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Role of Geophagy in Orally Acquired Helminthes and Toxic Metals Among Urban Population in Kenya

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Deliberate ingestion of soil/earth or geophagy, by humans is found in many societies worldwide including Kenya. Diverse reasons are attributable to geophagous habit. Physiologically, ingestion of geophagic material is believed to satisfy nutritional deficiencies of iron (Fe), calcium (Ca), Zinc (Zn) and other elements. However, health problems that may be associated with geophagy include helminthic infections, hypokalaemia, hypozincaemia, iron deficiency, tooth wear and intestinal blockage among others. This study was undertaken to quantify the risk of both helminthes and toxic metals associated with geophagy among Kenyan urban population. One (1.0) gram of each sample was digested in 1:1 HNO_3 in de-ionised distilled water and analysed for total metal content using atomic absorption spectrophotometer (AAS CTA 2000). Helminthes ova were recovered by sugar (S.G 1.300) floatation. Higher means (ova/120 g) were found in samples sold by street vendors in large towns, Nairobi (42.0), Eldoret (50.0), Kisumu (18.9) compared to supermarket (2.0) and rural (Rachuonyo 2.3) samples. Geophagic materials were also found to contain high levels of nutrients and non-nutrients pollutants minerals such as lead (Pb) and cadmium (Cd), negating possible nutritive benefits. Heat-treated (baked), packaged and hygienically handled geophagic materials had lower mean parasite ova/120 g.Geophagy as a practice thus predisposes to helminthes infestation and toxic metals. Proper packaging and hygiene of materials in question reduce risk associated with geophagy.

Key words: Geophagy; Pica; Geohelminthes; Hypokalaemia; Hypozincaemia and Toxic Metals

Introduction

Even though geophagy has been practiced for centuries, it is thought to predispose to a range of health problems, including parasitic infections, iron deficiency (Halsted, 1968; Danford, 1982), bowl disorders and perforations (Key *et al*., 1982 and Hooda *et al*., 2002) and nutritional dwarfism Prasad *et al*., (1961).

Geophagy is common among some expectant women and children in Kenya, as in other developing countries. Pica materials/rocks sold in supermarkets and by street vendors originate from rural areas surrounding major urban selling points, while some are imported from outside Kenya, sometimes as far as from Far East and Asia. In most cases, the selling of pica rocks by street vendors is done in situations where there are no sanitary facilities and generally in unhygienic conditions.

Pathogens commonly transmitted through consumption of contaminated food substances include; helminthes - *Ascaris lumbricoides, Trichuris trichuria, Necator americanus, Acylostoma duodenale, Enterobius vermicularis, Strongyloides stercolaris, Toxocara spp, and Taenia spp*., protozoan - *Entamoeba histolytica, Giardia duodinalis, Endolamix nana*, bacteria - *Salmonella typhi, Salmonella typhimurium, Shigella dysenteriae* and *Vibrio cholerae*. These pathogens flourish and persist where there is poverty, inadequate sanitation, limited resources for medical care and lack of health awareness and public education. The main mode of transmission of these parasites into the body is by faecal oral route, through the agency of food handlers and insect vectors such as the housefly (*Musca domestica*). Pica materials are usually handled and consumed without any form of prior decontamination and hygiene. It is therefore likely that this ‘rock food’ is vehicle of transmission for a variety of pathogenic organisms.

Rocks or lithosphere in general is an important repository of anthropogenic pollutants. Normally these rocks reflect elemental contents from other sources as well as those arising from their natural geological make up (Bailey *et al*., 1978). Therefore, toxic elements and helminthes may be inadvertently taken in with geophagy.

In a developing country like Kenya, intestinal parasitism is common among children and expectant mothers, but risk factors are not well characterized (Glickman *et al*., 1999). Past studies have implied a relationship between helminthes in school-going children and soil eating (Geissler *et al*., 1998a). Studies by Geissler *et al*., (1998b) in Kenya, indicate association of geophagia, anaemia, iron deficiency and helminthes infestation. Glickman *et al*., (1999) suggested that geophagy may in fact be an important risk factor for orally acquired nematode infestation in African children and other exposed people.

