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Temporal lead contamination and health risks of geophagia in Eldoret Municipality, Kenya

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ABSTRACT

In Kenya, geophagic soils have been commercialised and are currently packaged and sold in supermarkets or sold in open markets where they are exposed for long periods to environments with high probability of contamination such as vehicular lead. This study assessed concentration levels of lead (Pb) at source (Gituro quarry, Eldoret) and temporal Pb contamination of exposed geophagic soils sold in open markets in Eldoret Municipality. The results showed that mean Pb levels in the soil samples were all above naturally occurring levels indicating contamination from environmental sources. Lead concentration was lowest at source, and ranged from 31.5 mg/kg – 41 mg/kg with a mean of 32.5±2.2 mg/kg - 37.5±2.1 mg/kg. Exposed soils had highest Pb concentration at Langas site with a range of 57.5 mg/kg - 98.0 mg/kg while Huruma, Municipal market (1), and Municipal market (2) sites ranged from 46.5 mg/kg - 73.5 mg/kg Pb, 36.5 mg/kg - 84.5 mg/kg Pb and 55.0 mg/kg - 66.0 mg/kg Pb respectively. Regression of Pb levels with time gave strong positive relationships indicating temporal Pb accumulation. Health risk assessment showed that geophagia is a potential health hazard especially for soils exposed over a longer time in the open market. Geophagic soils sold at the open markets should be avoided.

Keywords: soils, environment, vehicular emissions, consumption, effects

INTRODUCTION

Geophagia is the deliberate ingestion of soil that has been practiced for centuries. Though it occurs throughout the world and is found in both sexes of all age groups, the practice is nevertheless most dominant in children and expectant women. The reasons for this behaviour are poorly understood (Wiley and Katz, 1998) but suggestions indicate that psychological upsets and physiological changes during pregnancy could motivate geophagia. In modern human societies, the practice of geophagia represents a complex eating behaviour with an obscure aetiology including physiological, psychological, cultural, religious and medicinal beliefs. Different types of soil are preferred because of variations in tastes and individual peoples' cravings.

Pollution of the environment over and above the background levels by heavy metals such as Pb emanating from human activities is now a worldwide problem. After release to the environment, the heavy metals become available for soil reactions through a variety of processes such as cationic exchange and complexation with organic ligands depending on the soils pH, the availability of adsorption sites and ligand binding capacity (Abrahim, 2008).

About a quarter of the Pb added in fuels as additives is retained within the exhaust systems and engine oil of motor vehicles while the remainder is discharged via the exhaust mainly in form of fine particles of Pb compounds. Half of the Pb particulate matter falls to the ground and is dispersed in the soil while finer particles are dispersed in atmosphere and carried through considerable distances (Atkinson et al., 1999). Lead is naturally present in all soils, typically in the range of less than 10-30 mg/kg (EPA, 2001). The amounts in the top soil layers however vary widely and can be much higher due to human activities. Onyari et al. (1991) indicated that Pb levels in soils within the city of Nairobi ranged from 137 - 2196 mg/kg with a mean of 659 mg/kg due to vehicular emissions, while in industrial area, the levels ranged from 148 - 4088 mg/kg with a mean of 624 mg/kg. Roundabouts, bus stations and other areas of the city characterised by heavy motor traffic showed high values.

With elevated levels in the environment, Pb moves along various pathways of human exposure (Figure 1), enters the food chain and gains entry into the human body (Mushak, 1998). Once in the body, Pb has deleterious health effects including neurotoxic effects, anemia, maternal and neonatal lead poisoning, and kidney damage, affecting the entire body (Ellen, 1993). Hooda et al. (2002), studied *In vitro* effects of geophagia and noted that it can potentially reduce the absorption of nutrients such as Cu, Zn, Fe and Mg, a phenomenon that increases the bioavailability and adsorption of Pb in the gut. The diet of geophagic individuals is often high in phytate which, because of its nutrient binding ability, can potentially further decrease the bioavailability of Fe, Zn and other nutrients (Lebrón, 2007). In a cross sectional study in an antenatal clinic at Kilifi district hospital in Kenya, Geissler et al. (1999) reported low Fe status and anaemia among 56% of pregnant women who practiced geophagia. Geophagic materials are also associated with transmission of worms and thus, geophagia poses health risks to consumers (Sera et al., 2004).

