Health Risk Assessment of Heavy Metal Exposures through Edible Clay from South-Eastern and South-Southern Nigeria

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ABSTRACT

Edible clay can attract heavy metals from the environment, when ingested; it can be solubilized by saliva and released into the body where it can trigger serious health issues. Edible clays were digested using standard method and assayed for heavy metals using atomic absorption spectroscopy (AAS). Result show concentration (mg/kg) of the heavy metals in the edible clays ranged from 0.0001-0.0021 mg/kg cadmium, 0.0856 - 0.1732 mg/kg arsenic, 0.091 - 0.170 mg/kg chromium, 0.0011 - 0.0108 mg/kg nickel, 0.0183 - 0.213 mg/kg cobalt, 0.0494 - 0.3255 mg/kg lead, 12.685 - 517.577 mg/kg iron, 1.983 - 25.658 mg/kg zinc and 0.0142 - 0.3588 mg/kg copper. The estimated daily intake (EDI) mg/kg/day of heavy metals in clays ranged from 1.904E-9 - 4.000E-8 for cadmium, 4.619E-7 - 1.906E-6 for arsenic, 4.911E-7 - 2.508E-6 for chromium, 5.936E-9 - 1.580E-7 for nickel, 9.876E-8 - 4. 057E-6 for cobalt, 9.093E-7 - 6.200E-6 for lead, 6.845E-5 - 9.858E-3 for iron, 1.068E-5 - 4.887E-4 for zinc and 8.041E-8 - 1.064E-5 for copper. The hazard quotient and hazard index value of the metals are < 1. The incremental lifetime cancer risk (ILCR) of the carcinogenic heavy metals Cd, Cr, As, Ni and Pb in the clays were 7.220E-10 - 8.170E-7 for Cd, 2.5E-7 - 4.585E-5 for Cr, 1.170E-7 - 3E-5 for As, 5.396E-9 - 1.437E-7 for Ni and 7.726E-9 - 5.270E-8 for Pb. In conclusion, the EDI, HI, and ILCR for the metals in the clays are all within the safe limit stipulated by US EPA.

(Keywords: edible clays, heavy metals, public exposure, health risk assessment, southeast Nigeria)

INTRODUCTION

Edible clay is clay that is prepared intentionally for sale and bought purposely for ingestion, although in some African communities, it is ingested directly without any further preparation or processing upon been obtained from the source. Processing of edible clay, for instance in Nigeria involves salting the edible clay obtained from source, molding into small spherical shaped solids, heating, and afterwards using for consumption. Consumption of edible clay is common in Africa; it is mostly eaten by children, women, and pregnant women, but is more prevalent among the latter.

Several studies have associated pregnant women with edible clay ingestion, for instance, studies conducted in Johannesburg, South Africa (Malthee *et al*, 2014), Ho municipality, Ghana (Kortei, *et al*, 2019), Dar es Salaam, Tanzania (Nyaruhucha, 2009), Nairobi, Kenya (Ngozi, 2008), Ngwa, Nigeria (Izugbara, 2003), and North London Borough (Madziva and Chinouya, 2020) shows significant numbers of pregnant African women eating edible clay. Many reasons have been attributed to edible clay ingestion which include among others; cultural belief (Madziva and Chinouya, 2020), cravings (Kortei, *et al*, 2019; Izugbara, 2003), taste, smell, peer influence (Kortei, *et al*, 2019), and to prevent vomiting, salivating, and spitting (Izugbara, 2003).

In Nigeria, edible clays are sold in most markets where they are bought by consumers for different applications; pregnant women buy it to prevent vomiting or discomfort associated with pregnancy, while others mostly, women buy it to satisfy their craving, having being addicted to its smell and taste.

Edible clay consumption in Nigeria cuts across the educated and uneducated. There is hardly any Nigerian market visited without edible clay displayed for sale, indicating its voluminous consumption till date. Apart from local demand, it is sought after outside the country necessitating its export. The danger that may be inherent with clay eating is intake of heavy metals. Clay can adsorb metal ions (El-Maghrabi and Mikhail, 2014). The negative charge of clay confers on it the ability to attract positively charged metal ion.

