

Full Length Research Paper

Evaluation of heavy metal application in urban grown vegetables in Thika Town, Kenya

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Consumption of leafy vegetables grown in urban areas contaminated with heavy metals is a major source of health problems for both humans and animals. This study was conducted to analyze the heavy metal levels in tomato (*Lycopersicon esculentum* L.) and spinach (*Spinacia oleracea* L.) grown in Thika town. Heavy metal concentration was analyzed using Atomic Absorption Spectrometry. The mean concentrations of lead (Pb), Zinc (Zn) and cadmium (Cd) in all the samples were more than the maximum permitted concentrations while there was no evidence of copper (Cu) contamination. Heavy metal uptake differences by the vegetables were attributed to plant differences in tolerance. Further Lead (mgkg⁻¹) concentration in the vegetables was above the maximum limit of 0.3 mgkg⁻¹ accepted for human health by World Health Organization (WHO) standards. Due to increased consumption of vegetables by urban communities, we suggest that it is important to treat industrial effluents which are significant sources of heavy metals and phyto-extract excess metals from polluted environments to reduce health risks.

Key words: *Lycopersicon esculentum*, *Spinacia oleracea*, lead, zinc, cadmium, copper, atomic absorption spectrometry.

INTRODUCTION

Vegetables are an important part of the human diet. They contain carbohydrates, proteins, as well as vitamins, minerals and trace elements that form an essential part of a healthy diet (Abdola and Chmtelnicka, 1990). In recent years, greater awareness of the food value of vegetables has led to increased consumption particularly among the urban communities. This is as a result of exposure to

other cultures and acquiring proper education (Thompson and Kelly, 2003). However, vegetables also absorb heavy metals that are a major concern to public health. Accumulation of such toxic elements in vegetables may pose a direct threat to human health (Damek-Poprawa and Sawicka-Kapusta, 2003). In developing countries such as Kenya, rapid and unorganized urban and industrial developments have caused elevated levels of heavy metals in the urban environments (Khillare et al., 2004; Sharma et al., 2008a). Heavy metals are non-biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables. Plants take up

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heavy metals by absorbing them from deposits on the parts of the plants exposed to the air from polluted environments as well as from contaminated soils (Sharma et al., 2008b). A number of studies have shown heavy metals as important contaminants of vegetables (Singh and Kumar, 2006). Heavy metal contamination of vegetables may also occur due to irrigation with contaminated water (Sinha et al., 2006). Emissions of heavy metals from the industries and vehicles may be deposited on the vegetable surfaces during their production, transport and marketing (Sharma et al., 2008b). Prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of heavy metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases [Jarup, 2003; Codex Alimentarius Commission (FAO/WHO), 2001].

Some heavy metals such as copper (Cu), cadmium (Cd), zinc (Zn), manganese (Mn), cobalt (Co) and Molybdenum (Mo) act as micronutrients for the growth of animals and human beings when present in trace quantities, whereas others such as Cd, As, and Cr act as carcinogens (Trichopoulos, 1997; Feig et al., 1994), and Hg and Pb are associated with the development of abnormalities in children (Pilot and Dragan, 1996). Monitoring and assessment of heavy metals concentrations in the vegetables from the market sites have been carried out in some developed (Milacic and Kralj, 2003), and developing countries (Radwan and Salama, 2006; Jassir et al., 2005).

However in Africa, there is limited published data available on heavy metal concentrations in the vegetables from the market sites (Agrawal, 2003). Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic (Yargholi and Azimi, 2008). Several investigations of water, soil and vegetables from urban areas have shown that these heavy metals are the main pollutants particularly of lands under irrigation with waste waters (Mohsen and Mohsen, 2008). The objective of this study is to analyze the heavy metal (Cu, Zn, Cd and Pb) concentrations in tomato (*Lycopersicon esculentum* L.) and spinach (*Spinacia oleracea* L.) grown locally in Thika town, Kenya and sold in the open urban markets.

MATERIALS AND METHODS

Study area

The study was carried out in Thika town situated in Central, Kenya within 1° 3' 0" South, 37° 5' 0" East. It is one of the major industrial towns with several manufacturing firms, factories and heavy traffic on major highways.

The vegetable samples were collected from six plots in each of the neighbouring farms at Makongeni, Majengo and Komu locations.

