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Environmental lead pollution and food safety around Kampala City in Uganda

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ABSTRACT
Objective: To determine lead levels in the environment and foods around Kampala city in Uganda and assess its implications to human health.
Methodology and results: The lead content in samples of soil, water and food was determined by spectrophotometry. The lead content in water samples from Lake Victoria and tap water ranged from 0.32 to 1.25 and 0.09 to 0.19 mg/100ml, respectively. Lead content in soil ranged from 0.17 to 0.88 and from 0.10 to 0.32 mg/100g for samples obtained along the highway, and at least 2 km away from the highway, respectively. The lead content in vegetables grown alongside highways ranged from 0.53 to 0.95, as compared to 0.10 to 0.62 mg/100g for vegetables obtained from markets.
Conclusion and application of results: The results indicate that there is significant lead pollution in the environment posing a high risk of exposure to people, animals, and plants. The lead content in all the water samples was above the maximum WHO limits. These results are useful in raising awareness about the risk of lead contamination to human health and in the enactment of policies and regulatory measures to limit lead pollution and contamination in foods and the environment in Uganda.

Key words: pollution, lead, water, soil, vegetables

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INTRODUCTION

Environmental pollution by heavy metals is a worldwide public health problem. Among the polluting heavy metals, lead is of great concern. Lead is widely distributed although its concentrations are low in environments where there has been little human activity. Lead has been used for centuries for industrial and purposes, e.g. paints, batteries and in petrol (JFAO/WHO, 2000).

Lead poisoning has severe adverse impacts on the nervous system and has been specifically linked to neurological, neurobehavioral and developmental problems in children that may be irreversible (IAEA, 1994). It also causes premature births and low birth weight, circulatory system damage leading to oxygen absorption decrease, increase in blood pressure and malfunctioning of kidneys (JFAO/WHO, 1995).

Lead pollution generally leads to elevated blood lead levels among subjects living in the polluted areas (Makokha, 2004), and also exacerbates the malnutrition situation, e.g iron deficiency leading to anemia whose prevalence among pregnant women and children in East Africa is very high (Marcus & Schwartz, 1987; JFAO/WHO, 1995; Mwaniki *et al*., 2001) In the USA, the prevalence of elevated blood lead levels among children living in neighborhoods of high lead pollution was observed to be several times higher than the national average (Braddman *et al*., 2001), and the children were more likely to be iron deficient.

Lead pollution may arise from motor vehicles in countries where leaded petrol is used, or from a variety of industrial and domestic sources, e.g. leaded water pipes and paints (Marzulli & Brown, 1972; UNEP, 2000). Lead does not degrade, therefore continual usage of lead results in its accumulation in the environment. Worldwide, leaded petrol causes more lead pollution to human beings than any other source (Ellen, 1996).

Therefore, lead contamination of soils from vehicular emissions has for long been a concern in areas where leaded petrol is used. As a consequence, many developed countries, and even some developing ones, have outlawed the use of leaded petrol and implemented strict regulations controlling the use of lead in other products, e.g. paint. Levels of lead in food and drinking water are closely monitored in most developed countries. Maximum limits of lead content in foods and water have been set at between 20 – 30 mg/100g by the Codex Alimentarius Commission (JFAO/WHO, 1999). However, the East African countries including Uganda have been slow in putting in place regulatory measures on leaded products. It is not until December 2005 when Uganda phased out the use of leaded petrol (UNEP-PCFV, 2008).

Despite the well-known adverse consequences of lead poisoning, there is only little data on the magnitude of lead contamination in Uganda. The objective of this study was to determine the extent of lead pollution around Kampala city in Uganda and assess the potential impact of such contamination on food and human health.

MATERIALS AND METHODS

Study area: The study was carried out in the Lake Victoria basin around Kampala in Uganda, with potential sources of pollution due to a high population, crowded old and new buildings, heavy industries (including smelting and metal works), and high motor vehicle traffic, especially along the Kampala-Jinja road which is also used by heavy trucks to the neighboring countries. Samples were taken within a radius of 20 km from Lake Victoria in these areas, including the lake itself. Sampling sites included (1) Ggaba landing site: Fish and water sample (2) Mulungu and Kitubulu sites: Fish and water samples (3) Kampala-Entebbe highway: Soil samples (4) Kampala-Jinja highway: Soil and food samples (5) Nakasero market: Fish and food samples

