Assessment of heavy metal concentrations in Mango fruits grown in Kasese district, Uganda

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Fruits are a good source of carbohydrates, sugars, dietary fiber, fat, proteins, vitamins and minerals. In this study, mango fruits grown in Kasese as well as the soil and irrigation water used in fruit growing were analysed for heavy metals cadmium (Cd), chromium (Cr) and lead (Pb). The mango fruits and soil samples were obtained from three sites; Mubuku Irrigation Scheme, Mpondwe-Lhubiriha Town Council (MLTC) and Nyakiyumbu Sub-County in Kasese district. The concentration of Cd was below detection levels in all samples of soil, irrigation water and mango fruits. The mean concentrations of Pb and Cr in the mango fruits was 0.32 ±0.08 and 0.4±0.07 mg/kg dry weight while in soil were 69.98 ± 4.24 mg/kg and 13.403±2.03 mg/kg respectively and that in irrigation water were 0.1127± 0.014 mg/L and 0.0171 ± 0.003 mg/L respectively. The concentration of Pb in mango fruits and in irrigation water was above the maximum permissible limits (MPL) while Pb in soil and Cr in all study matrices were within the MPL by WHO and Dutch standards. These findings suggest that in general, mango fruits grown in Kasese as well as irrigation water have high concentration of Pb and may be a health risk to consumers.

Key words: Heavy metals, Mango fruits, soil, irrigation water, Kasese, Uganda.

INTRODUCTION

Heavy metal pollution is widely spread globally due to the rapid pace of urbanization, land use changes, and industrialization, especially in developing countries with extremely high populations (UN-HABITAT, 2004). This has caused emerging issues of food security because of the increasing risk of contamination of food by pesticides, heavy metals, and/or toxins (Clarke and Smith, 2011; Säumel et al., 2012). Consequently there has been increased interest in food safety and this has encouraged research on possible contamination of foods by heavy metals, pesticides and other contaminants in the recent years (Thompson and Darwish, 2019).

Heavy metal accumulation in soils is of concern in agricultural production due to the adverse effects on food quality and crop growth (Nagajyoti et al., 2010). It has been known for long that plants take up metals by absorbing them from contaminated soil and waters (especially irrigation with contaminated water) as well as...
from deposits on different parts of the plants exposed to the air from polluted surroundings (Chojnacka et al., 2005). As a result, nearly half of the mean ingestion of heavy metals (e.g., lead, cadmium and mercury etc.) through food is due to plant origin (fruit, vegetables and cereals). Unfortunately, chronic low-level intakes of heavy metals have damaging effects on human beings and other animals, since there is no good mechanism for their elimination (ul Islam et al., 2007). For instance lead contamination in a long term adversely affects mental growth, causing neurological and cardiovascular diseases in humans, especially children (Zhou et al., 2016; Al-Saleh et al., 2017). Lead (Pb) and cadmium (Cd) have carcinogenic effects (Krueger and Wade, 2016; Al-Saleh et al., 2017; Ju et al., 2017) and can also lead to bone fractures and malfunction, cardiovascular complications, kidney dysfunction, hypertension, and other serious diseases of the liver, lung, nervous system, and immune system (Zhou et al., 2016; El-Kady and Abdel-Wahhab, 2018). Chromium(Cr) in its hexavalent form is considered among the 14 most harmful environmental pollutants and can cause non-carcinogenic human health hazards such as neurologic complications, headaches, and liver disease, it could also be a carcinogen associated with lung, nasal and sinus cancers (US-EPA, 2000; Xin et al., 2015; Mishra and Bharagava, 2016).

The effect of heavy metal contamination of fruit cannot be underestimated as fruits contain carbohydrates, sugars, dietary fiber, fat, proteins, vitamins and minerals which are important for human health when eaten and which of these nutrients especially protein, vitamins, iron and calcium are in short supply (Slavin and Lloyd, 2012). Fruits also contain anti-oxidants and other biologically active ingredients hence effective in treatment of numerous diseases (Kay et al., 2006; Habauzit and Horcajada, 2008). The fact that fruits are an important component of the human diet, the effect of heavy metal contamination in them cannot be ignored. Metals from both natural and pollutant sources however, have the potential for being assimilated by plants through foliar or root absorption processes (Smedley and Kinniburgh, 2002). This may result therefore, in a difference in heavy metal composition of fruits like mangoes grown in different geographical places. This study was done to find out the levels of heavy metals in Mango fruits grown in Kasese and also in soils where the mango fruits are grown as well as in the water used for irrigation.