Studies have shown that some edible clays contain mercury and cadmium at high levels (Kelle *et al,* 2018; Bonglaisin *et al*, 2011). When clay contaminated or polluted with heavy metals is ingested, digestive fluids can solubilize the clay, releasing the metals from clay and making them available for absorption by the body. Heavy metals can exert health issues in the body depending on the concentration of the metals and type of heavy metal; some heavy metals exert toxicity at elevated levels, while some such as arsenic, cadmium, chromium, lead and mercury even at low concentrations cause health problems (WHO, 1996; Tchounwou *et al*, 2012).

Pregnant women who are exposed to heavy metals can pass these metals to their unborn child (fetus) as studies have shown that mercury, lead, and cadmium cross the placenta and accumulate in fetal tissues (Gundacker and Hengstschlager, 2012). The danger is that some heavy metals like lead, mercury, arsenic, and cadmium can cause birth defects and brain developmental issues such as autism and attention deficit hyperactivity disorder (ADHD) in a developing fetus (Chen *et al*, 2014; Vanda, 2018; NIOSH, 2019; NIPH, 2021). Other issues associated with exposure of pregnant women to heavy metals is miscarriage and still birth (NIOSH, 2019; Gerhad *et al*, 1998). Pregnant Nigerian women who consume edible clays therefore may be at risk of experiencing miscarriage or stillbirth, and or transferring heavy metals during prenatal to their child.

Heavy metals occur naturally in rock, soil, sediments and water in trace amounts, but anthropogenic activities have led to their widespread in the environment in more than their normal background concentration inducing toxicity in both plants and animals (Beyersmann, 2008). Most edible clay deposit in Nigeria are located in Southeastern and South-southern Nigeria. Activities leading to the release of heavy metals in the environment are prominent in these regions and may contaminate the edible clay deposits. These activities include oil exploration and exploitation, oil spills (Nduka and Orisakwe, 2011), indiscriminate disposal of wastes (Nduka *et al*, 2008), and unregulated and indiscriminate location of automobile workshops. Automobile workshops in the region and Nigeria in general are involved with vehicle repair, vehicular painting activities, as well as housing aging and decomposing vehicles abandoned at auto workshops. These may release heavy metals that end up into soil and surface water (Nduka *et al*, 2016; Nduka *et al*, 2019). Because edible clay deposits in Southeastern and South southern Nigeria are disposed to heavy metal pollution and may be a source of heavy metal exposure through oral contact to its consumers it is important that edible clay from these deposits are analyzed, and its health risk assessed.

Though there has been some research done on assessment of heavy metals in edible clay from some region of Nigeria, there is still paucity of information as the work done does not cover the edible clays from the major edible clay deposits in Nigeria. This work tries to bridge the gap by studying heavy metals in edible clays from major edible clay deposits in Southeastern and South-southern Nigeria. The result of the study will be useful to pregnant Nigerian women, pregnant women generally and others who consume edible clay, in decision making on consumption of clay and help government health agencies educate the people and make decisions on edible clay consumption.

The aim of this study is to determine the concentrations of heavy metals in edible clays from Southeastern and South-southern Nigeria and health risk associated with its consumption.

MATERIALS and METHODS

Sample Collection

Two hundred (200) samples comprising 40 each of edible clays weighing between 1.5 – 2g from Emene in Enugu State, Ohia in Abia State, Mbaise in Imo State, Amaraku in Imo State all in Southeastern Nigeria and Eku in Delta State of South-southern Nigeria (Figure 1) were randomly selected and purchased from Oyingbo market, Lagos State, Nigeria. They were wrapped in separate polyethene bags, properly labelled for easy identification, and taken to the laboratory for analysis. The retailers of the edible clays provided the source of the edible clays. Sampling of the edible clays was done in August 2021.

