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Heavy metal content and potential health risk of geophagic white clay from the Kumasi Metropolis in Ghana

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ABSTRACT

Geophagia is the craving for non-food substances and commonly practiced among pregnant women and children. Consumption of geophagic clay samples can have serious implications on the health of the consumers as a result of the presence of toxic metals such as Pb, As, Hg and Cd. This study sought to determine the levels of heavy metals in the studied geophagic clay samples and to determine the potential risks of heavy metals as cumulative carcinogenic and non-carcinogenic risks to the health of the consumers via oral (ingestion) and dermal exposure routes. A total of thirty (30) white clay samples were analysed using Niton Thermo scientific XRF Analyser (Mobile Test S, NDTr-XL3t-86956, com 24). The clay samples were found to contain essential elements such as Ca, Fe, K and Zn as well as toxic metals such as As and Pb. There were isolated cases of the presence of Hg and all samples had Cd levels below detection. Health risk indices such as hazard quotient and cancer risk were calculated and the results indicated that consumers are likely to suffer from cancer through ingestion of geophagic clay. Bioaccessibility studies were done on zinc and it did not indicate any potential toxicity due to zincs essential nature. The levels of heavy metals in some of the geophagic clay consumed by some residents in the Kumasi were high compared to the Permitted Maximum Tolerable Daily Intake (PMTDI) by (WHO/FAO) and may pose potential health threat over time.

1. Introduction

Geophagia (the deliberate consumption of non-food substances [11] such as ingestion of soil/sand, clay blocks and mud) has been known for centuries. The practice of geophagia has been reported in several countries across continents including Africa (South Africa, Cameroon, Democratic Republic of Congo, Nigeria, Swaziland, Tanzania and Uganda), Asia (China, India, Philippines, and Thailand) and the Americas [20,6]. A variety of reasons for geophagia have been postulated to justify the practice, including religious, cultural, nutritional and medicinal practices, famine, perceived enhancement of personal appearance, pregnancy-related cravings, and enjoyment of the taste, texture or smell of the substance consumed [17]. Geophagy is observed to be more common in pregnant women and children [9,2]. For instance, [17] reported that twenty percent of pregnant women in his study undertaken in Johannesburg were geoghagic, at risk of anaemia and potentially adverse health outcomes. The consumption of geophagic clays can provide benefits such as the ability of clay to absorb dietary and bacterial toxins associated with gastro-intestinal disturbance [6] and free radicals and pesticides from the gastro-intestinal tract. Conversely, geophagia may also expose consumers to toxic or harmful materials such as heavy metals, pathogenic bacteria, viruses and parasites. Heavy metals (As, Se, F and other trace metals) occur naturally in soils during geological processes (weathering and alteration) and anthropogenic activities can also contribute to elevated levels in the soil. Excessive exposure to the harmful heavy metals could lead to one disease or another [31]. A research conducted by [31] revealed that geoghagic clayey soils sold in three major markets (Madina, Makola and Ashaiman) in Ghana contained high levels of As, Pb, Hg, Cd and Co. These results were higher than the WHO/FAO requirement and the levels established by the United States Department of Agriculture. The consumption of these clays by both adults and children could lead to various life threatening diseases. For instance, [24] observed that acute exposure to lead can affect the human central nervous, resulting in dysfunction of the kidney, liver and heart. According to [23], problems of ascariasis is also known to be common among children in Nigeria who practice

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geophagy. In Tanzania, a survey conducted by [14] reported that geohelminth infection and iron deficiency were observed among pregnant women and HIV infected women who indulge in geophagia. Extreme over indulgence in clay eating can block the colon, which can lead to the perforation and even death. In Ghana, the most patronized geophagic clay is the 'white clay' containing predominantly kaolin [18], particularly sourced from Anfoega in the Volta Region [31]. Several studies have been reported on the mineralogy and microbiology of geophagic clay in sub-saharan Africa including Ghana [5,10,8,21,3]. Heavy metal content of geophagic clayey soil has not been extensively studied in Ghana though geophagia has been practiced for many years.

This study seeks to determine the levels of heavy metals in geophagic white clay samples, their potential risks, cumulative carcinogenic and non-carcinogenic risks via the routes of oral (ingestion) and dermal exposure on the health of consumers.

2. Methodology

2.1. The study area

The Kumasi metropolis lies between latitude 6.35°–6.40° and longitude 1.30°–1.37°. It has an area of about 299 km^2 and elevation of 71 which ranges between 250 and 300 m above sea level. The metropolis is characterized by a tropical wet and dry climate, with relatively constant temperatures throughout the year. The Kumasi metropolis is predominantly a commerce/trade service economy inclusive with an employment level of 71% and this is followed by industry with an employment level of 24%, and agriculture with an employment level of 5%. Kumasi is home to the Kejetia Market otherwise known as the Kumasi Central Market which is the largest in West Africa. It is from this market that most produce are distributed to markets in other regions of the metropolis.

