



# Determination of metal ion contents of two antiemetic clays use in Geophagy



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## ARTICLE INFO

### Article history:

Received 23 April 2015

Received in revised form 2 June 2015

Accepted 12 June 2015

Available online 16 June 2015

### Keywords:

Nausea

Pregnancy

Eko

Omumu

Geophagy

Trace element and metals

Maternal and fetal health

Teratogenicity

## ABSTRACT

Nausea is usually associated with early to late stages of pregnancy. Geophagy—deliberate consumption of soil is a common method of managing gravidae-induced discomfort. To control nausea, pregnant women in Nigeria commonly eat baked clay called “Eko” and another type of clay that induces buccal constriction called “Omumu”.

The metal contents in Eko and Omumu, digested under different pH conditions (acidic, alkaline and neutral), were investigated using Inductively Coupled Plasma Optical Emission Spectroscopy (ICPS-OES). We identified and quantitate the elements present and speculate on their potential impact on maternal and fetal health upon gestational exposure beyond the acceptable exposure levels and the Millennium Contaminant Level Goals (MCLG) set by the United States Environmental Protection Agency (USEPA).

Specifically, our result indicates unacceptably high levels of aluminum in Eko and Omumu (>10-fold greater than the highest desirable levels set by the USEPA). The aluminum concentrations were influenced by the pH condition in which the samples were digested. Dietary exposure to aluminum at such high levels may be deleterious to maternal health and fetal development. Therefore consumption of Eko and Omumu as an antidote to reduce nausea during pregnancy should be discouraged. Future studies are planned to investigate specific impacts on fetal and maternal health and likely teratogenicity in rodent models.

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## 1. Introduction

Early stage of pregnancy is usually associated with a variety of symptoms, including intermittent nausea and emesis [30]. Approximately 80% of pregnant women experience nausea and vomiting [1,16,38] especially during the first trimester [37]. A broad variety of remedy is proffered and employed in the management of nausea and its associated emesis [17] during gravidae. Geophagy, the consumption of earthen materials, is a common type of pica across several cultures in many continents [52], including Sub-Saharan Africa countries e.g., Nigeria, Tanzania, Ghana, Kenya, South Africa. [44,45] In the Southern part of Nigeria, geophagy is believed to help in relieving nausea and emesis associated with pregnancy. Eko and Omumu (local names of specific baked earthen materials) and other

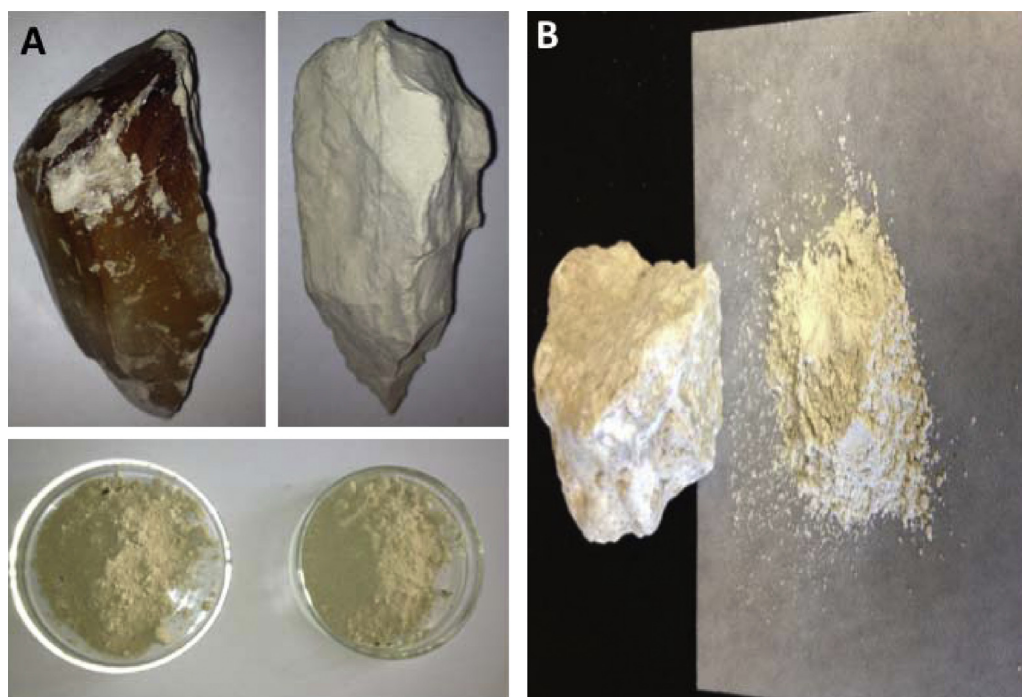
forms of geophagic materials are commonly consumed to manage nausea [43,44]. Consumption of Eko and Omumu is generally considered safe by tradition and folklore medicine without the benefit of scientific enquiry as to their content and the presumed short-term benefit of nausea relief. Metals occur naturally in the earths crust and as such present in geophagic materials consumed [21] in different proportions depending on the source of these material [34]. It is therefore imperative to conduct investigations, using modern analytical tools, to ascertain the nature and constituents of geophagic materials consumed during pregnancy [22,23].