Currently, the nature of helminthes and toxic metal risks associated with geophagia in Kenyan urban population where trade in clay/rocks used in geophagia practice is wide spread is unknown. This study investigated the nature and extent of helminthes, toxic and nutritive elements used in geophagia in Kenya.

Materials and Methods

Pica materials were purchased from the main street vendors in urban centres in Kenya namely Nairobi, Kisumu, and Eldoret and one rural market town in Rachuonyo district. The towns are well apart but are well connected by road and other means of transport. Nairobi is both the largest and most populous with a population of about 3 million people. Anthropogenic and industrial activities lead to increased pollution. About two – thirds of the people in the city, live in poor social-economic circumstances and have geophagic tendencies are common. Eldoret represents a rapidly developing urban centre compared to both Nairobi and Kisumu, with a projected population of 700,000 by 2001 spread over 3218 km^2 (GOK, 1997). The town is surrounded by large-scale commercial agriculture of maize, wheat and horticulture. Kisumu town has a population of 280,000 people according to 1989 projections spread over 312 km^2. It is the largest and most important urban centre in western Kenya (GOK, 1997).

Rachuonyo district is a rural setting with little industrial and automobile pollution. Subsistence and commercial agriculture are the main occupation of inhabitants. Cultural and traditional beliefs that may predispose to geophagia are still strong. The district has a population of 249,639 people sparsely distributed over 931 km^2 and is projected to over 320,000 by 2001 (GoK, 2001). Sixty percent are below 20 years and there are more females than males in age groups 15 – 69 years (GoK, 1997).

Sampling sites

Participating vendors were located at Gikomba market, Kenyatta market and Kibera slums in Nairobi. In Kisumu, Kibuye market, Bus station open – air market and Nyahera, near the main quarry. In Eldoret vendors were along the main road in Langas and Huruma, and at Eldoret Municipal Market. In Rachuonyo, all the three vendors were located in and around Nyakwere market. The vendors were chosen based on their strategic locations in their respective market/street and business turn – over. In each case proximity among vendors was taken into account. Only well-isolated and unrelated vendors were recruited to minimize biased assessment.

In each study location, the vendors were sampled three times at monthly interval, each time in triplicate. The interval was aimed at determining any variation in parasitic load and general contamination of geophagic samples over dry and wet seasons. About 400 g of geophagic material was picked in triplicate at random from vendor's stock. Every time the vendor was allowed to handle the rock materials in his/her "usual" manner and pack the materials in cellophane bags (10 cm diameter). The samples were then placed in a second cellophane bag to eliminate chances of mixing and cross contamination and thereafter handled using gloves. Double packed samples were then labeled with name of town, site vendor, date and time of collection before transport to Centre for Biotechnology Research (CBRD), Kenya Medical Research Institute (KEMRI), Nairobi for parasitological investigations. About 150 g of geophagic materials from each sample was initially used. The remaining portion was used for elemental analysis at Chemistry Department, Moi University using Atomic Absorption Spectrophotometer (AAS) – CTA 2000. For AAS analysis, triplicate sets from a single vendor were bulked after digestion.

Sample preparation and analysis for metal elements

Total elemental analyses were carried out according to Mendham *et al*. (2000). Briefly, geophagic materials were dried in beakers in an oven at 105 ^oC for 24 h to remove excess moisture. Dried samples were ground thoroughly and sieved through < 0.5 mm sieve. One (1.0) gram of the finely ground sample was accurately weighed into 100 ml beakers. To each sample, 20 ml of 1:1 HNO_3 (spectrosol grade) was added. The mixture was heated to boil gently on a hot plate until the volume of the acid reduced to 5 ml. Twenty (20.0) ml of distilled de - ionized water was then added and boiled gently until the volume reduced to approximately 10 ml. The suspension was cooled before filtering through Whatman™ no. 540 filter paper and the residue and beaker rinsed with small portion of de – ionized water until a volume of 25 ml was obtained. The samples were then transferred into 50 ml volumetric flask, and diluted to the mark with de – ionized water. The samples were then analyzed for total metal (zinc, cadmium, iron, calcium, and lead,) content using AAS – CTA – 2000. The metals analysed are indicate below with the machine detection limits in parts per million (ppm) were: Pb (0.0005), Zn (0.004), Cd (0.0001), Ca (0.002), and Fe (0.005).