The prevalence of geophagia is unknown because the disorder is often unrecognised and underreported. In addition, reported prevalence rates vary depending on the characteristics of the population sample and the methods used for data collection (Yao, 2006). Individuals who practice geophagia normally withhold the information regarding it as a secret and often deny when questioned. A reluctance to report the practice and its secretiveness on the part of patients frequently interferes with accurate diagnosis and establishment of prevalence (Horner et al., 1991). Soil ingestion by geophagic individuals is however highly variable; reports range from a few grams to 300 g per day (Simon, 1998) leading to variations in Pb exposure levels. This study determined temporal Pb contamination levels in geophagic soils arising from exposure at selected geophagic soil vendors in Eldoret municipality and assessed health risks associated with ingestion of Pb.

MATERIALS AND METHODS

Study sites

A preliminary study was done and involved determination of the sources (control) of geophagic soils sold in Eldoret Municipality. This was done by administering structured questionnaires to randomly selected soil vendors in the town. A visit was made to Gituro quarry, which is the major source of the geophagic soils. Gituro quarry is located about 4 km to the North of the central business district of Eldoret town, Uasin Gishu district in Rift Valley Province of Kenya, latitudes 0° 25'; 0° 31' N, and longitudes 35° 00'; 35° 17' E of Greenwich (Figure 2). The quarry measures approximately 1 km^2 and it is excavated mainly for construction materials – bush stones and ballast. Geophagic soils are excavated within the quarry from shallow open pits (1 m deep) of approximately 100 m^2. The soils are excavated and sized using hoes and transported to the markets in gunny bags.

Geology of the soils

The geology of the study area falls under volcanic system mainly constituting of volcanic rocks of tertiary age. The volcanic rocks are mainly of alkali type constituting of phonolites of the lower Uasin Gishu phonolite, and their pyroclastic equivalents (Jones and Lippard, 1979). The phonolites are aphanitic and blue-black in colour, with a pilotaxitic texture mainly consisting of aegirine, cossyrite and kataphorite with microphenocrysts of elongated soda – orthoclase feldspars and accessory granules of apatite and iron ore.

Soils covering the phonolites are relatively thin with a friable texture. The soils are mainly brown loams occurring as platy particles in fine grained aggregates.

Soil sampling

Geophagic soils recipients in the markets namely Huruma, Langas and Eldoret Municipal market (Figure 2), were identified. Huruma and Langas residential estates were selected due to their high population density, whereas the main municipal market was selected since it acts as the main source of supply for other retailing soil vendors in most residential estates besides other consumer goods. Local women soil miners at the quarry were also identified, and based on their experience, two sampling sites were purposely selected based on soils characteristics (peoples' popularity craving and sour tastes).

The quarry soil types were collected in bulk using the same tools as the soil diggers, and dispatched to the pre-determined market vendors for determination of temporal Pb contamination in the markets. Soils with popular craving taste were supplied to one vendor each at Huruma estate, Langas and the Municipal market (1) respectively. The sour taste soils were supplied to second vendor at the Municipal market (2). The soils were exposed to the market conditions and not sold. From the unexposed Gituro quarry soil types (control), approximately 0.5 kg each, in duplicate, were sampled for determination of Pb concentration at source.