**MATERIALS AND METHODS**

**Study area**

Kasese District is in western Uganda and is home to Kasese Airport. The city is near the Rwenzori Mountains and Queen Elizabeth National Park. Kasese is approximately 345 km, by road, west of Kampala, Uganda's capital and largest city. Kasese is also about 61 km by road, north-east of Mpondwe Lhubiriha Town council (MLTC), the border town at the international border between Uganda and the Democratic Republic of the Congo (DRC). The coordinates of Kasese are 0°11’12.0”N, 30°05’17.0”E (Latitude:0.186667; Longitude:30.088050). River Sebwe and Mubuku lie on the main Kasese-Fort portal Highway, which continues on to Mpondwe at the International border with the Democratic Republic of the Congo. The town sits on the eastern bank of Mubuku River, Mubuku is also about 14km from the nearest small town called Hima. River Sebwe is the main source of water for Mubuku irrigation scheme. Nyakiyunyu subcounty Borders Bwera Subcounty.

**Sampling procedure and sample size**

A total of 30 composite samples of mango fruits were obtained from farms around Mubuku irrigation scheme. Mpondwe – Lhubirha Town council and Nyakiyunyu subcounty in Kasese district. The sampling was done four times from each of the study areas. The fruits samples were collected in the same orchard in Mubuku irrigation scheme but from Nyakiyunyu and Mpondwe Lhubiriha they were collected from three different orchards randomly selected from each of the subcounties. The fruits were picked by hand from the mango trees during the day and in the dry season. Only the edible part of the fruit was analysed for the heavy metals and the rotten parts were removed first. Also, ten composite soil samples from two farms in Mpondwe- Lhubirha Town council, one Mubuku Irrigation scheme and two in Nyakiyunyu sub county were obtained around the mango trees at a depth of 0-20 cm using soil auger and bulked together to form a composite sample as has been done in other studies (Bian et al., 2015; Wang et al., 2015; Kacholi and Sahu, 2018). The ten water samples from River Sebwe (whose water is used in Mubuku irrigation scheme) were obtained. These samples were always obtained during the morning. No water samples were obtained from Mpondwe- Lhubirha and Nyakiyunyu since there is no irrigation in those areas. The collected soil and vegetable samples were put into zip lock bags and labelled, while water samples were put in previously rinsed and dried bottles. The samples were always collected on the same days.

**Sample preparation and treatment**

Mango fruit samples (each of 0.5 kg) were taken at random from the composite sample and processed for analysis by dry ashing method. The samples were oven dried at 105°C for 24 h first, the dried samples were then powdered manually in a grinder. Powdered samples (50.46 g for sample from Nyakiyunyu, 50.04 g for that from Mpondwe-Lhubirha Town council and 50.07 g for sample from Mubuku) with three replicates were taken from each of the ten samples, accurately weighed and then placed in a silica crucible. A few drops of concentrated nitric acid were added to the solid as an aid to ashing a process that was done in a muffle furnace by stepwise increase of temperature up to 550°C. The samples were left to ash at this temperature for 6 h. The ash was kept in desiccators and then rinsed with 3 M hydrochloric acid after which the ash suspension was filtered into a 50 ml volumetric flask through filter paper and the volume made to the mark with 3 M hydrochloric acid.

Soil samples were air dried first. From each sample, 1.250 g were transferred to the destruction tube, 50 ml of water and three boiling chips were added. 50 ml of HCl/HNO₃ 3:1 was also added. The resultant solution was then mixed and a funnel placed on top of the destruction tube. The tube was then heated to 100°C and
maintained for 1 h, increased to 125°C and maintained for 15 min, increased to 150°C and maintained for 15 min, increased to 175°C and maintained for 15 min, increased to 200°C and maintained for 15 min. The contents were concentrated to 5 ml and then cooled. 1 ml of 30% Hydrogen peroxide was added to the contents and then destructed for 10 min. 10 ml of water and 5 ml were added to the contents, mixed and heated until boiling and then cooled. The whole sample was transferred to a 50 ml volumetric flask which was then filled up to the mark, mixed and allowed to settle for 1 h. Finally, the absorbance of the clear supernatant was measured. The water sample was prepared by filtration, followed by acidification. 50 ml of the acidified sample were transferred into a 50 ml volumetric flask. The absorbance of the sample was then measured.