Sample Preparation and Analysis

Edible clay from each source was pulverized using a clean porcelain mortar and pestle and sieved through 0.5 mm sieve then oven dried at 105ºC to constant weight. 2 g of the dried sample was accurately weighed into a clean 200 ml beaker and 20 ml mixture of HNO_3/HCl (aqua regia) in a ratio of 1:3 was added to each sample and heated on a hot plate inside a fume cupboard until the solids dissolved completely.

The solution was left to cool and filtered through Whatman 110mm filter paper into a pre-cleaned 50 ml standard volumetric flask and made to mark with deionized water (USEPA, 1996; ISO, 1995). The filtrate was used for heavy metal determination using Schdmazu AA-6800 Atomic Absorption Spectrophotometer (Tokyo, Japan) with detection limit of 0.001 ppm. They were assayed at the respective wavelengths of the metals; 228.9, 357.9, 324.8, 232 and 217, 248.3, 213.9, 240.7, and 193.7 nm, for Cd, Cr, Cu, Ni, Pb, Fe, Zn, Co, and As.

1000 ppm stock standard solutions of the heavy metals (Zn, Fe, Co, Cr, Ni, As, Pb, Cu and Cd) were used to prepare working standard solutions for each metal, the standard solutions were assayed at the wavelengths of the metals. The instrument was calibrated using calibration blank of values reading as 0.00 ppm and different calibration levels. The calibration standards were used to generate calibration curve for each of the metals, from which samples of the digest were extrapolated.

The concentration in $mgkg^{-1}$ was calculated from the formulae;

$$\text{Concentration (mg/kg)} = \frac{Concentration\,\frac{mg}{l}\ \ X\ V}{W} \quad (1)$$