Sampling and analysis of geophagic soils was done fortnightly for a period of three consecutive months beginning from the month of June 2007 to August 2008. All the supplied quarry soil types were exposed to the same market vendors handling for the entire sampling period. A total of 60 samples, that is, 12 replicates from each of the five studied sites, were collected and analysed

Laboratory and analytical methods

The soil samples were oven dried at 55°C to constant weight and passed through a 0.2mm aperture sieve. Two soils weighing 2.0gm were taken from sub-samples of each sampling site and accurately measured into digestion flasks. Ten millilitres of 69% nitric acid (analar grade) was added and the mixture shaken gently for 2 minutes. Four millilitres of concentrated hydrochloric acid (analytical reagent grade) was then added while continuing to shake. The mixture was transferred to a hot plate and heated for about 2 hours while controlling the temperature at 70°C until no more brown fumes evolved. Nitric acid was added whenever necessary to avoid the samples running dry. The heating was continued until a pale brown colour resulted indicating digestion was complete (Lewis and McConchie, 1994).

The digests were cooled and extracts filtered through a 0.45 µm filter paper into a pre-washed measuring cylinder. The residue on the filter papers was washed three times with de-ionised water and filtrate made to the 100 ml mark with de-ionised water. Lead concentration in the digests was determined using an Atomic Absorption Spectrophotometer; Spectre F-AAS model Spectre AA 100/200 (IPCS, 1992).

Soil Pb concentration in mg/kg was calculated from the mg/l results by using the following formula:

Metal concentration (mg/kg) = (A × B) ÷ g (sample weight),

where: A = Concentration of metal in digested solution (mg/l) and B = final volume of digested solution (100 ml).

Standard solutions were prepared by dissolving 1g of 99.99% pure standard of Pb into 1:1 nitric acid: de-ionised water by volume and made to 1000 ml mark. This was used as stock solution to prepare 0.5, 1 and 2 ppm respectively of Pb metal for instrument calibration. De-ionised water was used to prepare blanks. Calibration of AAS was repeated after every 10 samples to ensure reliability of the results. Data was analysed by using 2-way ANOVA to determine significance (at 95% confidence level) of variation of means in relation to time and sites.

RESULTS

Lead concentrations of geophagic soils at source

Lead concentrations in geophagic soils collected from Gituro quarry (source) are summarized in Table 1. Least Pb concentration levels in popular graving soils were 31.5±1.7 mg/kg at sites GP_2 and were relatively high with mean of 37.5±2.1 mg/kg at site GP_3. The sour taste mean soil Pb concentrations were 39.5±3.3 mg/kg at GS_1 and 41.0±5.1 mg/kg at site GS_2. As is evidenced in Table 1, the sour taste soils with relatively higher lead concentrations were more acidic (low pH).

However, comparison of means by ANOVA showed no significant difference ($P > 0.05$) in the Gituro quarry soil Pb concentrations. Calculated mean concentration of Pb in bulked popular craving and sour geophagic soils at source were 34.5±3.2 mg/kg and 40.25±4.1 respectively. These were above the EU 'normal' soil concentration values that range from less than 10-30 ppm Pb (EPA, 2001).

Upon exposure at the four market sites, all supplied geophagic soil samples (100%) acquired significant amounts of Pb over and above the naturally occurring levels with time (Figure 3). A 2-way-ANOVA test of significance indicated that time ($F=43.071$, $P=0.000$, $\alpha=0.05$) and site factors ($F= 10.625$, $P=0.000$, $\alpha=0.05$) had significant effects on enrichment of Pb in the market exposed geophagic materials. Tukey's Post hoc test of homogeneity showed that geophagic soil samples from Langas were contaminated more than the soils from other experimental sites.

Table 1: pH and mean Pb concentration levels for unexposed popular craving and sour soil samples from Gituro quarry.

Sample	GP_1	GP_2	GP_3	GS_1	GS_2
pH	6.43	5.85	5.33	5.05	5.80
Pb (mg/kg)	32.5 ± 2.2^a	31.5 ± 1.7^a	37.5 ± 2.1^a	39.5 ± 3.3^a	41.0 ± 5.1^a

Values of Pb are Mean ± SD of 12 determinations; a = no significant difference within 95% confidence level; Pb = lead ; GP_1 = Gituro Popular soil site one; GP_2 = Gituro Popular soil site two; GP_3 = Gituro Popular soil site three; GS_1 = Gituro Sour soil site one; GS_2 = Gituro Sour soil site two.