Heavy metal analysis by atomic absorption spectrophotometer

Standard solutions of heavy metals (lead, chromium and cadmium) were prepared from the individual 1000 mg/L standards supplied in 0.1 M Nitric Acid. Reagent blanks of the different heavy metals were prepared by diluting 10ml of concentrated Nitric Acid to 100 ml in a volumetric flask. A series of working standards were prepared from the standard stock solutions to obtain heavy metal solutions of concentrations 0.1, 0.2, 0.3 and 0.4 M. The standards were fed into the flame atomic absorption spectrophotometer (AA 6300 shimadzu) and their absorbencies obtained which were used to obtain calibration curves. The samples were also fed into the atomic absorption spectrometer; their absorbencies obtained and then used to get their concentrations from the calibration curves. The detection limits were 0.0005, 0.001, and 0.004 mg L⁻¹ for Cd, Cr, and Pb, respectively. The results were subjected to analysis using SPSS ver. 20 statistics program (IBM Corp. Armonk, NY: Released 2011) to determine if there were any significant differences among the means. Significant differences between means were determined at 5% level of significance.

RESULTS AND DISCUSSION

Levels of heavy metals in soil

The study reports on the heavy metal concentration of Cd, Cr and Pb determined in soil samples collected from the selected mango fruit production areas in Kasese district. The observed concentrations of Cd, Cr and Pb in the soil were compared with Maximal Permissible limits by WHO (Cd=0.1 mg/kg, Cr=100 mg/kg and Pb=600 mg/kg). One sample T-test analysis was carried out and Cr in the soil sample results were found to be significantly lower than WHO permissible limits (Cr=100 mg/kg). Likewise, a one sample T-test was conducted for Pb soil sample results and it was significantly lower than the permissible limits (Cr=600 mg/kg). The mean concentration of heavy metals found in the soil samples are summarized in Table 1.

| Heavy metal | Mean concentration(mg/kg) ± SD | MPL (mg/kg) |
|------------|---------------------------------|-------------|
|            | Nyakiyumbu | MLTC | Mubuku | WHO (2017) | P-values |
| Cd         | -          | -    | -      | 0.1        | -        |
| Cr         | 64.356±3.78 | 78.256±4.48 | 67.323±4.47 | 100 | 0.00 |
| Pb         | 13.404±2.1 | 12.572±1.79 | 14.232±2.2 | 600 | 0.00 |

SD-standard deviation; *Values significantly below the permissible limits following one sample T-test (P<0.05).

Levels of selected heavy metals in water

The heavy metals concentrations of Cd, Cr and Pb was determined in water samples collected from River Sebwe from which water used in Mubuku irrigation scheme and for drinking is obtained. The heavy metals levels in water were highest for Pb followed by Cr and Cd was below detectable levels. The mean concentrations of Cr and Pb
were 0.0171±0.003 mg/L and 0.1127± 0.014 mg/L respectively. Cr concentration in the water from River Sebwe was significantly lower than the MPL while Pb concentrations was significantly higher than the permissible WHO limits. Basing on the MPL for Pb and Cr in water of 0.01 and 0.05 mg/L respectively (WHO, 2017), only Pb concentration was above the MPL.

The concentration levels obtained for Pb were lower than those obtained by Kacholi and Sahu (2018) in water in Dar es Salaam Tanzania and those reported by Bigdeli and Seilsepour (2008) of 0.06 mg/L in a local river for irrigation in Shahre Rey, Iran. The high concentration of lead obtained in this study is of concern because, in addition to effects on the nervous system, exposure to lead has effects both at low and high levels and at short and long term. Prolonged low level exposure, may lead to diminished intellectual ability while long term exposure may lead to kidney damage (Järup, 2003). The Lead (Pb) could be coming from lead acid batteries and paints (Kushwaha et al., 2018) since River Sebwe is not very far from Kasese town and Hima. It could also be from motor vehicle fuels as river Sebwe is near the main tarmac road from Kasese to Fort Portal. The concentration of chromium was higher than that obtained by Mousavi et al. (2013) in Mashhad, Iran but lower than that obtained by Bambara et al. (2015) in Burkina Faso. The water obtained from River Sebwe was therefore safe from any side effects of higher chromium concentration.