Where V = Final volume of sample solution
W = Initial weight of sample measured

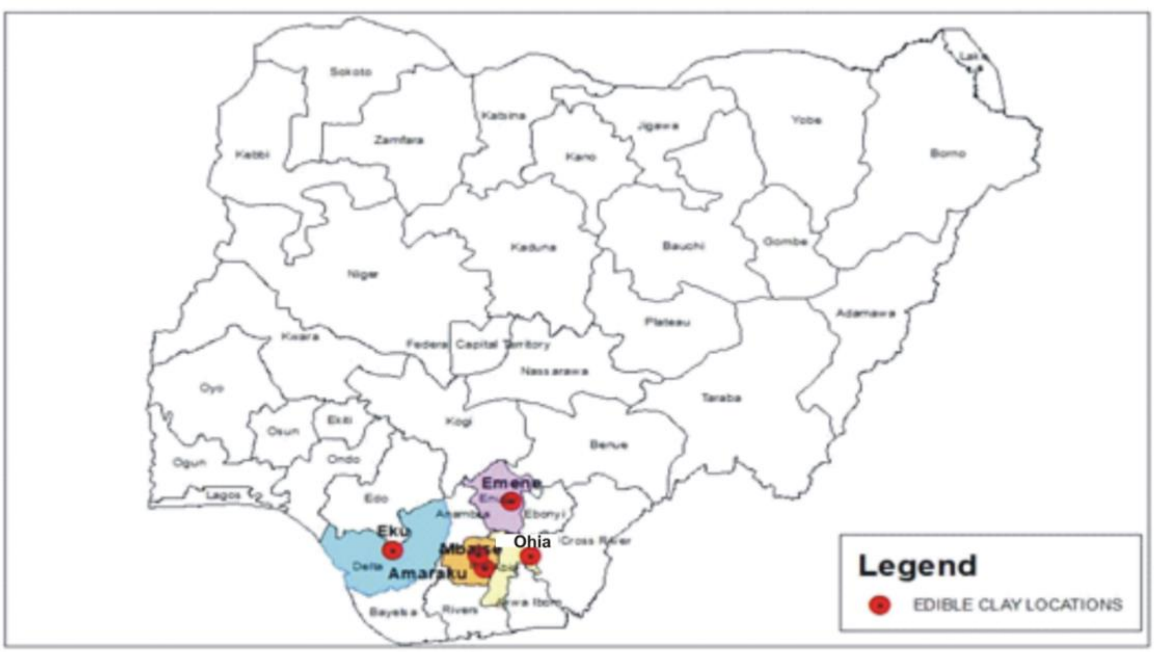

Figure 1: Sampling Locations of the Edible Clays**.**

The concentrations of the heavy metals were determined in triplicate and results presented as mean ± standard deviation. Linearity of the calibration curves of the heavy metals was evaluated by determining the coefficient of correlation (r^2) while the accuracy of the analysis was ascertained by spiking samples with 0.5 mg/L of the standard solutions of the metals before digestion, afterwards the spiked samples were subjected to the same analytical conditions as the test sample. The percentage recovery was obtained as follows:

$$\% \text{ Recovery} = \frac{\text{Concentration of the spiked sample} - \text{Concentration of un-spiked sample}}{\text{Actual spike concentration}} \quad \textbf{(2)}$$

The percentage recoveries ranged from 90 % to 102%.

HEALTH RISK ASSESSMENT

Estimation of Daily Heavy Metal Intake

Field survey was conducted to obtain estimate of average consumption (ingestion rate) of edible clay in Nigeria as there are no available data on this. This was done using the method described by Adekunle *et al (*2009)*;* the weight of edible clays consumed by an adult on daily basis was calculated and averaged, the estimated daily intake (EDI) of each heavy metal in the clays was determined by multiplying the concentration of each metal by the average weight of the clay and dividing the product by the body weight of an adult Nigerian (63 kg) (Kelle, *et al*, 2020).

$$EDI = \frac{C_R \times IR}{BW} \quad \textbf{(3)}$$

Where C_R is the average concentration of heavy metals in the clay samples (mg/kg), and IR is the daily clay ingestion rate i.e., average weight of edible clays consumed on daily basis by an adult Nigerian. BW is the average body weight BW.

Non – Carcinogenic Risk

Non–carcinogenic risk was estimated by determining the hazard quotient for individual heavy metal in each clay sample and hazard index (HI) which is the sum of all hazard quotients (HQ) of the heavy metals in each clay. Hazard quotient (HQ) is used to estimate the cancer risk for a single substance, while the hazard index (HI) is used to estimate the cancer risk for multiple substances (Gerba, 2019) that affect the same target organ or organ system (USEPA, 2005).

The hazard quotient (HQ) for individual heavy metal in clay samples was calculated using the equation (Gerba, 2019; USEPA, 2014):

$$HQ = \frac{EDI}{RfD} \quad \textbf{(4)}$$

Where RfD is the oral reference dose (mg/kg/day), RfD is an estimation of the maximum permissible risk allowable on human population through daily exposure, this takes into consideration sensitive groups that is likely to be without an appreciable risk of deleterious (non-cancer) effects during lifetime.

HQ < 1 represents no significant risk, HQ > 1 indicates likelihood of a potential risk (Gerba, 2019).

$$HI = \sum HQ \quad \textbf{(5)}$$

HI < 1 indicates safety from multiple substances that affect the same target organ or organ system, while H1 > 1 indicates chronic risks may happen (Gerba, 2019; USEPA, 2005; USEPA, 2014).

Carcinogenic Risk

Carcinogenic risk was estimated for only those heavy metals with evidence of probability or possibility of causing cancer. It is expressed in terms of incremental lifetime cancer risk (ILCR) which is the possibility of developing cancer through ingestion of carcinogenic substances. ILCR was calculated using (Gerba, 2019; USEPA, 2014):

$$ILCR = CDI \times CSF \quad \textbf{(6)}$$

CDI is chronic daily intake of chemical carcinogen, mg/kg BW/day, CSF is the cancer slope factor (CSF).

$$CDI = \frac{EDI \times EF \times ED \times CF}{AT} \quad \textbf{(7)}$$

Where EF is exposure frequency (days/ year); 365 days/year, ED is exposure duration (years); 54 years (life expectancy of an adult Nigerian) (World bank, 2018). AT is average time (days) (the period over which exposure is averaged), for carcinogens the average time is exposure frequency days/years) multiplied by exposure duration, CF is units' conversion factor.