Soil sampling and analysis

At each site, composite surface soil (0-10 cm) samples (from a bulk soil made up of 20 different soil samples per farm) of the vegetable farms were randomly collected separately and properly labeled. The samples were then transported to the research laboratory at the Jomo Kenyatta University of Agriculture and Technology, Kenya for analysis. The soil samples were air-dried and crushed to pass through a 2 mm mesh sieve. A total of 0.5 g of the ground soil was transferred to a 50 ml conical flask, and 5 ml of concentrated Sulphuric acid was added followed by 25 ml of concentrated Nitric acid and 5 ml of Hydrochloric acid. The contents of the conical flask were heated at 200°C for 1 h in a fuming hood and later cooled to room temperature. After the cooling, 20 ml of distilled water was added and the mixture filtered using filter paper No.1 (11 cm) to complete the digestion. The mixture was then allowed to settle for 15 h. The supernatant was analyzed for total Fe, Cd, Cr and Pb using Atomic Absorption Spectrophotometry (Model 2380, Perkin-Elmer, USA).

Vegetable sampling and analysis

Twenty five recently matured spinach leaves and tomato fruits were randomly selected from 25 different plants at the early maturity. The samples were then transported in plastic bags to the research laboratory at the Jomo Kenyatta University of Agriculture and Technology, Kenya where they were repeatedly cleaned with deionized water. After 2-3 days, the samples were dried in an oven at 65°C, ground and 0.5 g of ground samples digested with 5 ml of nitric acid and 3 ml of hydrogen peroxide at 160°C for 1h (Mohsen and Mohsen, 2008). The heavy metal concentration analysis was done using Atomic Absorption Spectrometry.

Stream water sampling and analysis

The surface composite samples of water were taken using clean wide mouthed bottles from small streams diverted to vegetable farms. About 5 ml of HNO₃ acid was added to clean 250 ml polyethylene bottles, before adding about 100 ml of water. The HNO₃ acid was added to preserve and acidify the water samples (Mohsen and Mohsen, 2008). These samples were analyzed for heavy metal concentration levels as described earlier.

Statistical analysis

Data collected was analyzed using the Statistical Package for Social Scientists version 16. The results on the concentration of heavy metals were expressed in terms of descriptive statistics while the figures were presented with mean values in triplicates. The statistical significance was computed using T-test at P<0.05.

RESULTS AND DISCUSSIONS

Levels of heavy metals in soil

The results on concentration of heavy metals in soils at

Table 1. Mean levels of heavy metals (mg/kg) in soils from the vegetable farms (Mean ± SE).

| | Fe | Cd | Cr | Pb |
|-----------|--------------|-----------|--------------|------------|
| Makongeni | 11803.0±61.9 | 13.6±4.1 | 1806.4±60.2 | 73.33±12 |
| Majengo | 15673.3±5.6 | 21.37±3.1 | 1939.20±30.4 | 693.33±8.8 |
| Komu | 16224.8±54.6 | 9.43±2.2 | 2020.0±22.5 | 57.7±2.3 |
| P value | 0.90 | 0.15 | 0.12 | 0.15 |

Table 2. Mean levels of heavy metals (mg/kg) in spinach grown in different farms around Thika town (Mean ± SE).

| | Fe | Cd | Zn | Pb |
|-----------|-------------|------------|-------------|--------------|
| Makongeni | 843.05± 2.6 | 0.67± 0.1 | 63.77 ±1.00 | 16.00± 1.04 |
| Majengo | 344.71± 2.9 | 0.70 ±18 | 65.07± 3.21 | 29.50 ± 1.26 |
| Komu | 811.3± 2.9 | 0.41± 0.16 | 76.9 ±0.8 | 13.3 ± 1.53 |
| P value | 0.9 | 0.22 | 0.03* | 0.3 |

* Significant at P<0.05.

location are summarized in Table 1. Fe levels in soils from the vegetable farms ranged between 16224.8 and 11803.0 mgkg⁻¹. The levels are above the accepted limits of 425.00 mgkg⁻¹ for agriculture as described by Food and Agriculture Organization (FAO) - World Health Organization (WHO) [Codex Alimentarius Commission (FAO/WHO), 2001]. The heavy metal concentration of Cd, Cr and Pb varied from 9.43-21.37, 1806.4-2020.0 and 57.7-693.33 mgkg⁻¹ which are above the maximum permitted levels of 0.1, 100 and 0.3 mgkg⁻¹, respectively [Codex Alimentarius Commission (FAO/WHO), 2001]. Therefore, these high levels of soil contamination could be attributed to effluents from major industries such as Tanneries, Painting Factories, Soap Factories, Food industries and Melting Industries within the vicinity of Thika town. Other sources of contamination could also be due to large volumes of domestic and industrial waste water that are discharged from garages, gas stations, hospitals and schools into the streams.