Sampling procedure: Six and four 1000ml water samples were obtained from Lake Victoria, and from drinking water sources, respectively. The water samples from the lake include those from onshore and those from at least 200 meters inshore. Ten 500g soil samples were obtained from purposively selected sites in the research area; areas of high motor vehicle volume and human activity were identified. These included areas next to the highways where motor vehicle pollution is relatively high. Another five 500g samples of soil were collected at least 2km away from the road and assayed as control. Five 500g of various food samples were obtained from the markets that sell food. Food samples included fish, which were purposely fished near the shore, and those obtained from vendors. Food samples from the market included 'kale' (*Brassica oleraceae* var. *acephala*), spinach (*Spinacea oleracea*), maize (*Zea mays*) grains, beans (*Phaseolus vulgaris*), peas (*Pisum sativum*), onions (*Allium cepa*), 'nakati' (*Solanum* spp.), and 'dodo' *Amaranthus* spp. The food samples were dried and prepared for analysis according to the International Atomic Energy Agency (IAEA) protocols, (1997).

Lead determination: Lead content in the soil, water and staple foods was determined using a Shimadzu Atomic Absorption Flame Emission Spectrophotometer model AA-6200 (Osborne & Voogt, 1978; AOAC, 1996). Sample pretreatment was done as described by IAEA (1997). Two grams of soil and food samples or 20 ml of water were digested using concentrated acids (wet ashing). Nitric acid, Sulphuric acid, and Hypochloric acid were mixed in the ratio of 2:1:1. Commercial lead standards ($Pb(NO_3)_2$ in 0.1 mol/l HNO_3) were used as reference.

Data analysis and interpretation: Both qualitative and quantitative data analysis approaches were used. Data were subjected to Analysis of Variance (ANOVA) and descriptive indices (means, standard deviation, range) determined. Lead levels in the environment were correlated to those in food and water, and also compared to the maximum permissible lead concentrations (JFAO/WHO, 1999).

RESULTS AND DISCUSSION

Water samples obtained from the Lake Victoria and from taps had high levels of lead content relative to the recommended levels of surface freshwater (0.01 mg/100ml) and drinking water (0.001 mg/100ml) respectively (USEPA, 2006) (Table 1). Water samples from the lakeshore had significantly higher lead levels as compared to those from at least 200 meters inshore with a mean of 1.23 and 0.44 mg/100ml, respectively. This is an indication that there is considerable environmental lead pollution nearer the shore. The most probable causes of lead pollution in the environment could be anthropogenic sources such as lead-based paints, automobile emissions and past industrial emissions (USEPA, 2000; Langley, 2007). Such lead deposits may end up leaching from the affected soil into the lake. The difference in concentrations between near the shore and 200m inshore water suggests a gradual diffusion of lead salts deposited into the lake.

Table 1: Lead content in water samples (mg/100ml) in Kampala city, Uganda.

Sample source	Mean	Range
L. Victoria (onshore)	1.23 ± 0.06^a	1.06 – 1.25
L. Victoria (inshore)	0.44 ± 0.09^b	0.32 – 0.61
Tap water	0.14 ± 0.03^c	0.09 – 0.19
WHO maximum limit, drinking water	0.001^d	

Each value is mean ±SE of three analyses done in triplicates. Means within columns followed by different letters are significantly different (p< 0.05, ANOVA) from each other.

Table 2: Lead content in soil (mg/100g) in Kampala, Uganda.

Sample source	Mean	Range
Kampala-Entebbe road	0.51 ± 0.11^a	0.17 – 0.84
Kampala-Jinja road	0.53 ± 0.13^a	0.22 – 0.88
2 km off Kampala-Entebbe road	0.19 ± 0.01^b	0.18 – 0.32
2 km off Kampala-Jinja road	0.15 ± 0.05^b	0.10 – 0.26
Average and common range in soils*	1.0^c	0.20 – 20.0
US Soil lead hazard (maximum limit)**	40.0^d	
EU Soil lead hazard**	30.0^e	

Each value is a mean ±SE of three analyses done in triplicates. Means within columns followed by different letters are significantly different (p< 0.05, ANOVA) from each other. *Lindsay (1979); ** Langley (2007).

The lead level in lake water samples is relatively high compared to recommended freshwater lead levels of 0.01 mg/100ml (USEPA, 2006). The area under study (Ggaba, Kitubulu and Mulungu beaches) is an entry point of water run-off from the busy Kampala city with heavy traffic and human population. In a related study the level of lead in the effluents as well as in water of Mehadrigedda stream of Vishakhapatnam in India ranged from 0.80 – 9.50 and 0.03 – 2.23 mg/l, respectively, in different seasons of the year (Rao *et al*., 1998). Nabulo *et al*. (2008) also reported lead levels that ranging from 10 to 250 µ/l in wetland water samples around Kampala city. In contrast, surface water from areas that are free from continental influences are reported to have lead levels averaging 0.07µg/l and 0.05µg/l, e.g. Bermuda and Central Atlantic, respectively (Chow, 1968). Although the present study was done over one season, there could be seasonal variations of lead levels in lake water depending on the amount of water runoff entering the lake.