Cancer risk of $1 x 10^{-6}$ - $1 x 10^{-4}$ is considered acceptable (USEPA, 2005).

RESULTS and DISCUSSION

Average Concentration of Heavy Metals

Table 1 shows the result of the concentration (mg/kg) of the heavy metals in the edible clays, the concentration range from 0.0001 to 0.0021 mg/kg cadmium; excluding the clays from Mbaise in Imo State and Ohia in Abia, Nigeria with cadmium concentrations below detectable limit, other heavy metals ranged as follows; 0.0856 to 0.1732 mg/kg arsenic, with the exception of edible clay from Emene in Enugu State, Nigeria whose arsenic concentration was below detectable limit, 0.091 to 0.170 mg/kg chromium, 0.0011 to 0.0108 mg/kg nickel, 0.0183 to 0.213 mg/kg cobalt, 0.0494 to 0.3255 mg/kg lead, 12.685 to 517.577 mg/kg iron, 1.983 to 25.658 mg/kg zinc and 0.0142 to 0.3588 mg/kg copper, except clay from Ohia in Abia State with copper concentration below detectable limit.

Among the edible clays, clay from Eku in Delta State, had the highest concentration of cadmium (0.0021 mg/kg), cobalt (0.213 mg/kg), lead (0.3255 mg/kg), iron (517.577 mg/kg), zinc (26.658 mg/kg) and copper (0.3588 mg/kg), while, edible clays from Amaraku in Imo State had the highest concentrations of chromium (0.170 mg/kg) and nickel (0108 mg/kg), that of Ohia in Abia State had the highest concentration of arsenic (0.173 mg/kg). Edible clays from Emene in Enugu State had least concentrations of cadmium and lead, while clays from Mbaise in Imo State was least in arsenic, chromium, nickel, iron and copper. Clays from Ohia in Abia State and Amaraku in Imo State had least concentrations of cobalt and zinc. Comparatively, the edible clay with the highest concentration of most of the heavy metals (67%) is edible clay from Eku, while that with the least concentrations of most of the heavy metals (60%) is clay from Mbaise in Imo State.

Table 1: Concentration of Heavy Metals in Edible Clay Samples.

S/N	Edible clay source	Clay Type	Heavy Metal (mg/kg)								
			Cd	As	Cr	Ni	Co	Pb	Fe	Zn	Cu
1	Amaraku, Imo State	Nzu (white clay)	0.0004 ±0.882	0.1452 ±0.111	0.170 ±0.941	0.0108 ±0.161	0.0697 ±0.792	0.2442 ±0.222	82.650 ±1.071	1.983 ±0.071	0.0149 ±0.449
2	Eku, Delta State	Ulo (grey clay)	0.0021 ±0.776	0.1001 ±0.774	0.1317 ±1.006	0.0078 ±1.482	0.213 ±1.091	0.3255 ±1.844	517.577 ±0.629	25.658 ±0.027	0.3588 ±1.201
3	Emene, Enugu State	Ulo, (grey clay)	0.0001 ±1.207	BDL	0.1017 ±0.288	0.0083 ±0.392	0.0433 ±0.911	0.0494 ±1.371	319.025 ±0.086	5.548 ±0.048	0.0448 ±0.814
4	Mbaise, Imo State	Nzu (white clay)	BDL	0.0856 ±0.501	0.091 ±0.557	0.0011 ±0.588	0.019 ±0.822	0.1685 ±0.767	12.685 ±0.073	2.513 ±0.080	0.0142 ±0.443
5	Ohia, Abia State	Nzu (white clay)	BDL	0.1732 ±0.646	0.147 ±0.483	0.0055 ±0.447	0.0183 ±1.004	0.3249 ±0.904	18.472 ±0.591	4.865 ±0.053	BDL

BDL = below detectable limit

Factor that might have contributed to edible clay from Eku having the highest concentration of most of the heavy metals apart from factors such as use of pesticides and herbicides for farming and indiscriminate disposal of refuse etc which is common to other (Mbaise, Emene, Ohia and Amaraku) communities from which the edible clays were excavated and sold in the market, is that, Eku situated in Ethiope East (latitude 5º N- 6º S and longitude 5.5º E – 6.5º W) Local Government Area (LGA) is within the oil and gas exploration and exploitation area of Nigeria called the Niger Delta region which is reputed to release voluminous amount of heavy metal into the environment (Nduka and Orisakwe, 2011).