Exposure to various forms of environmental contaminants during pregnancy [39] can only be exacerbated by geophagy as a result of the toxic elements that may be present in geophagic materials [10,45] in addition to potential risk from helminthic and other infection [27,36] that can result from this practice. Although the effect of geophagy on maternal and fetal health remains inconclusive as a result of disparate findings from some studies, [10,43,44,52] other researchers have however concluded that geophagy is deleterious to fetal and maternal health [14,24,33–35]. Specifically, intrauterine exposure to toxic metals from geophagic

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**Fig. 1.** Photomicrograph of Eko and Omumu: (A) Eko baked surface (brown) and the inner core (gray) top section and pulverized Eko in petri dishes prior to digestion bottom row. (B) Whole and pulverized Omumu.

materials, depending on quantity [44] and time of exposure, may carry teratogenic risk during organogenesis [15]. This may also adversely affect fetal development through epigenetic regulation [47] resulting in congenital malformation and further complicate pregnancy overall [32,33]. Results from several studies have suggested that dysregulation of epigenetic mechanisms, such as DNA methylation pattern and histone posttranslational modification marks, may play a role in metal-induced carcinogenesis [13,46]

The objective of the study herein described is to determine the total metal ions present in Eko and Omumu (Fig. 1) with emphasis on critical metals under different mild digestive conditions (neutral, acidic and basic) as encountered in the human biological system. We compared the observed metal concentrations relative to the maximum tolerable daily intake and the Millennium Contaminant Level Goals (MCLG) set by the United States Environmental Protection Agency (USEPA). Importantly, we detected unacceptably high levels of aluminum in Eko and Omumu, at concentrations >10-fold greater than the highest desirable levels set by the USEPA. Other metals and metalloid found in high or close to the MCLG levels are antimony, arsenic, beryllium and lead. Finally, we discussed the potential impact of the gestational exposure of these metals, beyond acceptable exposure levels, on maternal and fetal health.

## 2. Materials and methods

### 2.1. Sources of Eko and Omumu rocks

Eko and Omumu were sourced from the South-south region of (Sapele) Nigeria from open source market stalls. They samples were unpacked and can be easily identified by the sellers and buyers/users familiar to Eko and Omumu, although further information of the source can be provided by the merchants. Five representative samples of Eko and Omumu were purchased weighed between 100 and 150 g each. The Samples was properly packed in zip-lock bags to avoid any contamination, pulverized into fine powder with a mortar and pestle. The rest of this batch of Eko and Omumu pur-

chased were preserved for further studies. Samples of whole and pulverized Eko and Omumu are shown in Fig. 1.