Table 2: Amount of Pb taken by persons practicing geophagia and their percentage to PTWI for popular craving soils.

Pb concentrations in soil (mg/kg)		Amount of excess Pb per week (µg)	Calculated PTWI	% of heavy metal to PTWI Pb
Least	36.5	784.4	13.1	52.4
Highest	98.0	18650.1	310.8	1243.2

PTWI = Provisional Tolerable Weekly Intake

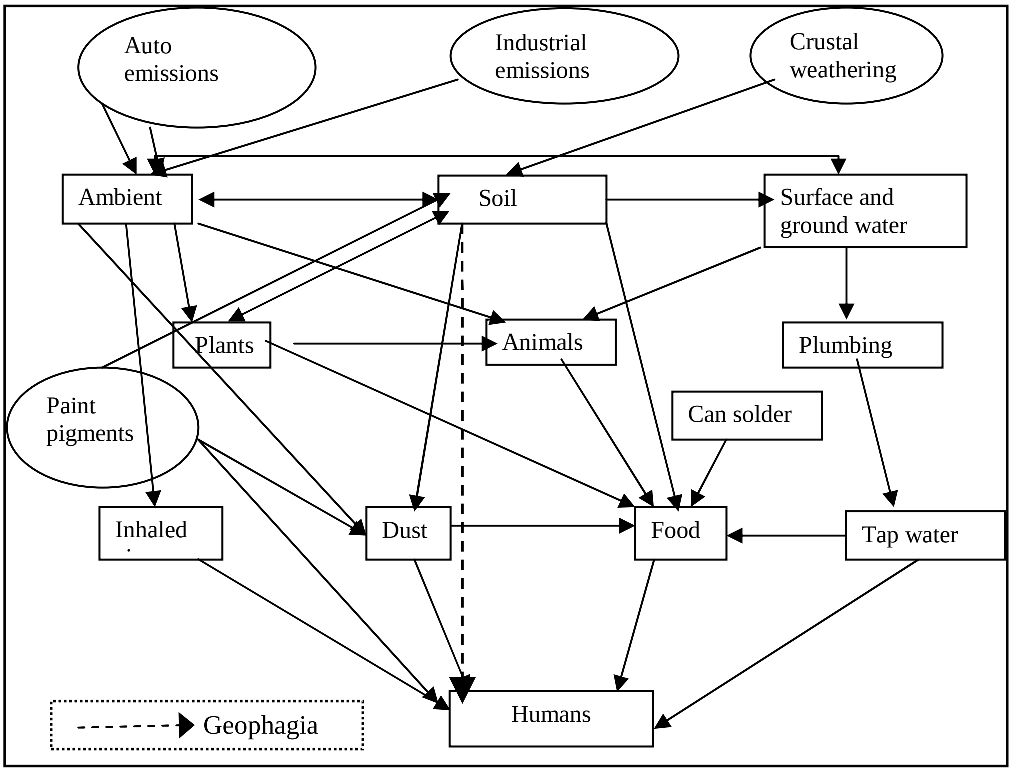

Figure 1: Flow scheme for Pb in the environment along pathways for human exposure. Adopted from Mushak (1998).

