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Prevalence and Concentration of Lead (Pb) and Cadmium (Cd) in Kales (*Brassica oleracea* Acephala) & Spinach (*Spinacia oleracea*) Sold at *Masaku* County, Kenya

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Abstract: Background: Exposure to heavy metals (Pb and Cd) through diet posses a significant risk to human health. Areas of *Mlolongo*, *Athi* River and *Syokimau* are surrounded by industries, which dispose off their waste water to existing rivers and streams. The waste water is further used for irrigation which increases consumption of vegetables contaminated with lead and cadmium by human populations. Sample collection and analysis: samples were collected from markets, supermarkets and open air markets in *Mlolongo*, *Athi* river and *Syokimau* areas. Samples were analyzed for Lead and Cadmium using the AAS method as outlined in the AOAC. Results: Kale from farms around *Mlolongo* had lead content of 41.10±3.15µg/Kg compared to kale from farms in *Syokimau* (0.36±0.01µg/Kg). Spinach had lower concentration of lead (14.10±1.05µg/Kg) in farms in *Mlolongo* and 1.70±0.06µg/Kg in supermarkets in *Syokimau*. Than spinach. To the contrary cadmium contents were higher in spinach (0.51±0.02µg/Kg in supermarket in *Mlolongo*) than kale (0.38±0.01µg/Kg supermarkets in *Mlolongo* and *Syokimau*). Kale had a higher lead than cadmium content in the firm one in *Athi* river (14.00±2.10µg/Kg) than 3.80±0.81 µg/Kg) in the second farm which was the lowest. Vegetables from farm one are irrigated using effluent water from close industries. Lead content was highest in the first market (14.00±2.10µg/Kg) than the second market (3.80±0.81µg/Kg) in Athi river town. Cadmium contents were lower than lead but highest in the third market than the second market in the same town (0.20±0.07µg/Kg). Cadmium content was high in kale from supermarket in Athi river at (3.70±0.07 µg/Kg). Concentrations of lead in spinach were highest in the first farm at 5.30±1.10 µg/Kg and least in the spinach in supermarket at 0.30±0.01 µg/Kg. Conclusions: Lead content in vegetables vended in *Athi* river, *Syokima* and *Mlolongo* were above those recommended by the Ministry of Health and WHO. Similarly, cadmium content were high but within normal requirements. Exposure of lead to human populations, especially children is harmful to neurological developments.

Keywords: Lead, Cadmium, Poisoning, Waste-water, Farm, Market

1. Introduction

In the recent past, Kenyans have been exposed to a number of heavy metals including lead, cadmium and manganese thanks to environmental pollution [1]. Exposure to heavy metals including Lead and Cadmium, has been recognized as a risk factor to human health through the consumption of vegetables and other foods produced using (industrial) waste water. Although lead is an environmental and public health hazard of global proportions, the global dimensions of poisoning emanating from this heavy metal remain poorly understood due to persistent lack of information. Kales are cultivars of cabbage grown for their edible leaves. A kale plant has green or purple leaves and the central leaves do not form a head. It is an annual plant grown from seeds with a wide range of germination temperatures. Spinach is a flowering plant of the order caryophyllales, family amaranthaceae and subfamily chenopodioideae [2-4]. These vegetables are the most consumed especially in the urban Kenyan households.

Kenya is a water scarce country with more than 70% classified as arid and semi arid lands (ASAL). *Masaku* county is one of the areas classified as ASAL, indeed most of the tap water in *Athi* river, *Syokimau* and *Mlolongo* towns is either from boreholes or sourced from outside the county. Potable water for irrigation and industrial use is generally unavailable which calls for alternative water sources. Despite the use of waste water being illegal in Kenya, use of waste water for irrigation in these towns has been observed. Polluted water might expose people to health risks such as increased vulnerability to cancer as some chemicals in waste-water are carcinogenic [2, 3]. The National Environment Management Agency (NEMA) standards for discharge of effluent into water or land are for lead (Pb) 0.1mg/l and cadmium (Cd) 0.1mg/l [3].