The average lead content in drinking/tap water from different sources in Kampala (Table 1) was significantly higher than the WHO maximum permissible limit (0.001 mg/100g) (JFAO/WHO, 1999). Whereas the contamination of sources of drinking water may contribute to the high levels of lead, plumbing containing 50/50 lead-tin solder used to join copper pipes, lead pipes and connectors' or brass fittings containing more than 8% lead have also been reported to be potential causes of high lead levels (McElgunn, 1996). Such metallic connectors, plugs and fittings are still being used widely in Uganda and might contribute to the high levels of lead in drinking water. The lead leaches into the water, especially if the fitting is less than five years old, or if water is soft, acidic or simply hot.

Table 3(a): Lead content in vegetables (mg/100g) in Kampala, Uganda.

Sample	Source	Mean	Range
Amaranthus sp	Kampala-Jinja roadside	0.78±0.11[a]	0.53 – 0.95
Fresh beans	Nakasero market	0.31±0.02[b]	0.29 – 0.32
Fresh peas	Nakasero market	0.25±0.03[b]	0.24 - 0.27
'Kale'	Nakasero market	0.29±0.01[b]	0.29 – 0.30
'Nakati'	Nakasero market	0.43±0.05[b]	0.32 – 0.62
Onions	Nakasero market	0.36±0.02[b]	0.34 – 0.39
Spinach	Nakasero market	0.10±0.01[c]	0.09 – 0.10
WHO Maximum limits, fruits and vegetables		0.03[d]	

Each value is a mean ±SE of three analyses done in triplicates.
Means within columns followed by different letters are significantly different ($p < 0.05$, ANOVA) from each other.

Table 3(b): Comparison of lead levels in vegetables (mg/100g) in Kampala, Uganda.

Sample	Source	Mean	Range
Amaranthus sp	Roadside	0.78±0.10[a]	0.53 – 0.95
Fresh beans & peas	Nakasero market	0.28±0.04[b]	0.25 – 0.31
Other leafy vegetables	Nakasero market	0.27±0.09[b]	0.10 – 0.62
WHO maximum limits (vegetables)		0.03[c]	

Each value is a mean ±SE of three analyses done in triplicates.
Means within columns followed by different letters are significantly different ($p < 0.05$, ANOVA) from each other.

The lead content in the soil samples obtained from the roadside (Entebbe-Kampala-Jinja highway) was significantly higher (≈0.5 mg/100g) than those of the samples obtained at least 2 km away from the highway (≈0.2 mg/100g) (Table 2). This is evidence of vehicular emissions pollution possibly due to the use of leaded gasoline. The average lead content in the soil samples in this study were within the common range of soils (0.2-20 mg/100g) as documented by Lindsay (1979). The results in this study are comparable to those reported by Nabulo *et al*. (2006) for Kampala where lead concentrations in roadside soils ranged from 30.0±2.3 to 64.6±11.7 mg/kg.

Lead is a widely distributed metal although its concentrations are low in environments where there has been little human activity (FSANZ, 2002). All soils naturally contain trace levels of metals; therefore the presence of metals in soil is not an indication of contamination. The concentration of metals in uncontaminated soil is primarily related to the geological nature of the parent material from which the soil was formed. It is through the comparison by direct analysis of uncontaminated and the contaminated soils that background levels of metals are established.

Lead does not biodegrade; therefore, children who live and play in the vicinity of lead industries, heavy traffic, garages, or in older, painted homes can be exposed to high levels of lead from contaminated soil and dust (McElgunn, 1996). It is estimated that an average child will ingest 100 mg/100g of dust a day, so a child playing in an area with 500 ppm (50 mg/100g) lead might ingest about 0.05 mg of lead per day. Areas along the highway and metal industries are therefore not fit to be used as a playground or for cultivation. While agricultural soils have a median lead content of 1.1 mg/100g and natural soil levels are below 5.0 mg/100g, urban environments often have levels >100.0 mg/100g with some reports of as high as 5,000 mg/100g (Langley, 2007).

Table 4: Lead content in dry maize and bean samples (mg/100g) sold in Kampala, Uganda.

Sample	Source	Mean	Range
Maize	Nakasero market	0.15±0.03[a]	0.14– 0.16
Beans	Nakasero market	0.16±0.02[a]	0.13 – 0.18
Peas	Nakasero market	0.15±0.02[a]	0.13 – 0.15
WHO maximum limits (maize, beans)		0.02[b]	

Each value is a mean ±SE of three analyses done in triplicates.
Means within columns followed by different letters are significantly different (p< 0.05, ANOVA) from each other.