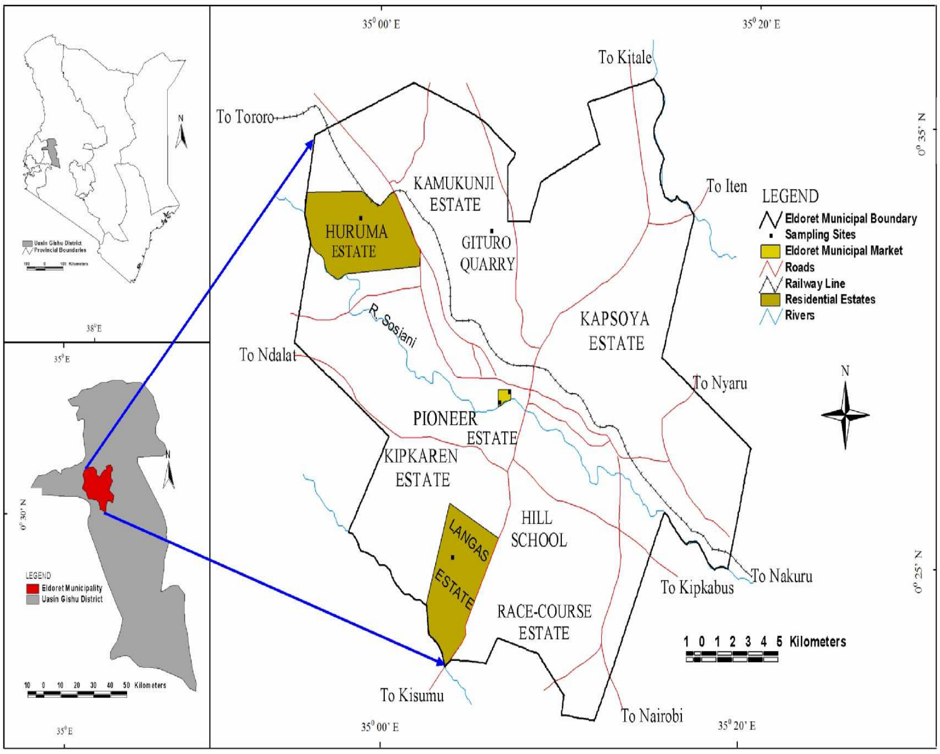

Figure 2: A map of Kenya showing Uasin Gishu district, and the location of the study areas in Eldoret Municipality and Gituro Quarry (source of the study geophagic soils).

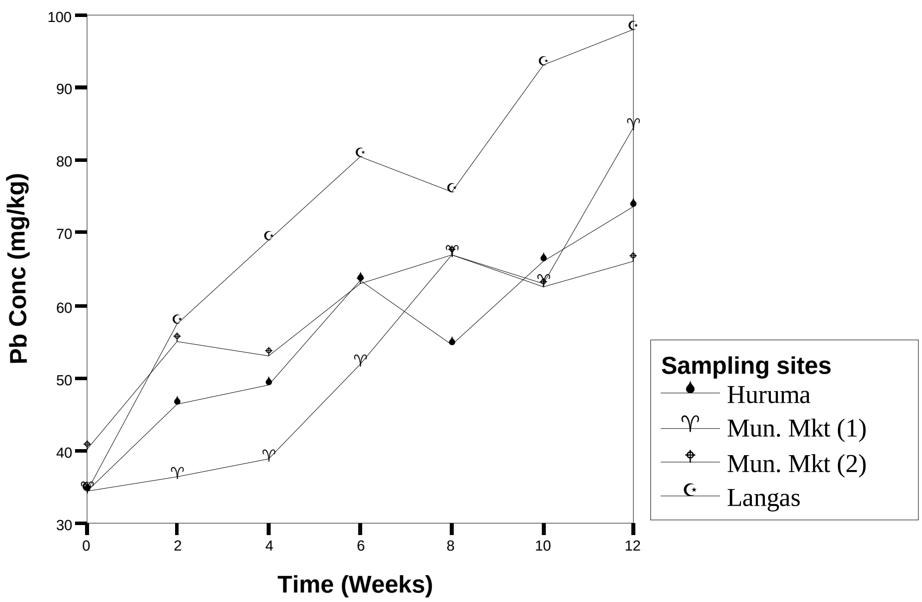

Figure 3: Temporal variations of Pb concentrations in exposed geophagic soils supplied to vendors at selected sites in Eldoret municipality.

Mun. Mkt (1) = Municipal Market site one; Mun. Mkt (2) = Municipal Market site two.

Figure 4: Exposed geophagic soils in Eldoret municipality.
Notice the proximity of the soils to the roadside.

