic functions such as Fe, Mn, Cu, and Al, were high in concentrations compared with the provisional maximum tolerable daily intake (PMTDI). Other metals such as Na, Mg, and K, were below the PMTDI.

Table 1: Physicochemical analysis of geophagic clay from Ubiaja, Edo state.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Units</th>
<th>Concentration</th>
<th>WHO/FAO standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>-</td>
<td>5.68±0.099</td>
<td>6.5-8.0</td>
</tr>
<tr>
<td>Electrical conductivity (EC)</td>
<td>µS/cm</td>
<td>657.667±11.181</td>
<td>1000 µS/cm</td>
</tr>
<tr>
<td>TDS</td>
<td>mg/l</td>
<td>329.333±5.888</td>
<td>500mg/l</td>
</tr>
<tr>
<td>Porosity</td>
<td>%</td>
<td>59.803±0.260</td>
<td>-</td>
</tr>
<tr>
<td>CEC</td>
<td>cmol/kg</td>
<td>8.210±0.157</td>
<td>3-15cmol/kg</td>
</tr>
<tr>
<td>Particle density</td>
<td>g/ml</td>
<td>1.733±0.008</td>
<td>2.60-2.75 g/ml</td>
</tr>
<tr>
<td>Bulk density</td>
<td>g/ml</td>
<td>0.697±0.004</td>
<td>&lt;1.6 g/ml</td>
</tr>
</tbody>
</table>

Values were expressed as Mean ± Standard Deviation, n=2.
The values were compared with the WHO/FAO standard.
TDS - Total dissolved solids, CEC- Cation exchange capacity.
Table 2: Elemental analysis of geophagic clay from Ubiaja, Edo state.

<table>
<thead>
<tr>
<th>Analyte</th>
<th>Units</th>
<th>Concentration</th>
<th>WHO/FAO PMTDI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride</td>
<td>mg/kg</td>
<td>353.333±5.888</td>
<td>2500mg/day</td>
</tr>
<tr>
<td>Sulphate</td>
<td>mg/kg</td>
<td>2029.667±49.093</td>
<td>NA</td>
</tr>
<tr>
<td>Calcium</td>
<td>mg/kg</td>
<td>182.333±1.944</td>
<td>1000mg/day</td>
</tr>
<tr>
<td>Sodium</td>
<td>mg/kg</td>
<td>216±3.563</td>
<td>1600mg/day</td>
</tr>
<tr>
<td>Magnesium</td>
<td>mg/kg</td>
<td>111.333±4.292</td>
<td>220mg/day</td>
</tr>
<tr>
<td>Potassium</td>
<td>mg/kg</td>
<td>344.333±16.738</td>
<td>3500mg/day</td>
</tr>
<tr>
<td>Aluminium</td>
<td>mg/kg</td>
<td>59.367±0.545</td>
<td>7mg/kg weekly</td>
</tr>
<tr>
<td>Iron</td>
<td>mg/kg</td>
<td>60.633±0.359</td>
<td>10-20mg/day</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/kg</td>
<td>5.3±0.078</td>
<td>900µg/day</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/kg</td>
<td>1.913±0.011</td>
<td>3mg/day</td>
</tr>
<tr>
<td>Manganese</td>
<td>mg/kg</td>
<td>3.333±0.041</td>
<td>1.8mg/day</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/kg</td>
<td>0.42±0.013</td>
<td>25µg/day</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/kg</td>
<td>0.26±0.013</td>
<td>35µg/kg weekly</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/kg</td>
<td>0.30±0.004</td>
<td>65µg/day</td>
</tr>
</tbody>
</table>

Values were expressed as Mean ± Standard Deviation, n=2. NA - Not available

The values were compared with the WHO/FAO standard for the daily permissible limits.

Discussion

Certain physicochemical characteristics influence the availability of nutrients present in geophagic soil and also determine to what extent such nutrients can be exposed to the individual involved in the practice of geophagy. Some of these characteristics include pH, cation exchange capacity (CEC), and electrical conductivity (EC), all of which affect the interaction in the gastrointestinal tract (Morman et al., 2009; Ngole-Jeme et al., 2015). The pH is a value that expresses how alkaline, neutral, or acidic a solution is (Badu et al., 2020). Results from the assessment of the pH of the geophagic clay used in this study showed a pH value of 5.68 (Table 1), which is slightly acidic. The acidity or alkalinity of the clay determines the taste. Soil tastes sour when acidic, thus this plays a role in the taste of the geophagic clay. It has been reported that the taste is one of the reasons that attracts most geophagous men and women to its consumption. For pregnant women, this characteristic taste can account for its ability to reduce excessive salivation and nausea (Diko & Ekosse, 2014).

Electrical conductivity is a measure of dissolved nutrients in the clay (Duplex et al., 2018; Kambunga et al., 2019). The EC value of the geophagic clay used in this study (657.7 µS/cm), was within the acceptable limits for EC in edible foods (1000 µS/cm), and hence shows the ability of the clay to make available its nutrients. This correlated with the findings of Kambunga et al. (2019), in which a high EC value was seen in the clay studied.
An indication of the total capacity of the soil to hold exchangeable cations which in solution can be given up in exchange for negatively charged ions, is known as the cation exchange capacity (CEC). The CEC seen in the studied geophagic clay (8.21 cmol/kg), was within the set standard as approved by WHO/FAO, indicating that the sample can easily give out its exchangeables. Kumari & Mohan (2021), stated that macro and micronutrients can be released easily in a clay sample that is fairly well saturated and has a high cation exchange capacity. Thus the CEC as seen in our studied clay indicated the possibility of release of its constituents when ingested.