Table 5: Lead content in fish (mg/100g) consumed in Kampala, Uganda.

Species	Source	Mean	Range
Tilapia	Ggaba onshore	0.42±0.15[ab]	0.29 – 0.56
Tilapia	Mulungu onshore	0.63±0.03[a]	0.59 – 0.65
Tilapia	Nakasero market	0.60±0.02[a]	0.58 – 0.62
Dagaa	Mulungu & Owino market	0.13±0.04[b]	0.11 – 0.14
WHO maximum limits		0.02[c]	

Each value is a mean ±SE of three analyses done in triplicates.
Means within columns followed by different letters are significantly different (p< 0.05, ANOVA) from each other.

Depending on the nature of the soil, different regulatory bodies have established varying hazard levels. The United States Environmental Protection Agency (USEPA) has established a soil hazard level at 40 mg/100g for bare soil in play areas and an average of 120 mg/100g for bare soil in other areas. The European Union (EU) has set the lead standards for residential soils to range from 0 to 15.0 mg/100g; while lead guideline for soils used by children in Canada is set at 14.0 mg/100g. According to our findings, the soil in Kampala has lead content below the hazard limits set by some developed countries.

The lead content of all vegetables studied in this study was above the WHO maximum limit of 0.03 mg/100g set for vegetables (Table 3a). The vegetable samples obtained from the roadside (*Amaranthus* sp) had strikingly higher lead concentration (mean of 0.78 mg/100g) than those obtained from Nakasero market that ranged from 0.10 to 0.62 mg/100g (Table 3b). This suggests that vegetables grown along the roads are much more exposed to motor vehicle pollution.

Our results are consistent with those of other studies carried out in similar or larger cities. In New Delhi, 100% of the palak (spinach beet) samples analyzed exceeded the safe limit of 0.03 mg/100g (Marshall *et al*., 2003) while in Thailand, Leelhaphunt *et al* (1994) reported lead levels of 0.21 mg/100g in tomatoes. Furthermore, the lead levels for vegetables obtained from Port Kembla in Australia ranged from 0.002 to 0.613 mg/100g dry weight (Kachenko & Balwant, 2006). Pandya (1983) reported lead level between 0.20 to 1.05 mg/100g in vegetables in Ahmedabad city in India. It is obvious, therefore, that where environmental lead pollution is high, lead levels in food may be much higher than the maximum safe limits thus posing a high risk to consumers' health.

The lead level in all samples of dry maize, beans and peas were above the WHO maximum limits of 0.02 mg/100g (Table 4). However, there was no significant difference in lead content among these foods ($p>0.05$), though these lead levels are significantly higher than those reported elsewhere. Yang *et al*. (1994) reported lead level of 0.006 mg/100g for cereal in China, whereas Ysart (1994) reported mean lead content of 0.002 mg/g for cereal products in the UK. Pandya *et al*. (1983) on the other hand, reported lead level in food grains in Ahmedabad city in India ranging from 0.55 to 1.05 mg/100g. The high level of lead in cereal and beans in Kampala might arise from the geological influence of the soil Most grains in Kampala are brought from up country. The soil samples that were obtained further away from the highway had lead content that corresponds to the level of lead in maize and beans.

The lead levels in the fish samples were significantly higher above the WHO maximum safe limits, and correspond to the level of lead in the lake water. Considering that lead has a cumulative effect, older fish would be expected to have higher lead levels than the younger ones. The body weight might also influence the level of lead in an organism. In this study, the small fish (*dagaa*) obtained from Mulungu and Owino markets had less mean lead content of 0.13 mg/100g as compared to tilapia obtained from Ggaba and Mulungu beaches whose mean lead content were 0.42 mg/100g and 0.63 mg/100g, respectively. Tilapia from Nakasero market had 0.60 mg/100g (Table 5). These results correspond to those published by National Environmental Engineering Research Institute in India (NEERI) (1987) where samples of fish from River Ganga were found to have lead levels ranging from 1.44 to 15.33µg/g, but higher than those of fish samples obtained from various places in Mwanza which ranged from 5.38 to 26.7 ppm (Kisamo, 2003).

This study has shown that there is considerable environmental lead pollution around Kampala city. The relatively higher levels of lead content in soil and vegetables grown along the roadside as compared to those at least 2 km away suggests that motor pollution is a major contributing factor.. This calls for sensitization of people living along the roads of the risks they might suffer as a result of cultivating crops along the road. The government should also consider enacting measures to ensure that other sources of lead contamination such as leaded paints and plumbing equipment are outlawed. There is also a need to monitor the levels of contamination in order to establish the impacts of banning leaded petrol. Further data could be obtained through a systematic longitudinal study in selected areas.

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