Helminthes ova Isolation and identification

In order to isolate helminthes ova from geophagic samples, sheather's sugar floatation technique were used (Sheather, 1923). Briefly, 120g of each sample of geophagic materials was placed in 40-ml floatation sugar solution of specific gravity (S.G) 1.300 in beakers using a pair of sterile forceps. The mixture was then stirred until thorough mixing for 1h, after which the sediments were filtered through fabric screen with 12 holes per centimeter into different containers to remove large particles. The filtrate was then centrifuged at 1500 rpm (microfufe™) for 5 minutes. A drop of the supernatant was then transferred from the centrifuge tube to a drop of water on a microscope slide using a headed glass rod, to ensure complete transfer of a drop, a headed glass rod held at 450^o and rotated in the drop of water on the microscope slide while avoiding contact of the slide. A cover slip was then carefully placed on the drop to eliminate the formation of air bubbles. Each slide preparation was systematically examined at X40 magnification by moving the microscope slide back and forth until the whole area had been scanned. Objects that resembled parasite forms were further examined under high magnification (X400). Parasite identification was done using manuals available at Centre for Biotechnology Research and Development (CBRD), Kenya Medical Research Institute – Nairobi.

The collected data were analysed by Statistics Package for Social Scientists (SPSS) version 11.0 and Microsoft® Excel for analysis of Variance (ANOVA) among vendors in different study locations. Multiple correlations of total metal concentrations amongst metal elements were also determined for possible relationships. Spearman Rank Correlation analysis was used to find any significant relationship between the study locations and occurrence of helminthes ova contamination.

Results

Helminthes ova isolated from geophagic materials from vendors

The mean parasite ova count per 120g ± SD in geophagic materials from vendors in various towns. There was consistently higher mean ova per120g pica of *A. lumbricoides* in many of samples. Vendors in Eldoret town had the highest mean (50) parasite ova/120g of pica compared to Nairobi (42), Kisumu (18.9), Rachuonyo (2.3) and Supermarket (2.0). Mean ova per 20 g for Nairobi was lower than for Eldoret but higher than all other locations. Results on mean parasite ova count per 120g ±SD in geophagic materials are summarized in Table 1.

Table 1. Mean parasite ova count per 120g ±SD in geophagic materials from vendors in various towns

	Nairobi	*Kisumu*	*Eldoret*	*Rachuo nyo*	*Sp/market*	*Total*
A.lumbricoides	26.7±4.7	5.3±3.8	29.7±11.7	1±0.8	0±0	62.7±21
E vermicularis	1±0.5	0±0	0±0	0±0	0±0	1±0.5
T.saginata	11.3±4.1	5.3±2.0	10±7.5	0.3±0.5	0±0	26.9±28
Toxocara spp	1±0	2.7±2.8	0±0	0±0	1±1.4	4.7±4.2
S. stercolaris	2±1.6	1.3±1.9	3.3±4.7	0±0	1±0	7.6±16
Hymenolepis spp	0±0	2±2.4	6.7±4.9	0±0	0±0	8.7±7
Unidentified	0±0	2.3±2.1	0.7±0.9	1±1.4	0±0	4.0±4
Total	42±11	18.9±15	50±25	2.3±2.7	2±1.4	115±81

Type of helminthes isolated from geophagic materials

All samples except those from supermarkets contained ova, in particular *A. lumbricoides*, *E. vermicularis*, *T. saginata*, *Toxocara spp*, *S. stercolaris*, *Hymenolepis spp* as well as some unidentified parasites. Figure 1 shows that *A. lumbricoides* was the most commonly occurring parasitic contaminant in geophagic materials offered for sale by vendors in all the study locations followed by *T. saginata* and *E. vermicularis*. Recovery of *Toxocara sp.* from some Nairobi samples indicates possible dog and/or cat contamination of pica probably during storage in pest infested warehouses.