Lead is a bluish gray metal in color with no characteristic taste or smell naturally found in the environment however, most of it found in the environment is due to human activities (UNEP, 2000). Lead is insoluble in water and does not burn (USEPA 2003). The metal is cumulatively toxic and it affects multiple body systems. Lead is particularly harmful to young children because they absorb 4 to 5 times as much ingested lead as adults from a given source [5]. Additionally, adults lose more than 90% of ingested lead while children lose only 36% after a fortnight [1]. Children at high risk are the very young and impoverished because their bodies absorb more lead if other nutrients such as calcium and iron are lacking in the diet [5]. Lead in the body is distributed to the brain, kidney and bones, and stored in the teeth and bones where it accumulates over time. It is released in the blood during pregnancy and becomes a source of exposure to the developing fetus [4].

Sources and routes of exposure to lead are: Ingestion of lead contaminated food and water, inhalation of lead particles generated by burning materials [6].

Effects of lead poisoning to children on ingestion at high levels include attack on the brain and central nervous system to cause comma, convulsions and even death; at low levels of exposure it affects children brain development resulting in reduced intelligence quotient (IQ), behavioral changes such as reduced attention span, increased antisocial behavior and reduced educational attainment. These effects are believed to be irreversible. Lead exposure causes anemia, hypertension, renal impairment and toxicity to the reproductive system [7-9]. These outcomes are high in countries where children are exposed to lead poisoning due to gold mining [10].

Cadmium is a lustrous, silver white, ductile and malleable metal with a bluish tinge surface. The trace element is soft but it tarnishes in air [11]. Humans can be exposed to cadmium through a number of avenues such as inhalation from the air and oral ingestion from contaminated foods. High cadmium intake can lead to disturbances in calcium metabolism and the formation of kidney stones. High intakes also causes cancers of the kidney and prostate. Cadmium accumulates in the kidneys damaging filtering mechanisms causing the excretion of essential proteins and sugars from the body and further kidney damage [9]. its content in plants vary with parts, with leaves containing the most. Storage roots and tubers follow, then seeds/grain and fleshy fruits. Naturally, cadmium can be found in soils, rain and irrigation water (which generally have very low cadmium content), biosolids (sewage and sludge) have significant amounts of cadmium. Cadmium may also be available in air from industrial activities such as smelting. Additionally, organic wastes and manures may also contain cadmium [10, 11]. The objective of this study was to establish the prevalence of lead and cadmium contamination on leafy vegetables, kales and spinach sold in *Mlolongo, Athi* River and Syokimau townships in Masaku county, Kenya. These towns are relatively industrialized, and River Athi, the second longest river in Kenya passes through them.

2. Materials and Methods

2.1. Sampling and Sample Size

Samples were collected during the dry season in *Athi* river, *Mlolongo* and *Syokimau*. In *Athi* river and *Mlolongo* samples were collected from farmers, open air markets and supermarkets while in *Syokimau* samples were collected from the markets and supermarkets because there are no farms in the area. The sampling sites are illustrated in Figures 1, 2 and 3. A questionnaire was used to establish from the vendors in the markets and supermarkets their sources of vegetables. Vendors were also queried on their mode of vegetable storage to establish any possibility of contamination during storage.

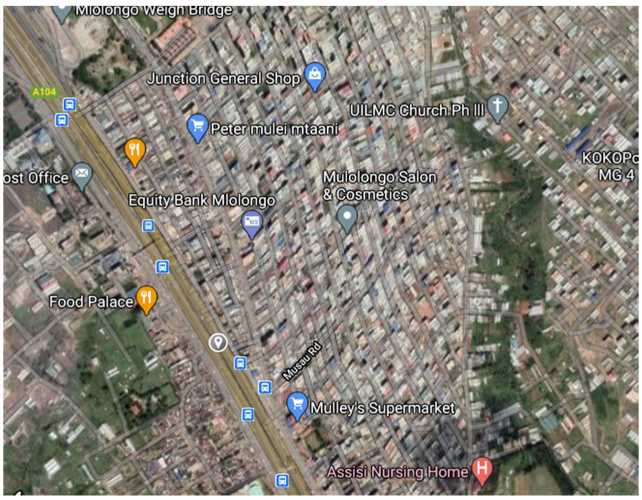

Figure 1. *Google image of Mlolongo market within Masaku county.*

Figure 2. Google image of Syokimau market within Masaku county.