Assessment of elemental composition in the geophagic clay revealed the presence of some essential (Fe, Mn, Cr, and Zn) and toxic metals (Pb and Cd) (Table 2). Concentrations of heavy metals (Pb, Cd, Al and Cr) in the analyzed geophagic clay exceeded the PMTDI. This result is consistent with various reports on the heavy metal concentrations in geophagic clays assessed in different locations (Nkansah et al., 2016; Miller et al., 2018; Orisakwe et al., 2020). Some elements of biological significance such as Ca, Na, Mg, K, Cl and Zn were within the WHO-acceptable concentrations (PMTDI) of these elements in edible foods. When there is an undue increase in the concentration of metal formed or excessive damage to the same, it can result in alterations of the metal homeostatic balance in the system which can lead to varying health-threatening disturbances (Skalnaya and Skalny, 2018).

Iron (Fe) is a trace element that plays an essential role in humans. It functions largely as a cofactor with most of the proteins in the animal system that play vital metabolic roles, such as mitochondrial respiration, and participates in varying cellular metabolic processes. Nearly two-thirds of iron (Fe) is incorporated in hemoglobin, making it very essential in the transportation of oxygen. It also plays a role in free radical generation within biological systems (Skalnaya and Skalny, 2018). Despite its wide range of usefulness, when used in excess, it causes toxic damage to vital organs. The iron (Fe) concentration in the studied geophagic clay was higher than the daily PMTDI as given by WHO. This may account for the biased concept that the consumption of geophagic clay can help alleviate anaemia; although a high concentration was seen in the studied clay (Table 2), it was less than the toxic threshold of iron (Fe) (200 mg/day) as given by WHO (Skalnaya and Skalny, 2018). This result is similar to that presented by Odongo et al. (2016) in their study.

Manganese (Mn), an essential trace element performs a co-factor function in many enzymatic processes. It plays a vital role in iron (Fe) transportation and functions in the brain, reproductive, and immune systems. However, when in excess, it can be the basis for the propagation of toxic responses that have direct effects on the central nervous system which can lead to a myriad of neurological diseases (Skalnaya and Skalny, 2018). The concentration of Mn in our studied clay was higher (3.33 mg/kg) than the PMTDI (1.8 mg/day), for Mn in edible foods. Although this concentration may not be toxic because concentrations ≥ 40 mg/day are what is usually considered toxic (Skalnaya and Skalny, 2018), the goephagous individual’s consciousness should be drawn to the possible toxicity that may arise when these clays are consumed in excess.

The concentration of Al in the studied geophagic clay was far higher than the PMTDI for Al in edible foods (Table 2). Aluminum (Al) toxicity has been reported in many literature (Owumi and Oyelere, 2015; Tiegoum, 2017; Rohilla et al., 2020; Choquenaira-Quispe et al., 2023). Some of the debilitating effects of exposure to high Al
concentrations include; neurological disorders, defects in hematopoietic and musculoskeletal systems, and can cause a wide range of defects in fetuses and infants, especially when geophagic clay is consumed by pregnant women. This result was similar to that of Owumi & Oyelere (2015), who reported a >10-fold increase in the concentration of Al in their studied clays when compared with the highest desirable levels set by WHO/FAO (2004).

Cadmium (Cd), which is a known toxic heavy metal, was seen to be higher in concentration (0.30mg) in the studied geophagic clay, than the PMTDI for edible foods. It is reported that Cd accumulates in the human body over time, leading to damage to vital organs, especially the kidneys (Mezynska & Brzóska 2018; Kar & Patra 2021). Lar et al. (2015) and Orisakwe et al. (2020), in their studies of clay, reported similar cases of high Cd concentrations, thus rendering such cays unsafe for consumption. The high concentration of these toxic metals may be reasons to explain the toxicity that may be attributed to the consumption of GC in geophagous individuals.

The toxicity of lead (Pb) cannot be overemphasized, as it is said to be very toxic even at very minute concentrations (Paul & Babatunde, 2021). Exposure to Pb has very debilitating effects on infants and children due to their rapid developmental stages. The brain is a major target for Pb toxicity, and as such, even the smallest of exposures are highly discouraged. The concentration of Pb in the studied geophagic clay was higher than the PMTDI for edible foods. This is similar to the results presented by Owumi & Oyelere (2015) and Orisakwe et al. (2020), in their study of geophagic clays. Such concentrations in edible foods render them unsafe for human consumption.

CONCLUSION
The results revealed that geophagic clay from Ubija in Edo State, Nigeria, contains high levels of some toxic heavy metals (Pb, Cd, Cr). This is a cause of public health concern, and as such, the willful consumption of this clay should be highly discouraged. The figures obtained in our findings show that ‘Eko’, could pose debilitating and detrimental effects to exposed individuals, especially fetuses, and infants who may be unduly exposed, by their geophagous pregnant mothers.

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CONFLICT OF INTEREST
The authors unanimously declare that there is no conflict of interest whatsoever.

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