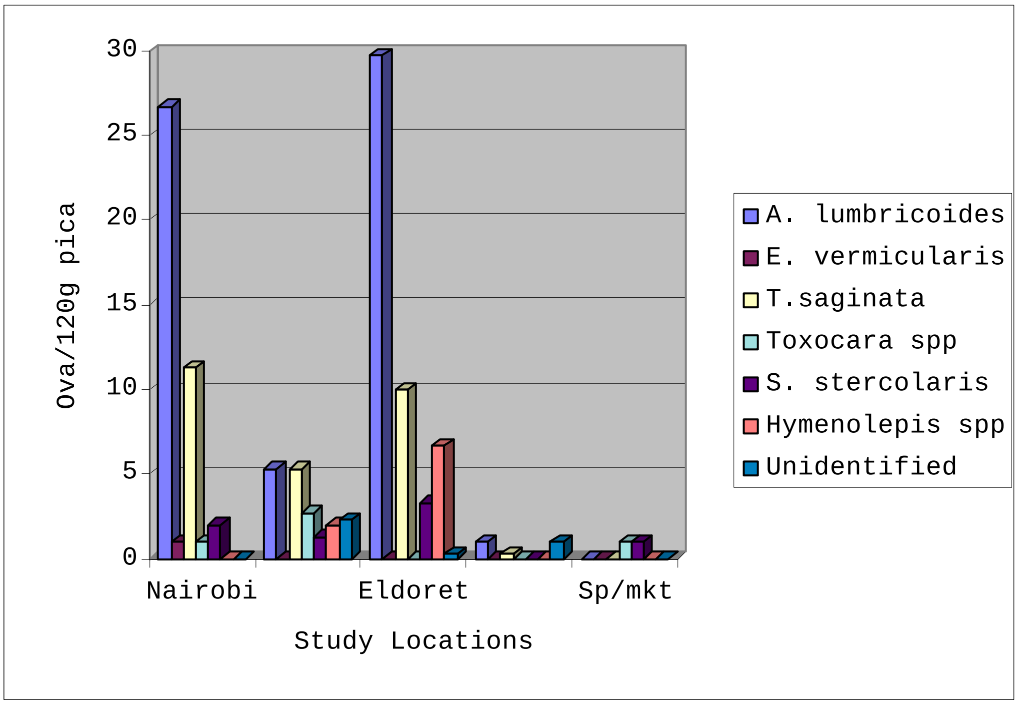

Figure 1. Composition of parasite ova per 120g of pica from vendors

Comparison of helminthes contamination between study sites

There were significant differences of mean ova per 120 g pica between Rachuonyo (2.3) and Eldoret (50, p=0.006), and between Eldoret and supermarket (p=0 .0059). Rachuonyo and supermarket (2.0) samples represented the lowest parasitic contamination among the studied locations. Rachuonyo being rural in setup had to lower level of parasite ova concentration. Materials sold in supermarkets, are probably preheated or subjected to some form of decontamination before being presented for sale.

There was significant (p=0.05) spearman rank correlation coefficient (p=0.9) for the level of helminthes contamination and the various study locations, suggesting that there is relationship between study locales ranked by population sizes and level of helminthes contamination. In larger towns there is greater likelihood of inadequate sanitation and chances of environmental contamination including parasitic infestation.

Concentration of Zn, Cd, Pb, Ca and Fe in geophagic materials from vendors

Mean total concentration ±SD (mg kg^{-1}) of selected metals in geophagic materials in various study locations. The concentration of heavy metal elements varied for the three – months study period on season and town-to-town basis. Lead levels in samples collected from vendors in the study sites, ranged from 310 – 1000 mg kg^{-1}. One vendor in Eldoret, had the highest total concentration of lead (1.00±. 94 mg kg^{-1} 10^3) while the lowest was supermarket samples (0.31±. .03 x 10^3 mg kg^{-1}). Mean total concentration±SD (mg kg^{-1}) of metals in materials in various study locations are summarized in Table 2.

Table 2. Mean total concentration±SD (mg kg^{-1}) of metals in materials in various study locations

	Zn	Ca	Fe	Cd	Pb
Eldoret	2.1	5.7	406.8	0.03	0.6
Kisumu	1.9	1.3	667.1	0.04	0.7
Nairobi	1.7	42.2	349.7	0.02	0.4
Rachuonyo	2	1.9	634.2	0.05	0.7
Sup/mkt	0.9	94.3	45.3	0.03	0.3

Supermarket samples had the highest total calcium concentration while Kisumu and Rachuonyo and Kisumu samples had the highest concentration of iron > 600 X 10^3 mg kg^{-1} (Figure 2). The mean total Zn concentration in geophagic materials from all the study locales was 1860 mg kg^{-1}. Mean values for Cadmium and Zinc were also higher than the background/natural level (0.06 and 50 mg kg^{-1} respectively) suggesting possible pollution. Table 3 shows multiple correlation matrices of metals. There is strong positive correlation between lead (Pb) and cadmium (Cd) (r= 0.5).