### 2.2. Sample Preparation for Inductively Coupled Plasma Optical Emission Spectroscopy (ICPS-OES) analyses. Representative procedure described for Omumu. The same procedure was used to prepare Eko

A chunk of Omumu rock (approx. 2 g) was grinded into fine powder using a mortar and pestle. Separately, 25 mg of Omumu powder was dispensed into three sterile 50 mL Falcon tubes and to each tube was added the following solvent: the first (1) tube dilute HCl (0.01 M, 25 mL), the second (2) tube dilute  $\text{NH}_4\text{OH}$  (0.01 M, 25 mL) and the third (3) tube Milli-Q water (25 mL). These conditions simulate the environments within the digestive tracts (mildly acidic – stomach, and mildly basic – small intestine) and the plasma (neutral pH) in normal human physiological state. Although some other works on geophagic materials have been done with samples digested using harsher chemical conditions (e.g., Aqua regia or 1N acidic) [22,23]. These harsher conditions are far from what is obtainable in a normal state, including during pregnancy, as they will digest almost all metals from their covalent combination state in Eko and Omumu, consequently overstating the exposure levels of metals in geophagic materials so treated.

Each sample was incubated on a rocker at room temperature for 24 h and thereafter centrifuged at  $13.2 \times 10^3$  RPM for 5 min. Supernatants (10 mL) were then collected from each sample for ICP-OES analyses.

### 2.3. ICP-OES analyses

The ICP-OES experiments were performed at the CAIS/Chemical Analysis Lab, University of Georgia, Athens, GA. The USEPA standardized method 6010C method [6,26,49] was used to generate all the ICP-OES data therein presented. The concentrations of the metal ions in both samples are reported in parts per million (Table 1).

**Table 1**  
Metal levels in Eko and Omumu assayed by Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). The digestion conditions and the emission wavelengths of each metal are indicated at the top panel. Data is presented in parts per million (ppm).

Samples		EKO			Omumu			
Digestion condition		Acidic 0.01M HCl (1)	Alkaline 0.01M NH <sub>4</sub> OH (2)	Neutral DI H <sub>2</sub> O (3)	Acidic 0.01M HCl (1)	Alkaline 0.01M NH <sub>4</sub> OH (2)	Neutral DI H <sub>2</sub> O (3)	
Elements	Emission spectra							
1	Silver (Ag)	328.06	<0.001	<0.001	0.000	0.000	0.006	0.001
2	Aluminum (Al)	396.15	0.395*	0.700 <sup>#</sup>	0.004 <sup>§</sup>	0.535	0.283	0.147
3	Arsenic (As)	188.79	<0.001	0.002 <sup>#</sup>	0.006 <sup>§</sup>	0.009*	0.007 <sup>#</sup>	<0.001
4	Boron (B)	249.67	0.032	0.001	−0.007	0.239	0.152	0.187
5	Barium (Ba)	233.52	0.075	0.001	0.011	0.004	0.002	0.001
6	Beryllium (Be)	313.04	0.004*	0.000	0.000	0.001	0.000	0.000
7	Bismuth (Bi)	223.06	<0.001	<0.001	<0.001	0.004	0.004	<0.001
8	Calcium (Ca)	317.93	0.398	0.005	0.046	4.000	2.341	2.267
9	Cadmium (Cd)	228.80	0.000	0.000	<0.001	0.000	0.002	0.001
10	Cobalt (Co)	228.61	0.005	0.001	0.000	0.001	0.000	0.000
11	Chromium (Cr)	267.71	0.000	0.001	0.000	0.000	0.002	0.000
12	Copper (Cu)	327.39	0.004	0.000	0.001	0.000	<0.001	<0.001
13	Iron (Fe)	238.20	0.613	0.142	0.002	0.319	0.135	0.115
14	Gadolinium (Gd)	342.24	0.012	0.001	0.000	0.001	0.000	0.000
15	Potassium (K)	766.49	<0.001	0.163	0.216	40.724	29.654	32.287
16	Magnesium (Mg)	285.21	0.299	0.008	0.081	0.343	0.068	0.070
17	Manganese (Mn)	257.61	0.056	0.002	0.010	0.026	0.003	0.002
18	Molybdenum (Mo)	202.03	<0.001	0.001	0.001	0.001	0.002	0.004
19	Sodium (Na)	589.59	<0.001	<0.001	<0.001	257.63	188.387	209.984
20	Nickel (Ni)	231.60	0.010	<0.001	0.000	0.000	0.000	<0.001
21	Phosphorous (P)	213.61	0.047	0.012	<0.001	1.063	0.763	0.884
22	Lead (Pb)	220.35	0.003*	0.002 <sup>#</sup>	−0.006	0.004	0.005	−0.004
23	Antimony (Sb)	206.83	0.001*	0.002 <sup>#</sup>	−0.003	0.010	0.001	0.006
24	Selenium (Se)	196.02	<0.001	<0.001	0.014	<0.001	<0.001	0.003
25	Silicon (Si)	251.61	0.542	5.588	0.198	0.673	1.742	1.312
26	Tin (Sn)	189.92	<0.001	<0.001	<0.001	<0.001	0.001	<0.001
27	Strontium (Sr)	421.55	0.008	0.000	0.001	0.035	0.014	0.015
28	Titanium (Ti)	336.12	<0.001	0.035	0.003	0.002	0.008	0.009
29	Vanadium (V)	290.88	0.001	0.014	<0.006	0.016	0.010	0.006
30	Zinc (Zn)	206.20	0.060	0.001	0.000	0.014	0.001	0.000

Notes: ICP-OES analysis for critical metals; Eko: Al: 1 = 0.395 ppm (395 ppb)\*; 2 = 0.700 ppm (700 ppb)<sup>#</sup>; 3 = 0.004 (4 ppb)<sup>§</sup>. As: 2 = 0.002 ppm (2 ppb)<sup>#</sup>; 3 = 0.006 ppm (6 ppb)<sup>§</sup>. Be: 1 = 0.004 ppm (4 ppb)\*. Pb: 1 = 0.003 ppm (3 ppb)\*; 2 = 0.002 ppm (2 ppb)<sup>#</sup>. Sb: 1 = 0.001 ppm (1 ppb); 2 = 0.002 ppm (2 ppb). Omumu: Al: 1 = 0.535 ppm (or 535 ppb); 2 = 0.283 ppm (or 283 ppb); 3 = 0.147 (147 ppb). As: 1 = 0.009 ppm (9 ppb); 2 = 0.007 ppm (7 ppb). Be: 1 = 0.001 ppm (1 ppb). Pb: 1 = 0.004 ppm (4 ppb); 2 = 0.005 ppm (5 ppb). Sb: 1 = 0.010 ppm (10 ppb); 2 = 0.001 ppm (1 ppb) 3 = 0.006 ppm (6 ppb). Limit of detection (LOD) = 0.001.

The highest desirable level of Al = 0.05 ppm (50 ppb) [51], the United States Environmental Protection Agency (USEPA) standard for As in drinking water is 0.010 ppm (10 ppb), Millennium Contaminant Level Goals (MCLG) is 0 ppb [7]. The MCLG for Be = 0.004 mg/L (4 ppb) [2,8], and the MCLG set by USEPA for Pb = 0 ppm [5]. The MCLG for Sb is 0.006 (6 ppb) [9].

### 3. Results and discussion

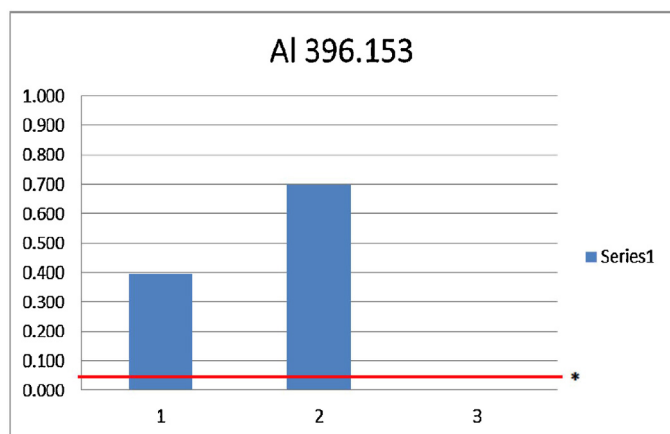
While some metals ion were not detected at any considerable levels, metal ions of critical importance to maternal health and fetal development in utero were found to be present at higher levels (Table 1). These metal ions are aluminum, arsenic, beryllium, lead and antimony.