DISCUSION

As evidenced from the study results, Pb concentration in geophagic materials at source are relatively higher than normal. However, the pb concentrations in Gituro geophagic soils are much less compared to polluted soils, for example, in Nairobi (mean of 659 mg/kg Pb) (Onyari et al., 1991). Conversely, the calculated means Pb concentration levels in popular craving and sour geophagic soils at source are attributable to natural geochemistry of the soils at the quarry. This is expected given the ubiquitous nature of Pb in the environment (NTDS, 2000). Exposure of geophagic materials exacerbates pb contamination levels as was established in Langas geophagic soil materials.

The steep rise of Pb levels (R^2 = 0.916) in samples from Langas is probably due to vehicular emissions, since this is a very busy town service bus terminus and geophagic soils are sold exposed at the road sides (Figure 4). According to Kunguru and Tole (1994) soils samples from road verges were contaminated with Pb, which they attributed to motor vehicle emissions. Furthermore, Jua Kali (Open-air Artisan Works) activities thrive at Langas site; Pb contamination from paints, especially due to dust could be a possibility.

Health risks

Continuous ingestion of Pb contaminated soils may be risky to human health particularly if consumption rates exceed the Provisional Tolerable Weekly Intake (PTWI). Soil ingestion by geophagic individuals however is highly variable; reports range from a few grams per day to 300g per day (Simon, 1998) leading to variations in Pb exposure levels. While information concerning permissible levels of Pb in geophagic soils is not yet available, geophagia is rampant and there is need to address its health implications.

Lead concentrations from analysed geophagic soils were used in risk analysis based on the assumptions that PTWI adopted from FAO/WHO recommendation is 25µg/kg body weight of Pb (IPCS, 1992; FAO/WHO, 1986), that average adult female weighs 60 kg), and that on average women consume 41.5 g/day of geophagic soils (Geissler et al., 1999). The human health risk assessment was estimated by comparing the metal intake from the consumption rate of geophagic soils with the PTWI.

The amount of Pb taken weekly by an adult person from the exposed geophagic soils (i.e. in excess of the soils Pb levels at source), was calculated according to Bernhard (1982) and Nyamari and Simiyu (2007).

The estimated geophagic exposures for Pb in µg/kg body weight, based on the least (36.5 mg/kg Pb, at Municipal market site 1) and highest (98.0 mg/kg Pb at Langas) concentration levels are presented in Table 2. The excess weekly Pb ingested from least contaminated geophagic soils at the vendors' stocks is 52.4% of the PTWI values, which is less by more than half. However, in case of the worst scenario, Langas site, the excess weekly Pb ingested significantly (1243.2%) surpassed the PTWI values. This indicated that exposed geophagic soils at the busy bus terminus could pose higher Pb health risks.

Whether there is no Pb health risk for the human consumption of geophagic soils at source may not be inferred with certainty since the percentage of Pb bioavailability was not determined. Similarly for geophagic soils or clays currently packaged and sold in supermarkets. Although they are less exposed to contaminating environments, their source and Pb concentration levels are uncertain. Thus, there could be a potential danger depending on the source and the amount of soils consumed from such markets. There is need for caution because according to NTDS (2000), there is no established "no effect level" for Pb in animals or humans and its ubiquitous nature precludes it from complete elimination from foods.

Conclusions

Results of this study showed that geophagic soils sold in Eldoret municipality open markets, particularly Langas estate, are contaminated with Pb. The Pb contamination could be emanating from environmental sources including vehicular emissions. The Pb concentrations levels in geophagic soils tended to increase with time of exposure and location of the sample in the market.

It is discernable that ingesting exposed soils sourced from an urban setting and close to roads characterised by heavy traffic is a potential health risk to consumers. Potential clinical implications associated with consumption of Pb contaminated geophagic materials, especially on expectant women and the unborn foetus should be assessed since they are most vulnerable considering prevalent geophagia among women. Packaging and healthy handling of geophagic soils is recommended to minimise Pb exposure risks for consumers. There is also need for education awareness to sensitise the public on risks of consuming geophagic materials.

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