### Levels of heavy metals in fruits

Heavy metal concentration of Cd, Cr and Pb was determined in mango fruits collected from production sites in selected areas in Kasese district. The mean concentrations of heavy metals found in fresh fruits are summarized in Table 2.

| Heavy metal | Mean concentration(mg/kg) ±SD | WHO (2017) MPL (mg/kg) | P-values |
|-------------|-------------------------------|------------------------|----------|
|             | Nyakiyumbu | Mubuku | MLTC |                  |            |
| Cd          | -          | 0.0925±0.06 | 0.4025±0.10 | 0.4265±0.06 | 0.2 | - |
| Cr*         | 0.3789±0.06 | 0.4025±0.10 | 0.4265±0.06 | 2.3 | 0 |
| Pb          | 0.2907±0.07 | 0.3139±0.07 | 0.3627±0.09 | 0.3 | 0.137 |

SD-Standard deviation. *Values significantly below the permissible limits following one sample T-test (P< 0.05).

One sample T-test analysis for Cr in mango fruits indicated that the results were significantly lower than the WHO Permissible limits. Pb concentrations in mangoes were not significantly different from the WHO Permissible limits. Fruits from Mpondwe-Lhubiriha Town council had the highest levels of both Cr and Pb whereas Nyakiyumbu Sub-County fruits had the lowest levels of the metals followed by those from Mubuku Irrigation scheme. The concentration of Pb in Nyakiyumbu is within the recommended levels of Pb in Mango fruits. This could be due to the fact that of all the three study sites, Nyakiyumbu is the most rural and has less influence from vehicle traffic, garages and other potential sources of lead. Several studies show that heavy metal contamination of garden soils is rampant in urban areas due to industrial activity and the use of fossil fuels (Ahmed and Ishiga, 2006; Wong, 2010; Sterrett et al., 1996; Chronopoulos and Haidouti, 1997; Wong, 2010).

Basing on the MPL for Cd, Cr and Pb in fruits (0.2, 2.3 and 0.3 mg/kg respectively) (FAO and WHO, 2017), the levels of Cr in fruits from all the three study areas are lower than the MPL whereas levels of Pb are higher than the MPL except for those from Nyakiyumbu. The mean concentrations of Lead obtained in mango fruits in this study are lower than those obtained in Misurata-Libya, Bangladesh and Bangalore city, India (Elbagermi et al., 2012; Shaheen et al., 2016) in Mahdavian and Somashekar (2008). The concentrations of Pb and Cr were higher in the mango fruits and this could be because plants absorb the heavy metals when they are deposited on their leaves through the tissues (Kachenko and Singh, 2006) in addition to what they absorb from the water and soils. One of the important dietary sources of metals to plants is through irrigation with contaminated water (Banerjee et al., 2010). The main sources of heavy metals to mango fruits and other plants are their growth media (soil, air, nutrient solutions) from which these are taken up by the roots or foliage (Lokeshwari, 2006). The higher concentration of Pb from fruits obtained from Mpondwe Lhubiriha Town council could probably be due to the fact that the area is more semi urban and has many activities and vehicle traffic as well as garages that could be sources of lead acid batteries.
Conclusion

Generally, the concentration of Pb in Mango fruits was higher than the MPL by WHO except for the fruits obtained from Nyakiyumbu. concentration of chromium in fruits was within the MPL by WHO. The concentration of Cr, Pb and Cd were all within the MPL in soil. Meaning that soils are not yet contaminated by these heavy metals in all the study sites and hence still good for farming. The concentration of Pb in the waters of River Sebwe was higher than the MPL while that of Cr was within the limits. Cd was below detection levels therefore, the water may be a risk to human health due to the high concentration of Pb. These findings suggest that in general the presence of high concentration of lead in the fruits could probably be from the water being used for irrigation but also from other sources in the environment.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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