2.2. Experimental procedures

2.2.1. Sampling

A total of thirty (30) pieces of baked ready to eat geophagic white clay samples were randomly obtained from ten (10) markets in the Kumasi Metropolis in the Ashanti region. A total of three (3) samples each were collected from the ten (10) major markets in the meptropolis. These markets are; Abuakwa, Asafo, Asuoyeboah, Ayigya, Bantama, Central Market, Kwame Knrumah university of Science and Technology (KNUST), Kwadaso, Santasi and Tanoso. Pictures of freshly baked clay samples before and after grin have been presented (Figs. 4 and 5).

2.2.2. Sample preparation and analysis

The geophagic clay samples obtained from the markets were dried at room temperature until a constant weight was obtained. Dried clay samples were crushed in turns in a crucible. The crushed samples were then sieved through a 250 μm sieve. The crucible and sieve were cleaned after each sample preparation to avoid contamination. The samples were placed in clean polythene bags, sealed and labelled for easy identification prior to analysis.

2.2.3. Determination of metals in dry powdered white clay by X-ray fluorescence

The heavy metal content in the clay samples were analysed using Thermo scientific Niton XRF Analyser (Mobile Test S, NDTr-XL3t-86956, com 24). The XRF analysis followed the USEPA method 6200 field portable X-Ray Fluorescence Spectrometry for the determination of elemental concentrations of soils and sediments [27]. The equipment was calibrated with reference material OC USGS SAR-M 180–673. The polyethylene sample holder was filled halfway (~3.0 g) with sieved sample. The sample holder was covered with a Mylar film and cupped. The cupped sample was then placed in the XRF shroud and scanned for 180 s to obtain the desired result. All the samples were treated in the same manner.

2.2.4. Wet acid digestion of clay samples

A selection of six (6) of the sieved clay samples were analyzed for total metals after modified aqua regia digestion. An aliquot of 0.5 g sample was added to 3 ml of 1:1:1 $HCl - HNO_3 - H_2O$ mixture. The mixture was digested at 95 °C for 1 h in a heating block. The sample was made to volume with dilute HCl and analyzed by ICP-MS.

2.2.5. Extraction of white clay samples

The extraction protocol was based on the Standard Operating Procedure for an In Vitro Bio-accessibility Assay for Lead in Soil, EPA Method 9200.2-86 [28]. QA/QC included a procedure blank and a laboratory control sample. The sieved clay sample was weighed by difference (1.00 ± 0.05 g) into a 125 ml acid cleaned HPDE bottle. An aliquot of 100 ± 0.5 ml of extraction fluid was measured and added to the bottle. This yielded a sample mass to fluid ratio of 1:100. The pH of the soil/extraction fluid mixture was measured. The extraction solution consisted of 30 g/L glycine (Calbiochem) adjusted to a pH of 1.5 with concentrated HCl (Fisher Scientific, trace metal grade). The bottle was then sealed and placed into the extractor in batches of eight and rotated end-over-end in a 37° ± 2 °C water bath for 1 h. After the extraction was completed, the bottles were removed. Each extract was drawn directly into a disposable 20 ml plastic syringe with a luer slip (National Scientific). A 0.45 μm cellulose acetate filter (25 mm diameter, Cole Palmer) was attached to the syringe and the extract was filtered into a clean 20 ml polyethylene scintillation vial (Wheaton). The filtered extract was stored at 4 °C and subsequently analyzed for metals by ICP-MS.

2.2.6. Analysis for metals in extracts

Metal analysis was conducted with an Agilent Model 7500ce Collision Cell ICP-MS based on United States Environmental Protection Agency (USEPA) SW846 Method 6020A, Inductively Coupled Plasma – Mass Spectrometry, Revision 1 [27].

3. Bioaccessibility calculations

Metal bioaccessibility was calculated as follows:

$$Bioaccessibility, \% = \frac{(Concentration\ in\ extract,\ \mu g/L)\ x\ vol\ of\ extract,\ L}{Concentration\ in\ soil,\ mg/kg\ x\ mass\ of\ soil\ used,\ g} \times 100$$

3.1. Quality control

The XRF analyser was calibrated using certified reference material (OC, USGS, SAR-M AND 180–673) to ensure that the concentrations of the various metals corresponded with the respective concentrations given on the accompanying chart. In order to control the analytical procedure, precision of the analytical results was estimated by replicate analysis.

3.2. Calculation of the average daily intake (ADI)

The amounts of heavy metals consumed were calculated using the average of samples from each location (three each), as indicated in Tables 1a and 1b. The heavy metal content in 70 g is calculated for each location (indicated in Table 2b) and this is used to predict the amount of clay consumed. The values obtained are then compared to the Permitted Maximum Tolerable Daily Intake (PMTDI) recommended by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO).