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Determination of essential and toxic elements in clay soil commonly consumed by pregnant women in Tanzania

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HIGHLIGHTS

- We assessed exposure of heavy metals to pregnant mothers who consume geophagic soil.
- We analyzed 100 samples of soil originated in Tanzania.
- The technique used was energy dispersive X-ray fluorescent.
- Essential and toxic elements were detected in concentrations above WHO limits.
- Hence, geophagy is exposing pregnant mothers and their children to metal toxicity.

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ABSTRACT

A habit of eating clay soil especially among pregnant women is a common practice in Tanzania. This practice known as geophagy might introduce toxic elements in the consumer's body to endanger the health of the mother and her child. Therefore it is very important to have information on the elemental composition of the eaten soil so as to assess the safety nature of the habit. In this study 100 samples of clay soil, which were reported to be originating from five regions in Tanzania and are consumed by pregnant women were analyzed to determine their levels of essential and toxic elements. The analysis was carried out using energy dispersive X-ray fluorescent technique (EDXRF) of Tanzania Atomic Energy Commission, Arusha. Essential elements Fe, Zn, Cu, Se and Mn and toxic elements As, Pb, Co, Ni, U and Th were detected in concentrations above WHO permissible limits in some of the samples. The results from this study show that the habit of eating soil is exposing the pregnant mothers and their children to metal toxicity which is detrimental to their health. Hence, further actions should be taken to discourage the habit of eating soil at all levels.

1. Introduction

Geophagy is a human behavior common among pregnant women involving the ingestion of earthy substances such as soil and clay. Several studies agree that this behavior is rooted from evolution and is common among animal kingdom (Gilardi et al., 1999; Mahaney et al., 1996). The reasons for soil ingestion are not scientifically supported however; the habit is believed to be influenced by traditional, physiological, psychological, medicinal, cultural and religious beliefs (Hooda et al., 2004). For instance, in some parts of Africa, soil ingestion is considered to be medicinal for childbearing and for treatment of diarrhea and intestinal parasites (Hunter, 1973; Vermeer and Ferrell, 1985). Several studies have associated the cation exchange capacity (CEC) of the ingested soils with the properties of clay to control diarrhea which is attributed to the surface area and water retention capacity of the clay soil (Mahaney et al., 1996). Geophagy around the world can also be linked with deficiency of essential nutrients in human metabolism (Hooda et al., 2002). Iron (Fe) deficiencies which lead to anemia is thought to be a reason which attract pregnant and lactating woman to consume soil (Lanzkowsky, 1959; Danford, 1982). In Tanzania, this habit is practiced in many regions and common among lactating and pregnant woman. The clay soil which is made into a shape of a sausage is sold in markets across the country in places such as Kariakoo, Kilombero and Ngamiani in Dar es Salaam, Arusha and Tanga Regions, respectively.

Despite of all reasons that elucidate the motivation of soil eating practice, the concentration of metal consumed by geophagic individuals remain unknown. Therefore, quantification of essential and toxic elements from geophagy is important to assess the safety of the practice in the country.

2. Materials and methods

Hundred samples of soil sausages each of about 40 g were purchased at Kariakoo, Kilombero and Arusha main markets.

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The samples which were reported to originate from Kigoma and Morogoro were purchased at Kariokoo market, those from Arusha and Kilimanjaro regions were bought at the main market in Arusha and those from Pemba were purchased in a market in Tanga region. The samples were identified by vendors as commonly eaten by pregnant women. Section 2.1 shows the regions where the soil samples are originating.

2.1. Map 1

In the laboratory, the soil was oven dried at 60 °C for 2 days until a constant weight was achieved. The dried samples were disaggregated with mortar and pestle and sieved through 0.5 mm polystyrene sieve and kept in well labeled polythene bags. A dry weight of 12 g of soil sample with 2.7 g of cellulose binder were thoroughly mixed, homogenized and be compressed into pellets of diameter of 32 mm to give reproducible irradiation and counting geometry. The elemental analyses of samples were conducted using a bench top energy dispersive X-ray spectrometer of TAEC in Arusha. The machine which is operated by automated turbo-quant X-lab ProTM software was operated at a rate of 50 W and 50 kV voltage and the florescent X-rays were collected by a Si(Li) detector having a resolution (FWHM) at Mn$K\alpha \leq 160$ eV. A spectrum run for 15 min gave a good continuity statistics and resolution of the peaks. The concentrations of individual elements were determined by using fundamental parameter method inbuilt in X-lab Pro computer software in which matrix effects was counted for. Quality control was carried out using IAEA soil 7, to verify the accuracy and reliability of the analytical data. Table 1 shows that the analyzed elements were within 13% accuracy.

3. Results and discussion

3.1. Minimum detection limit (MDL)

In this study the calculation of the MDL of each element was carried out using the turbo-quant method incorporated in the X-lab Pro software package. The following relation was used to determine the MDL values (Rousseau and Bouchard, 2005).

$$\mathrm{MDL} = \frac{3 \times C_i}{I_p - I_b}\sqrt{\frac{I_b}{T_b}} \quad (1)$$

where

T_b = Time used to measure background intensity
C_i = Concentration of the analyte
I_p = Peak intensity
I_b = Background intensity

The minimum detection limits of elemental concentrations in soil for EDXRF system used in this study are presented in Table 2.

3.2. Elemental concentrations in soil

The mean concentrations of essential elements and toxic heavy metals in clay soil originating from five regions in Tanzania are presented in Table 3.

3.2.1. Essential elements

As Table 3 shows, the ingested soils are a potential source of essential elements. The concentration of Fe was found to be higher in soils from Arusha and Kilimanjaro regions than soils from other regions. The lowest concentration of Fe was found in soil from Pemba. The Kilimanjaro and Arusha regions have high concentrations of Fe probably because their soils were developed from volcanic eruptions of several mountains in the regions. It is documented elsewhere that volcanic soil usually contains high concentration of Fe (Quantin, 2004; Garcia-Rodeja et al., 2004). Since this soil is eaten then it is important to compare the concentration of elements found in the soils with FAO/WHO permissible limits in food. The Fe concentrations found in the soils in this study were higher by the factor of 63, 459, 567, 752 and 699 for clay soil from Pemba, Kigoma, Morogoro, Arusha and Kilimanjaro, respectively, than the permissible level in food of 214 μg/g set by FAO/WHO (2001). Although the adequate iron intake is an important component in decreasing the incidence of anemia, high concentrations of Fe may lead to tissue damage, as a result of the formation of free radicals in the body (Gurzau et al., 2003).

The concentration of manganese (Mn) ranged from 120 ± 2.9 μg/g to 1215 ± 18 μg/g with lowest concentration for samples from Pemba and highest from Arusha. Manganese is an essential element which is present in metalloproteins, such as

Table 2
The minimum detection limit (MDL) in μg/g of the EDXRF system used in this study for elements in soil.

Elements	MDL	Elements	MDL
Ag	3.9	Mn	5.0
As	1.3	Ni	2.5
Bi	0.7	Pb	1.0
Cd	6.6	Se	0.6
Co	15.7	Sn	6.7
Cr	15.1	Th	1.0
Cu	2.1	U	2.8
Fe	5.0	V	31.5
Hg	1.4	Zn	1.1
I	18.5		

Table 1
Experimental and certified concentrations (μg/g ± SEM) of elements in reference materials IAEA Soil 7.

Element	Reference value(μg/g)	Experimental value	Element	Reference value (μg/g)	Experimental value(μg/g)
As	13.4 ± 0.9	14.1 ± 0.4	Mn	631 ± 4	647 ± 12
Al	47000 ± 21	43570 ± 40	Na	2400 ± 18	1700 ± 9
Ba	159 ± 9	155 ± 6	Ni	26 ± 3	26.5 ± 1.2
Br	7.0 ± 0.6	8.1 ± 0.5	P	460 ± 5	562 ± 12
Ca	163000 ± 62	161100 ± 231	Pb	60 ± 6	66 ± 1
Ce	61 ± 1	59 ± 2	Rb	51 ± 3	48 ± 2
Cr	60.0 ± 2.0	59.1 ± 0.6	Si	180000 ± 10	153400 ± 135
Cd	1.3 ± 0.1	1.2 ± 0.1	Sr	108 ± 4	103 ± 2
Cu	11.0 ± 0.7	12.6 ± 0.1	Th	8.2 ± 0.4	7.8 ± 0.9
Fe	25700 ± 85	26660 ± 44	Ti	3000 ± 13	3527 ± 28
Hg	0.04 ± 0.001	0.03 ± 0.1	U	2.6 ± 0.3	2.5 ± 0.7
K	12100 ± 45	11080 ± 14	V	66 ± 1	75 ± 2
Mg	11300 ± 39	7600 ± 22	Y	21 ± 0.6	24.5 ± 1.1