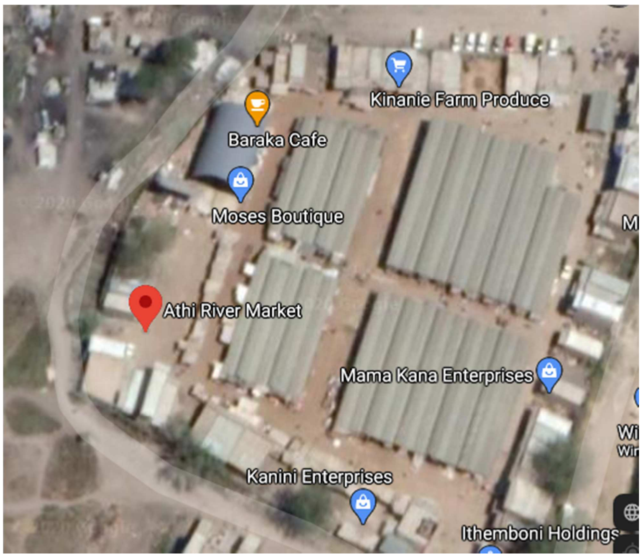

Figure 3. Google image of Athiriver market within Masaku county.

2.2. Sample Analysis

Sample pre-treatment was done as described in the International Atomic Energy Agency (IAEA) (1997) protocols. In this method, approx. 1.5 g of each ground dried sample was placed in a small beaker. 10 ml of concentrated nitric acid was added to the beaker and allowed for digestion.. After digestion, the samples were diluted to a volume of 50ml with deionized water and filtered using a filter paper to volumetric flasks.

2.3. Lead and Cadmium Analysis Using AAS

Lead and cadmium was determined using a *Shimadzu* Atomic Absorption Flame Emission Spectrophotometer Model AA-6200. [12, 13, 15, 17]. Commercial lead standards ($Pb(NO_3)_2$ in 0.1 mol/l. HnO_3) were used as referenced (Wako Pure Chemical Industries Ltd., Japan).

2.4. Data Analysis and Interpretation

Statistical analysis of data was done using analysis of variance (ANOVA) to compare lead and cadmium concentrations in vegetables from different sampling areas. Both qualitative and quantitative data analysis approaches were used. Descriptive indexes such as means and standard deviation and correlations were used [14]. Results of analysis were compared with the maximum permissible lead and cadmium concentrations (MPC) by WHO [9].

3. Results and Discussions

3.1. Lead and Cadmium

Results for lead and cadmium concentration in vegetables) sold in *Mlolongo* and *Syokimau* townships are presented in Table 1 and Table 2.

Lead content ranged between 1.39±0.81 and 41.10±3.15 µg/kg and highest in vegetables from farms in *Mlolongo* than in farms from *Syokimau* townships (Table 1).

Table 1. *Lead content in kale and spinach from Mlolongo and Syokimau townships in µg/Kg.*

Sample source	Mean[1]
Mlolongo farms (kale)	41.10±3.15
Mlolongo farms (spinach)	14.10±1.05
Mlolongo supermarket (spinach)	1.70±0.06
Mlolongo supermarket (kale)	4.43±1.54
Syokimau farm (kale)	1.39±0.81
Syokimau market (kale)	2.74±0.08
Syokimau supermarket (kale)	1.89±0.06
Syokimau supermarket (spinach)	2.88±0.09

[1]Each value is a mean±SD of five analyses done in triplicates.

Similarly, vegetables sold in these places were found to be contaminated with cadmium also (Table 2). However, these levels are majorly below those permissible by FAO/WHO recommendations [16, 17]. The levels ranged from 0.20±0.00 to 0.44±0.01 µg/kg. Cadmium content was highest in spinach sold in *Syokimau* supermarkets and lowest in kales sold in markets in *Mlolongo* town. Kales from farms around *Mlolongo* had lead content of 41.10±3.15µg/Kg higher than kale from farms in *Syokimau* (1.39±0.81µg/kg). Spinach had lower concentration of lead (14.10±1.05µg/Kg) in farms in *Mlolongo* and 1.70±0.06µg/Kg in supermarkets in *Syokimau.* To the contrary cadmium contents were higher (0.51±0.02µg/Kg) in spinach in supermarket in *Mlolongo* than kales. (0.38±0.01µg/Kg) Within places and between samples, lead was higher in kale than spinach, perhaps because spinach has a higher moisture content than kale leading to a greater biomass and trace element bioaccumulation.

Table 2. *Cadmium content in kale and spinach from Mlolongo and Syokimau townshipsin µg/Kg.*

Sample source	Mean[1]
Mlolongo farms (kale)	0.20±0.00
Mlolongo farms (spinach)	0.32±0.01
Mlolongo supermarket (spinach)	0.44±0.01
Mlolongo supermarket (kale)	0.38±0.02
Syokimau farm (kale)	0.36±0.01
Syokimau market (kale)	0.38±0.01
Syokimau supermarket (spinach)	0.51±0.02
Syokimau supermarket (spinach)	0.44±0.01

[1]Each value is a mean ± SD of five analyses done in triplicates.

Lead content in vegetables in *Athi* river was lower than *Mlolongo* and *Syokimau* at 18.00±2.15 µg/kg (highest) and 3.80±0.81 µg/kg (lowest). On the other hand, Cadmium levels were varied in both locations. Cadmium content was highest in kale sold in supermarkets in *Syokimau*. There appears to be a higher degree of Lead contamination compared to Cadmium in vegetables in *Mlolongo* and *Syokimau*. Kale had a higher lead than cadmium content in one farm in *Athi* river (14.00±2.10µg/Kg) than 3.80±0.81 µg/Kg) in the second farm. It was established that Vegetables from farm one were irrigated using effluent water from neighboring industries. Lead content was highest in the first market (14.00±2.10µg/Kg) than the second market (3.80±0.81µg/Kg) in *Athi* river town. Cadmium contents were lower than lead but highest in the third market than the second market in the same town (0.20±0.07µg/Kg). vegetables in the third market were not irrigated with much effluent water from industries. Cadmium content was high in kale from supermarket in *Athi* river at (3.70±0.07 µg/Kg). Concentrations of lead in spinach were highest in the first farm at 5.30±1.10 µg/Kg and least in the spinach in supermarket at 0.30±0.01 µg/Kg. Perhaps because of differences in contamination causes for the two heavy metals. Similar to *Mlolongo* and *Syokimau,* lead contamination was higher than cadmium contamination in Athi river. However, cadmium contamination was highest in Athi river compared to *Mlolongo* and *Syokimau* (Table 3 and Table 4).

Table 3. *Lead and Cadmium content (µg/kg) in Kales from markets, farms and supermarkets in Athi river town.*

Source[1]	Mean±SD (Pb)	Mean±SD (Cd)[2]
Market		
1	14.00±2.10	0.70±0.24
2	3.80±0.81	0.20±0.07
3	11.00±1.21	1.50±0.07
4	6.20±0.82	0.40±0.02
Farm		
1	7.60±1.13	0.40±0.09
2	13.00±1.34	0.60±0.03
3	18.00±2.15	0.70±0.02
Supermarket		
1	4.50±1.51	3.70±0.07
2	6.40±0.09	0.50±0.08

[1]Numerical digits under "source" indicate sample location.
[2]Each value is a mean±SD of five analyses done in triplicates.

Table 4. *Lead and Cadmium content (µg/kg) in Spinach from market, farm and supermarkets in Athi river town.*

Source[1]	Mean[2] (Pb)	Mean[2] (Cd)
Market		
1	2.60±0.06	0.40±0.01
2	7.80±1.23	0.50±0.01
3	5.90±1.40	0.70±0.02
4	3.70±1.10	1.50±0.08
Farm		
1	1.40±0.05	5.30±1.10
2	10.00±2.10	0.50±0.03
3	8.60±1.81	0.60±0.02
Supermarkets		
1	5.20±0.09	0.30±0.01
2	5.40±1.31	0.40±0.01

[1]Numerical digits under "source" indicate sample location.
[2]Each value is a mean±SD of five analyses done in triplicates.

3.2. Interviews

Interview conducted with retailers in the study areas to investigate their sources of vegetables for sale established that source of kales and spinach at the supermarkets in *Mlolongo* were from a farm in *Masaku* but they were not able to specify the farm. For the supermarkets in *Syokimau* the vegetables were sourced from *Limuru* while the vendors in markets around bought from *Mlolongo* and *syokimau.* Those from *Athi River* obtained their vegetables) from farms in *Mlolongo* and *Kikuyu*. The source of vegetables in *Syokimau* and *Molongo* townships indicates that half of the vegetables consumed by residents are imported from outside the localities.. Most residents buy vegetables from the market and not supermarket. Surprisingly, farmers around river *Athi* irrigate their vegetables with water contaminated with human waste. This was evident from the overwhelming stench (at the time of sample collection) but these farmers have no option because they must eke their living.

The availability of industries in *Athi* river, *Mlolongo* and *Syokimau* causes a major risk where industrial waste is deposited into nearby rivers leading to contamination. Water from these rivers is used for irrigation. County governments and the Kenya National Environment Management Agency (NEMA) should ensure appropriate disposal of waste water so as to reduce the amount of heavy metal contamination in vegetables and other foods. Effective management of waste water will ensure concentrations of lead and cadmium in kale and spinach grown in these and other areas with industries conform to the standards set by the state and the World Health Organization (WHO).

There has been increased population in *Mlolongo*, *Athi* river and *Syokimau* areas. These populations require vegetables and other foods such as fruits. Production of waste waters has increased alongside this rural urban migration, especially in *Mlolongo* and *Athi* river townships has threatening human health, especially in children aged younger than six years. Continuous consumption of foods contaminated with heavy metals might lead to biomagnification of these trace elements. Increased bioacculuation of trace elements has been established to occur in plants with with narrow stem. Figure 4 illustrates how waste water ends up in vegetables in an urban environment where it is not treated.

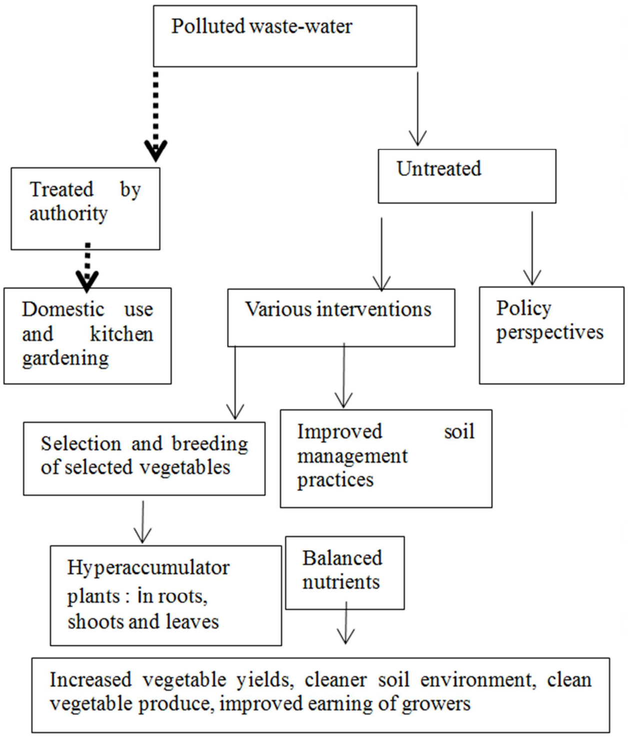

Figure 4. *Conceptual framework showing waste-water treatment and utilization initiatives by different stake holders. Source: Gweyi-Onyango and Osei-kwarteng [18].*

The United Nations Population Funds (UNFPA) had projected the urban population to outnumber rural population in 2007. In line with this projections, urban population is likely to keep increasing in the coming years [19]. increased urban population leads to consumption of water which results in an increment in waste water. These waste water is used to irrigate vegetables in urban and per-urban such as *Masaku* county in Kenya. Use of waste water has been institutionalised for irrigation in some urban areas [20]. Based on available evidence, these waste water is not treated and the qualuty of effluent was below the performance of treatment [19].

4. Conclusion

Consumption of spinach and kale in *Mlolongo*, *Athi* river and *Syokimau* areas predisposes people, especially children to lead poisoning and the negative aspects of Cadmium. According to WHO there are no safe levels for Lead. Consumption of vegetables with bioaccumulated Lead and Cadmium can be prevented the nastional and county governments ensuring zero tolerance to production of vegetables and foods using waste water and managing effluent from light industries including the battery factory in *Athi* river town whose effluent contaminates river *Athi*. Elevated levels of the two heavy metals in spinach and kale is an indication of the negative consequences of poor management of the environment by some counties (Masaku and Kiambu) and laxity by the the national environment management Authority (NEMA).

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