The variation of Cd levels could also be attributed to the different soil fertility management practices, use of chemical pesticides/herbicides that are used in the farms as well as the underlying parent rocks in the sites. Lead can also be introduced in soils from lead based and industries and auto emissions (Singer and Hanson, 1969). Heavy metal contamination of soils leads to lower the leaf production rate and the plant mass as well as poor development of flowers (Ryser and Sauder, 2006). Heavy metal contamination of soil via industrial effluents, sewage influx and contaminated ground waters can induce serious problems to soil, cropping, vegetation and in turn human health (Jaja and Odoemena, 2004). Heavy metal accumulation by plant tissues, its presence in the soil persistently or its presence in ground waters is not

a healthy sign for the environment (Rabia and Ali, 2007). The variation of heavy metal depositions in the soils at Majengo, Makongeni and Komu locations could also be associated with a wide range of sources including small scale industries found in Thika town. The industries are found close to the farms and engage in battery production, metal products, metal smelting and Cable coating industries. Other likely sources may be brick kilns; vehicular emissions; re-suspended road dust and diesel generator sets.

Levels of heavy metals in vegetables (*Lycopersicon esculentum* and *Spinacia oleracea*)

The heavy metal concentrations varied between the farms and vegetables as shown in Table 2 and 3. The levels of Pb and Cd in spinach and tomatoes varied from 13.3-29.5, 0.41-0.70 mgkg⁻¹ and 3.5-20.5, 0.7-0.95 mgkg⁻¹, respectively. The Cd levels were above the maximum levels (ML) of 0.10 mgkg⁻¹ permitted by FAO-WHO in vegetables (Codex Alimentarius Commission (FAO/WHO), 2001). The Fe levels were highest in spinach (843 mgkg⁻¹) and lowest (344.71 mgkg⁻¹) at Makongeni while concentration of Zn ranged from 76.9-63.77 mgkg⁻¹. The Fe levels in Komu and Makongeni were above the FAO-WHO accepted maximum limits of 425 mgkg⁻¹ while Zn levels were within the accepted limits of 100 mgkg⁻¹. Statistical analysis of Zn levels in spinach and Cd as well as Zn in tomatoes using paired samples T-test showed significance difference (P<0.01). The concentration of Pb in both spinach and tomatoes was found to be above the maximum limit of 0.3 mgkg⁻¹ accepted for human health by WHO standards [Codex

Table 3. Mean levels of heavy metals (mg/kg) in tomato fruits grown in different farms around Thika town (Mean ± SE).

| | Fe | Cd | Zn | Pb |
|-----------|-------------|------------|--------------|------------|
| Makongeni | 23.66± 1.2 | 0.7 ±0.10 | 80.66 ± 2.55 | 11.2±1.42 |
| Majengo | 88.4 ±1.2 | 0.75± 0.17 | 81.09 ±2.75 | 20.50±0.76 |
| Komu | 48.03± 0.25 | 0.95± 0.21 | 92.05± 1.38 | 3.5±0.58 |
| P value | 0.9 | 0.03* | 0.002* | 0.76 |

* Significant at P<0.05.

Table 4. Mean levels of heavy metals (mg/kg) in small streams flowing into the vegetable farms (Mean ± SE).

| | Fe | Cd | Cr | Pb |
|-----------|-----------|-----------|-----------|-----------|
| Makongeni | 1.08±0.19 | 0.09±0.0 | 6.91±0.15 | 0.37±0.03 |
| Majengo | 1.17±0.01 | 0.03±0.01 | 7.12±0.14 | 0.08±0.08 |
| Komu | 0.64±0.03 | 0.08±0.01 | 7.4±0.1 | 1.07±0.02 |
| P value | 0.35 | 0.16 | 0.02* | 0.5 |

*Significant at P<0.05.

Alimentarius Commission (FAO/WHO), 2001]. Lead is known to be toxic and harmful to plants, although many plants usually show some ability to accumulate large amounts of lead without visible changes in their appearance or yield (Wierzbicka, 1995). In most plants, the accumulation of lead can exceed several hundred times the threshold of maximum level permissible for human. Introduction of lead into the food chain affect human health (Coutate, 1992). Acute Pb poisoning (exposure to a high concentration during a short time period) can lead to death (Laura et al., 2009), while chronic exposure (prolonged exposure at lower concentrations) may affect reproductive success behavior immune response (Snoeijs et al., 2004) and physiology (Fair and Ricklefs, 2002).

This could cause disruption of biochemical processes which may in turn lead to cardiovascular, nervous system, kidney and bone diseases (Jarup, 2003; WHO., 1992). Similarly, Cd levels were found to be higher than 0.1 mgkg⁻¹ which is accepted by WHO standards in vegetables [Codex Alimentarius Commission (FAO/WHO), 2001]. These findings confirm earlier studies that showed high accumulation of Cd in lettuce and spinach grown in urban areas (Torabian and Mahjouri, 2002). Cadmium accumulation in the aerial parts of a plant is higher than in the parts below the ground (root) which is in line with other previous studies (Doyle, 1998; Sanita di Toppi and Gabrielli, 1999).

Exposure to high levels of Cadmium can lead to cancer and kidney failure to humans (Snoeijs et al., 2004). The studies revealed that cadmium is a highly mobile metal, easily absorbed by the plants through root surface and

moves to wood tissue and transfers to upper parts of plants (Gardiner et al., 1995). The elevated concentration levels of the heavy metals in vegetables observed in this study may be due to the physical and chemical nature of the soil in the farms, absorption capacities of heavy metals by vegetables and atmospheric deposition of heavy metals. The high levels may also be influenced by environmental factors such as temperature, moisture, wind velocity and the nature of the vegetables (Zurera et al., 1989). The vegetables this study varied in the concentrations of heavy metals which could be as a result of anthropogenic activities such as brick kiln activities, addition of phosphate fertilizers or use of metal-based pesticides in the farms and urban industrial activities at the open air market sites around the farms.

Levels of heavy metals in the stream waters

The results revealed varying heavy metal level concentrations in the three streams as summarized in Table 4. The levels of Fe, Cd, Cr and Pb ranged between 0.64-1.17, 0.03-0.09, 6.91-7.40 and 0.08-1.07 mgkg⁻¹, respectively. There was significant variation (P<0.01) in the levels of Cr. Lead concentrations were lower than European Commission (EC) upper limit of 300 mgkg⁻¹ (EC, 1986) and also within the maximum tolerable levels proposed for agricultural soils (Kabata-Pendias and Pendias, 1984). The Cd levels in the streams were below the lower limit of the recommended 1–3 mgkg⁻¹ (EC limit). The presence of heavy metals in the streams could be due to high levels of industrial effluents from surrounding

industrial sources that enter into the streams. Further, there is little or no treatment that is applied to the industrial discharges to detoxify the waste water draining into the streams. Sources of Cd in the urban areas could also come from metal plating and lubricating oils as well as due to the rough surfaces of the roads which increase the wearing of tyres, and run-offs from the roadsides. Urban grown vegetables take up the heavy metals from soil irrigated with water from contaminated urban streams. Low doses of Cadmium are harmful to humans and cause coughing, headaches, and vomiting while extended doses can accumulate in the liver and kidneys leading to painful disorders in the second case, and even fatal in the former (Shannon, 1998). Chromium exposure leads to skin irritation, ulceration, damage to circulatory and nerve tissue while lead leads to health problems such damage to the nervous system, mental retardation, and even death (Bubb and Lester, 1994).

CONCLUSIONS AND RECOMMENDATIONS

In this study, urban grown vegetables grown at the three different locations in Thika town were found to contain high levels of heavy metals. Heavy metal depositions were associated with effluent from local industries, pesticide and fertilizer inputs. Since the soils, stream waters and vegetables were found to be contaminated with heavy metals, it is recommended that vegetables should not be cultivated in farms in urban areas and fields irrigated by urban and industrial waste water or water contaminated by heavy metals. Further, it is also important to reclaim contaminated lands to avoid heavy metal pollution. Town planners should also ensure that setting up of all industries in urban and peri-urban areas are approved only when there is evidence of effective waste treatment for the heavy metals. This should form part of the environment impact assessment.

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