In a sample dependent manner, we observed that the digestion conditions significantly impacted the availability and quantity of metals detected. Alkaline digestion of Eko resulted in more aluminum (0.70 ppm) while acidic digestion of Omumu released more aluminum (0.54 ppm) (see Table 1). Of great concern is the fact that the detected levels of aluminum were relatively higher than the stipulated conditions set by the USEPA for safe threshold of human exposure and maximum contaminant levels (0.05 ppm (50 ppb)) [51]. Arsenic was detected at neutral and alkaline pH in Eko (0.006 ppm & 0.002 ppm, respectively); in acidic and alkaline pH in Omumu (0.009 ppm and 0.007 ppm, respectively) while not detectable at neutral pH in Omumu and in acidic pH in Eko. Beryllium was detected only at acidic pH in both samples (Eko: 0.004 ppm and Omumu: 0.001 ppm). Lead

and antimony were detected in Eko under acidic (0.003 ppm and 0.001 ppm, respectively) and alkaline (0.002 ppm and 0.002 ppm, respectively) digestion conditions but were not detectable at neutral pH. Similarly, lead was detected in Omumu only under Acidic (0.004 ppm) and alkaline (0.005 ppm) conditions, while antimony was detected under acidic, alkaline and neutral pH conditions (0.010 ppm, 0.001 ppm, and 0.006 ppm, respectively). The detected amounts of these elements are higher than or equivalent to the levels (Pb = 0 ppm, Sb is 0.006) set by the USEPA for safe threshold of human exposure and maximum contaminant levels [9].

The metals that we detected to be present in high levels in Eko and Omumu have been implicated in a plethora of disease conditions. We speculate that the geophagic exposure to such high levels of these metals may be detrimental to the health of the mother and the developing fetus. Exposure to aluminum [28,29,51] and lead [11,18,20,40] in quantities above the USEPA set levels has been widely reported to cause toxicity in fetuses and adults. In fact, the USEPA set MCLG for lead is 0 ppm, underscoring the need for lead to be completely eradicated as any form of contaminants in items humans is exposed to. The measured levels of lead in Eko and Omumu, 2–6 ppb (Table 1), are obviously unacceptable. Arsenic is also quite notorious for its toxicity [10,19] in adults and fetuses. The USEPA has set the arsenic standard for drinking water at 0.010 ppm (10 ppb) while the permissible arsenic MCLG is 0 ppm. Although arsenic contents of Eko and Omumu are lower than the USEPA standard for arsenic in drinking water is (0.010 ppm), it is worthy to note that they are still higher than the MCLG of 0 ppb [12]. This anticipated total eradication of arsenic as a contami-

## Aluminum Content of Eko



\* Highest Desirable Level of Aluminum = 0.05 ppm

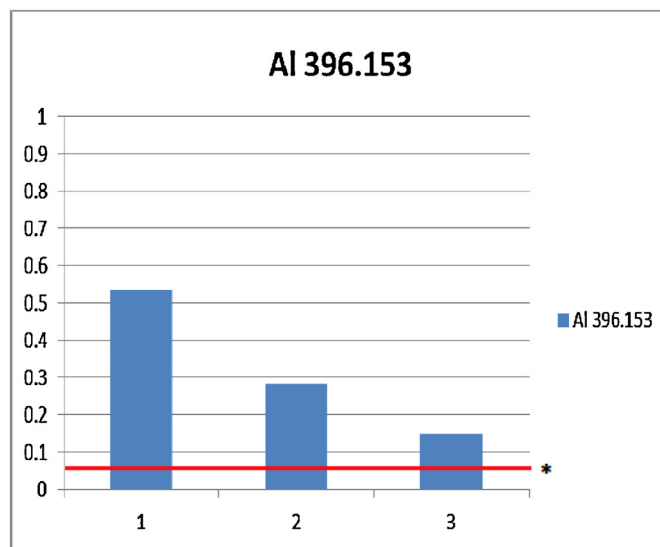
**Fig. 2.** Bar graph showing the aluminum content in Eko, digested under different conditions of pH, (x-axis) 1 = acidic (0.01 M HCl), 2 = basic (0.01 M NH<sub>4</sub>OH) and 3 = neutral condition (Millipore deionized water), relative to the highest desirable level (y-axis) (red line) set by the USEPA and the European Union [51]. aluminum concentration was highest under basic digestion condition in Eko and >10-fold in excess of the desirable limits. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