The maximum permissible level (MPL) for arsenic, cadmium, lead, copper and iron in most food substances range from 0.1 to 0.5 mg/kg, 0.05 to 0.5 mg/kg, 0.02 to 0.5 mg/kg, 0.1 to 0.4 mg/kg and 2.5 to 5.0 mg/kg respectively. There is no maximum permissible level (MPL) for zinc and cobalt in food substances (FAO/WHO, 2011). Food and Agricultural Organization (FAO) and World Health Organization (WHO) and other international regulatory bodies such as CODEX Alimentarium do not have set standards for chromium and nickel in food substances. The concentrations of arsenic, cadmium, lead, copper was within the maximum permissible limits of these metals in food substances, except iron which is present in all the edible clays in concentration far above the MPL for Iron in most food substances. The concentration of the metals in the clays indicates that the edible clays are not contaminated with As, Cd, Pb and Cu.

Clay from Eku is made up of highly plastic clays (mainly kaolinite, mica and quartz minerals), sand and cohesive salty and clayey soils that are partly permeable and of quaternary age (FBN, 2015). Previous study undertaken on soil/clay/sediment in Eku, shows that most abundant heavy metals in the soil/clay of Eku is iron with a range from 78.9 to 210.3 mg/kg followed by 36.6 to 49.69 mg/kg zinc and 10.23 to 19.21 mg/kg copper (FBN, 2015). Similar trend is observed in the edible clay from Eku in this study. Edible clays from Eku and Emene in Enugu State are same in appearance and texture; they are both plastic clays and are grey to black in colour, while clays from Mbaise, Amaraku and Ohia are mainly kaolin clay; they are white clays with yellowish, reddish to dark brown/black coloration. The constituent of kaolin clay is the mineral kaolinite ($Al_2Si_2O_5(OH)_4$), while plastic clay is composed of mineral kaolinite ($Al_2Si_2O_5(OH)_4$), mica (group of hydrous potassium, aluminium, silicate minerals) and quartz (SiO_2). Kaolinite, mica and quartz are usually associated with impurities which include iron oxides, iron hydroxides and iron sulphides which impart coloration to the clay, depending on the type of iron which is dominant. This explains the presence of iron in all the clays analysed. The presence and amount of these iron compounds in the clay depend on origin and depositional environment of the mineral (Grinshaw, 1971).

Comparing the edible clays from Eku and Emene, whose iron concentrations are 517.577 mg/kg and 319.025 mg/kg respectively, with that from Amaraku, Mbaise and Ohia with iron concentrations of 82.650 mg/kg, 12.685 mg/kg and 18.472 mg/kg respectively, there is a staggering difference in iron concentration between clays from Eku and Emene (plastic clays) and the other clays (kaolin clays). This may be so, because the other clays are mainly kaolinite and the iron impurities is in the kaolinite structure only, while the clays of Eku and Emene which are plastic clays will have iron impurities in the kaolinite, mica and quartz structures. This suggest that, apart from origin and depositional environment of the mineral constituent of clay, the amount or number of constituents of the clay that attract iron impurities may be a factor determining the concentration or amount of iron in the clay.

Estimated Daily Intake of Heavy Metals

The estimated daily intake (EDI) mg/kg/day of the heavy metals in the clays (Table 2), ranged from 1.904E-9 to 4.000E-8 for cadmium, 4.619E-7 to 1.906E-6 for arsenic, 4.911E-7 to 2.508E-6 for chromium, 5.936E-9 to 1.580E-7 for nickel, 9.876E-8 to 4. 057E -6 for cobalt, 9.093E-7 to 6.200E-6 for lead, 6.845E-5 to 9.858E-3 for iron, 1.068E-5 to 4.887E-4 for zinc and 8.041E-8 to 1.064E-5 for copper.

The acceptable daily intake (ADI) mg/kgBW of cadmium, arsenic and lead were calculated from the provisional tolerable monthly intake (PTMI) of cadmium (25 μg/kgBW/month) and provisional weekly tolerable intake (PTWI) of arsenic (15 μg/kgBW/week) and lead (25 μg/kgBW/week) (FAO/WHO,2011) by conversion to daily basis; 25 μg/kgBW/month to 0.00083 mg/kgBW for cadmium, 15 μg/kgBW/week to 0.0021 mg/kgBW for arsenic and 25 μg/kgBW/week to 0.00357 mg/kgBW for lead.

There is no set standard for acceptable daily intake for chromium, nickel and copper through food by international agencies such as WHO and FAO, however the oral daily intake of nickel and Copper through food are Ni < 300 μg/kg, i.e., < 0.3 mg/kg (WHO, 2000) and Cu 0.5 mg/kg bw per day (FAO/WHO, 1982), these values were used to compare with the estimated daily intake of these metals. The provisional maximum tolerable daily intake (PMTDI) mg/kg bw of iron is 0.8 mg/kg bw (FAO/WHO, 2011). The values of the estimated daily intake of the metals in the clay samples are lower than their compared values, suggesting no evidence of health risk

Hazard Quotient and Hazard Index

Table 3 is result of hazard quotients (HQ) and hazard indexes (HI) of the heavy metal ingestion through edible clays. The hazard quotient of the metals; Cd, As, Cr, Ni, Co, Pb, Fe, Zn, and Cu range from 4E-9 to 2.15E-9, 4.819E-7 to 1.906E-6, 4.911E-7 to 2.508E-6, 5.93E-9 to 1.580E-7, 9.876E-8 to 4.057E-6, 9.093E-7 to 6.200E-6, 6.845E-5 to 9.858E-3, 1.068E-5 to 4.887E-4 and 8.041E-8 to 1.064E-5.

The hazard indexes of the metals in each clay range from 0.0015 to 0.08. The hazard quotient and index of iron in the clays were not calculated because a reference dose (RF_D) for iron is not available (USEPA, 2006). The hazard quotients and hazard indexes of the other metals in the edible clay are less than 1 (< 1), implying that none of these metals may cause systematic toxicity or significant risk, and consumption of combination of these metals in each clay may not cause chronic health effects (Gerba, 2019; USEPA, 2005; USEPA, 2014).

Cancer Risk or Incremental Lifetime Cancer Risk

Table 4 shows the result of incremental lifetime cancer risk (ILCR) of the carcinogenic heavy metals Cd, Cr, As, Ni and Pb in the clays. It ranged from 7.220E-10 to 8.170E-7 for Cd, 2.5E-7 to 4.585E-5 for Cr, 1.170E-7 to 3E-5 for As, 5.396E-9 to1.437E-7 for Ni and 7.726E-9 to 5.270E-8 for Pb Respectively. These values are within the safe limit of $1\,x\,10^{-4}$ to $1\,x\,10^{-6}$ for cancer risk (USEPA, 2014). Therefore, there may be no likelihood or probability of carcinogenic risk from these metals in the clays.

Table 2: EDI of Heavy Metals through Consumption of Edible Clays (mg/kg).