Table 3. Multiple correlation matrixes for Zn, Ca, Fe, Cd, and Pb

	Zinc	Calcium	Iron	Cadmium	Lead
Zinc	1				
Calcium	-0.36858	1			
Iron	0.014316	-0.93254	1		
Cadmium	-0.31696	-0.48828	0.689505	1	
Lead	0.407091	-0.96797	0.894735	0.503164	1

Discussion

Helminthes contamination of geophagic materials

Helminthes ova were recovered from samples from nearly all the vendors under study. This suggests that most of the materials offered for sale in the study locations are contaminated with parasites ova. Some parasites spend part of their life cycle in soil (geohelminthes) and certain ova can persist in soil for several years. *A. lumbricoides* and *T. saginata* ova can remain viable in soil for up to ten years (Markell and Voge, 1984).

Contamination of geophagic materials appears to occur primarily because of unhygienic handling and/or defaecation by humans, domestic and wild animals. Probably due to anthropogenic, animal pests and pet's contamination of geophagic materials, given the type of parasite like *Toxocara spp* and level of Pb found by this study.Higher ova per 120 g counts observed for *A. lumbricoides* may be that *A. lumbricoides* is the most prevalent in the general population under study. Some unidentified ova recovered are probably of non-human parasites – originating from domesticated and wild animals that inhabit human environment. Most vendors do not properly handle their pica ware as foods. The materials are offered for sale without any form packaging, thus allowing for greater exposure and subsequent contamination with helminthes and other pathogens. In most cases, vendors operate without toilets and/or water creating favourable conditions for parasitic ova contamination.

Previous past studies have reported a variety of helminthes associated with geophagia. Giesler *et al*., (1998) found that 48% of soils eaten by primary school children in western Kenya were contaminated with various helminthes ova. Glickman *et al*., (1999) have also noted that high level of intestinal parasitism in children and expectant mothers is greatly contributed by geophagy. In this study, the occurrence of helminthes ova in geophagic materials may shed light into intestinal parasitism common in children and expectant mothers in these areas.

In large urban centres with large human population, there is greater likelihood of higher levels and variety of helminthic infestation because of poor sanitary situations amongst populations. Supermarket samples had comparatively lower concentration of ova per 120g geophagic materials, probably due to improved packaging, pre – heat treatment and general hygienic handling. Some materials from Far East are in fire – baked before sale. Heat treatment eliminates parasites and microorganisms, hence reduced helminthes ova concentration for Supermarket (control) samples.

Metals elements in geophagic materials

The study covered metals indicative of pollution such as Cd, Pb, and Zn as well as non-pollutants Fe and Ca (Abrahams and Steigmajer, 2003). Although the level of Cd in pica appears to be low (0.20 – 0.50 mg kg^{-1} dry mass), the long biological half – life of up to 25 years may prolong Cd opportunity to exert its effects on target cells and tissues to induce a wide range of effects such as neoplasm. Lung tumor, prostate tumors and testicular tumors have been associated with cadmium toxicity, (Foulkes, 1990). Assuming a daily intake of 10 g of geophagia and concentration of 53.3 mg kg^{-1} Cd geophagic material, then the daily intake will be 1070 μg.