nant further highlights its toxicity to exposed human populations [3,4] and the need for zero contamination. Occupational exposure and polluted water source caused massive arsenic poisoning in Bangladesh. This has been described as the largest poisoning of a population in history [48] with its associated risk including endocrine disruption to carcinogenesis [12]. Earlier reports have presented evidence of geophagic arsenic exposure [10], showing the arsenic content in Sikor, a form of geophagic material widely consumed by Bangladeshi women living in Bangladesh and in the diaspora, exceed the permitted maximum tolerable daily intake (PMTDI) by over two fold ([4]; Agency). Consequently, fetal and maternal exposure to arsenic from Eko and Omumu during pregnancy should be of concern. Although the amount of arsenic present therein is lower than the drinking water standard, consumption over time may result in bioaccumulation and increases bioavailability of this toxic metal that may be teratogenic to the fetus even if the mother is less susceptible.

Our analysis indicated that the beryllium levels in Eko, digested under acidic pH, is the same as the USEPA set MCLG of 4 ppb with no detectable amount in the same sample digested under alkaline and neutral conditions. In contrast, Omumu has very low beryllium levels, containing only 1 ppb when digested under acidic digestions. The MCLG for antimony is 6 ppb. We detected antimony at 1 ppb at the lowest limits in Eko and 6 ppb in Omumu at neutral pH (Table 1). Both beryllium [31,41] and antimony [42,50] have been reported to exhibit various toxic effects and are suspected carcinogens. Clearly, the levels of these metals in Eko and Omumu are unacceptably high.

The drinking water standards set out by the USEPA for aluminum specify a 'highest desirable level' of 0.05 ppm (50 ppb) [25]. Our assessment of Eko and Omumu indicated a very high concentration of aluminum in both samples under the different digestion conditions. An upper limit of approximately 14-fold higher than what is recommended was recorded for Eko under alkaline digestion, and lower limits of over 8-fold in Eko digested in acidic medium (Fig. 2). On the other hand, aluminum appears to remain slightly within the recommended levels of 50 ppb in Omumu digested in acidic condition but insignificant in alkaline and neutral pH conditions (Fig. 3). On absorption aluminum accumulates in bone, brain, liver and kidney with the bone being the major site of accumulation in humans

## Aluminum Content of Omumu



\* Highest Desirable Level of Aluminum = 0.05 ppm

**Fig. 3.** Bar graph showing the aluminum content in Omumu, digested under different conditions of pH, 1 = acidic (0.01 M HCl), 2 = basic (0.01 M NH<sub>4</sub>OH) and 3 = neutral condition (Millipore deionized water), relative to the highest desirable level (red line) set by the USEPA and the EU [51]. aluminum concentration was highest in Omumu digested under acidic condition and >10-fold in excess of the desirable limits. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

[51]. Chronic aluminum toxicity manifest as defects in the musculoskeletal and hematopoietic (microcytic hypochromic anemia) system. Amongst others, the preterm infant is at an elevated risk of systemic aluminum intoxication [51] with neurological effect ranging from speech difficulty to multi facial seizure. It has also been reported that exposure to excess aluminum can lead to development of dementia in children. It is possible that this could be a major problem especially if fetuses are exposed in utero [33].

Based on the foregoing, continuous exposure to Eko and Omumu during pregnancy, as a means of reducing nausea, is not desirable. The intrauterine exposure to the levels of the toxic metals herein identified may portend serious deleterious health consequences to the fetuses that may neither be apparent nor linked, in the long run, to challenges manifesting from their prenatal exposure to geophagic materials. Also, aluminum toxicity can impact maternal health as well. Therefore, geophagic consumption of Eko and Omumu should be discouraged or out rightly discontinued for the long-term benefit of both maternal and child health. Public awareness and campaign in prenatal clinics should emphasize the implicit dangers of indulging in Eko and Omumu geophagy.

## Conflict of interest

The authors declare there are no conflicts of interest in the reported study.

## Acknowledgement

Dr. Ruth Oyelere is sincerely appreciated for the design and illustration of the graphs and figures in the manuscript.

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