S/N	Edible clay source	Edible clay type	Cd	As	Cr	Ni	Co	Pb	Fe	Zn	Cu
1	Amaraku,Imo State	Nzu (white clay)	2.15E-9	7.83E-7	9.17E-7	5.828E-8	3.761E-7	1.317E-6	4.400E-4	1.068E- 5	8.041E-8
2	Eku, Delta State	Ulo (grey clay)	4.00E-8	1.90E-6	2.50E-6	1.485E-7	4.057E-6	6.200E-6	9.858E-3	4.887E-4	1.064E- 5
3	Emene, Enugu State	Ulo, (grey clay)	1.90E-9	BDL	1.93E-6	1.580E-7	8.247E-7	9.409E-7	6.000E-3	1.000E-4	8.533E-7
4	Mbaise, Imo State	Nzu (white clay)	BDL	4.61E-7	4.91E-7	5.936E-9	1.025E-7	9.093E-7	6.845E-5	1.356E-5	8.041E-8
5	Ohia, Abia State	Nzu (white clay)	BDL	9.34E-7	7.93E-7	2.968E-8	9.876E-8	1.753E-6	9.969E-5	2.625E-5	BDL

Table 3: Hazard Quotient (HQ) and Hazard Index (HI) of Heavy Metals through Consumption of Edible Clay.

S/N	Edible clay source	Edible clay type	HQ								HI = $\sum HQ$
			Cd	As	Cr	Ni	Co	Pb	Zn	Cu	
1	Amaraku, Imo state	Nzu (white clay)	2.150E-6	2.60E-3	3.000E-4	2.90E-6	1.880E-5	9.00E-4	3.33E-5	2.00E-6	0.0039
2	Eku, Delta State	Ulo (grey clay)	4.000E-5	7.00E-2	8.000E-4	7.00E-6	2.000E4	4.33E-3	1.60E-3	2.50E-4	0.08
3	Emene, Enugu State	Ulo, (grey clay)	1.900E-6	BDL	6.333E-4	7.50E-6	4.000E-5	6.57E-4	3.33E-4	2.12E-5	0.0015
4	Mbaise, Imo State	Nzu (white clay)	BDL	1.53E-3	1.666E-4	2.95E-7	5.126E-6	6.29E-4	4.33E-5	2E-6	0.0023
5	Ohia, Abia State	Nzu (white clay)	BDL	3.00E-3	2.633E-4	1.50E-6	4.900E-6	1.11E-3	8.66E-5	BDL	0.0045

RfD = Cd (0.001); Cr (0.003); As; (0.0003); Ni (0.02); Pb (0.00143); Cu (0.04); Co (0.02); Zn (0.3)

Table 4: Incremental Lifetime Cancer Risk (ILCR) through Consumption of Edible Clay.

S/N	Edible clay source	Edible clay type	ILCR				
			Cd	Cr	As	Ni	Pb
1	Amaraku, Imo state	Nzu (white clay)	8.170E-7	4.585E-5	1.170E-7	5.296E-8	1.105E-8
2	Eku, Delta State	Ulo (grey clay)	1.520E-8	1.250E-6	3.000E-5	1.274E-7	5.270E-8
3	Emene, Enugu State	Ulo, (grey clay)	7.220E-10	1.930E-6	BDL	1.437E-7	7.726E-9
4	Mbaise, Imo State	Nzu (white clay)	BDL	2.500E-7	6.915E-7	5.396E-9	7.726E-9
5	Ohia, Abia State	Nzu (white clay)	BDL	3.950E-7	1.401E-6	2.693E-8	1.479E-8

CONCLUSION

The estimated daily intake (EDI) of all the metals: Cd, As, Cr, Ni, Co, Pb, Fe, Zn, Fe and Cu are within the safe limit of their acceptable daily intake (ADI), hence may not pose any health risk to consumers. The hazard quotients (HQ) and hazard indexes (HI) of the metals through consumption of the edible clays are within the safe limit for hazard quotient and hazard index, therefore, none of the metals may cause systematic toxicity or significant risk, and consumption of the combination of the metals in each clay may not cause chronic health effects.

The incremental lifetime cancer risk (ILCR) for the carcinogenic metals (Cd, As, Ni, and Pb) in the clays are within the safe limit for cancer risk; the probability of developing cancer by consumers of these clays due mainly to the carcinogenic heavy metals in the clays may be unlikely.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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