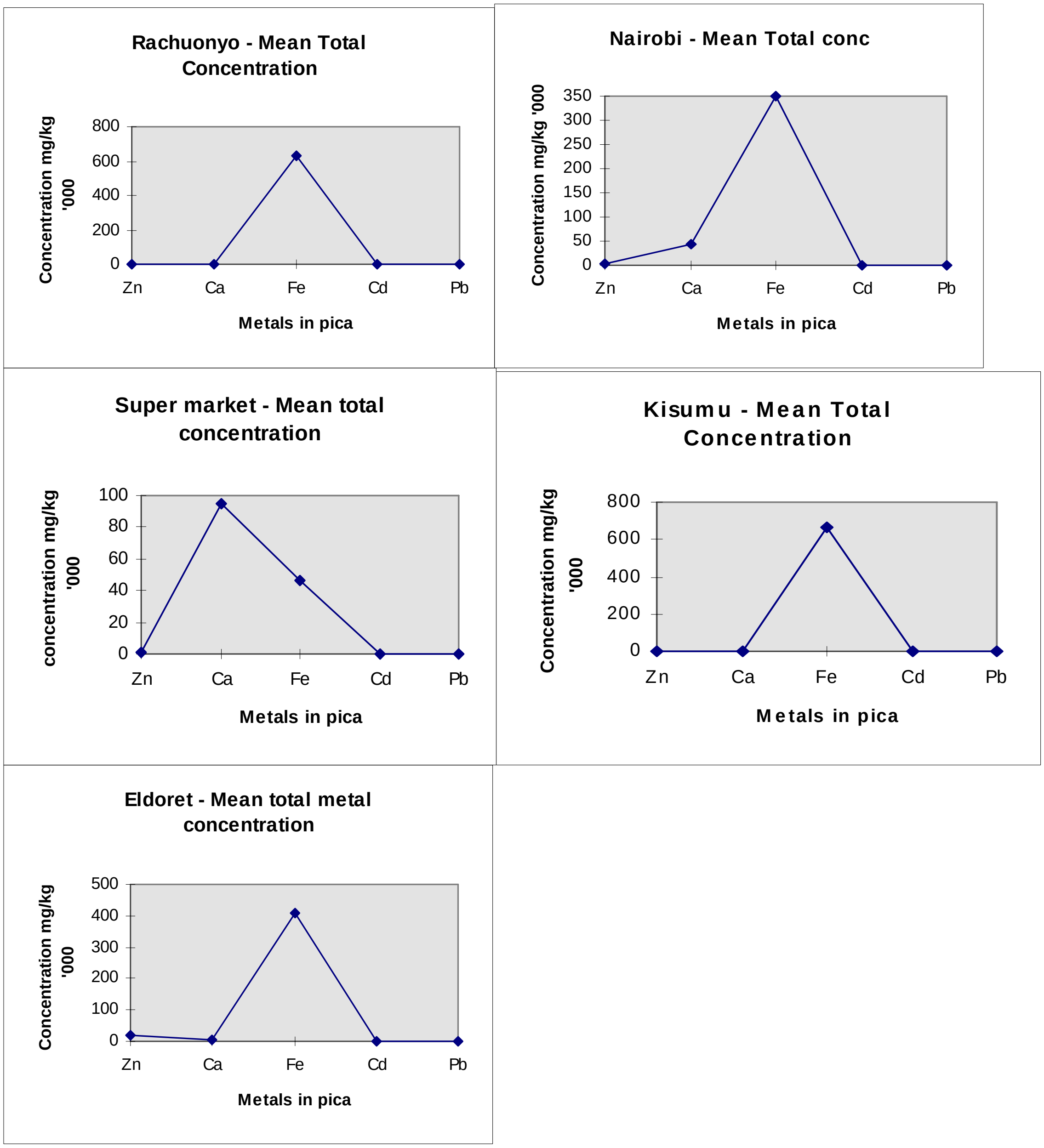

Figure 2. Total concentration of Zn, Ca, Cd and Pb in geophagic materials from the study sites

This value is below the maximum tolerable daily intake for adults but exceed the tolerable values in children and infants (WHO, 1992). This suggests possible on- going deleterious effects in the young.

Lead values are far above the background level of 10 mg kg^{-1} (Bohn *et al*., 1985). Higher concentrations and large variance amongst samples form the different study locations suggest that underlying varied pollution factors and the high geophagic ingestion of materials containing such Pb concentrations may lead to considerable health implications. Lead is toxic and plays no important physiological role in living organisms (WHO, 1989). Moderate to low levels exposure to lead and its compounds may lead to morbidity over time. Affected organs and organ systems, especially in children, include kidney and central nervous system (CNS) (WHO, 1982). Prolonged geophagy practice in these locations is therefore likely to lead to higher lead bioburden (Pb – B) among consumers. No detected – effect level is estimated at 60 – 70 μg/100 ml for adults and 50 – 60 μg/100 ml for children (WHO, 1989). In all the studied scenarios, these levels are more likely to be exceeded. Joint FAO/WHO Expert Committee on Food recommends that weekly intake should not exceed 2 – 26 μg/kg/week and 2 – 24 μg/kg/week for adults and children respectively (WHO, 1982). This suggests that the health impacts of geophagy may be more than is currently appreciated, with respect to Pb.

Zinc levels (1860 mg kg^{-1}) were higher compared to natural background levels of 10 – 300 mg kg^{-1} dry weight (dw) in soils (WHO, 2001). The supermarket geophagic materials had the lowest total Zn, while samples from Eldoret town vendors had the highest. There was a small variation among large towns (Eldoret, Kisumu and Nairobi) but generally higher than Rachuonyo (rural) and supemarket values. Most Supermarket geophagic materials originate from Asia and Far East countries. Zinc levels in urban and industrial areas are usually higher than rural areas, (WHO, 2001). The higher level of zinc in some samples may be due to, in part, natural occurrence of zinc-enriched ores due to anthropogenic causes. This signifies expected higher level of contamination and/or pollution associated with industrial and human activities in major town. Assuming at least 50% bioavailability and intake rate of 300g daily, there will be 833.16 mg zinc daily intake. This is well beyond the recommended Daily Allowance of 10mg for adults (Brody, 1994). It seems, in most cases geophagic subjects overdose with Zn beyond the nutritional optimum assuming average daily intake of 300g. Studies by Hooda *et al*. (2002) have indicated that soil eating can influence negatively Zn nutrition due to sorption of zinc under gastrointestinal conditions leading to zinc deficiency in the body.

Iron (Fe) levels were the highest of all the study sites (Figure 2), Rachuonyo and Kisumu samples had the highest total iron concentration, > 6.7 X 10^5 mg kg^{-1} while Supermarket ones had the least compared to the background level of iron in the earth's crust is equally high, > 5.0 x 10^4 mg kg^{-1} (Brody, 1994), this is probably due to anthropogenic factors.

The high iron concentration in geophagic materials is thought to be the major reasons for geophagia (Hooda *et al.*, 2002). The view that iron Fe deficiency causes geophagia has not been fully substantiated. Some recent simulation studies using geophagic materials from Uganda, Tanzania, Turkey and India, indicate that geophagic materials under gastrointestinal conditions, reduce absorption of mineral nutrients including iron (Hooda, 2002). Sedentary lifestyle in urban centres and major towns may be a contributory factor to the observed widespread pica practice in Kenyan cosmopolitan areas as exemplified by geophagia sales turn – over by the vendors. Reduced energy requirements lead to inadequate iron nutrition (Schuette and Linkswiller, 1984). Iron overload and reduced mineral nutrient uptake in the gut may follow enormous concentrations of iron in geophagic materials.

In the study, there is a strong relationship between iron micro – nutrient and helminthes infestation. The consumption of iron – rich geophagic materials coincided with high helminthes ova isolates. Body's iron demand shoots up to cover for increased intestinal losses of blood by helminthes, (Schuette and Linkswiller, 1984). The amount of blood lost is proportional to the type and helminthes load present. A single *Ancylostoma* *spp* can consume up to 0.2 ml of blood per day leading to anaemia depressing the normal haemoglobin level13 g/dl and 12 g/dl for men and women respectively (Markell and Voge, 1984). A standard deviation of ±2 is considered an anaemic situation.

Conclusions

Geophagic materials offered for sale by street vendors are contaminated with helminthes and probably other pathogens as well. Geophagy practice poses serious health implications in terms of orally acquired helminthes and other pathogens. The range of helminthes recovered suggests diverse sources or origins of contamination. *Toxocara* and *Hymenolepis sp* are feline occur in cats and dogs.

Possibility of heavy metal (Cd, Pb and Zn) intoxication is evident from the findings of this study as their levels were well above the background/natural levels, therefore it may be concluded that geophagy exposes individuals to harmful effects of toxic heavy metals, in these study areas.

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