AJ ACADEMIC JOURNALS
expand your knowledge

African Journal of Environmental Science and Technology

Full Length Research Paper

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

Godfrey Muhwezi[1*], Johnson Thembo[2] and Juliet Kyayesimira[3]

[1]Department of Chemistry, Faculty of Science, Muni University, P. O. Box 725, Arua, Uganda.
[2]Cipla Uganda Limited, P. O. Box 34871, Luzira, Kampala, Uganda.
[3]Department of Biology, Faculty of Science, Kyambogo University, P. O. Box 1, Kyambogo, Kampala, Uganda.

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 malformation, 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 most 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. Nyakiyumbu 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 – Lhubiriha Town council and Nyakiyumbu 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 Nyakiyumbu 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- Lhubiriha Town council, one Mubuku Irrigation scheme and two in Nyakiyumbu 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- Lhubiriha and Nyakiyumbu 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 Nyakiyumbu, 50.04 g for that from Mpondwe-Lhubiriha 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/HNO_3 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

Table 1. Mean concentrations of selected heavy metals detected in soil samples.

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).

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 concentrations of soils determined was based on sample dry weight. Levels of Cd were not detected, Cr was lowest at Nyakiyumbu (64.356 mg/kg) and highest at Mpondwe Lhubiriha Town council (78.256 mg/kg) and Pb was lowest at Mpondwe Lhubiriha Town council (12.572 mg/kg) and highest at Mubuku irrigation scheme (14.232 mg/kg). Mean concentrations of Cr and Pb in soil were 69.98 ± 4.24 mg/kg and 13.403 ±2.03 mg/kg respectively. The concentrations of Cr, Pb and Cd detected in the soil samples from all study sites were very much below the Maximum allowable concentrations by Dutch standard (Pb, 85 mg/kg and Cr 100 mg/kg). The mean concentration of Cr and Pb obtained in this study was higher than that obtained by Wang et al. (2012) in soil from a waste water irrigated area in China and that reported by Bahmanyar (2008) from soils under long term irrigation with waste water in Iran. The concentration levels of Pb and Cr was also higher than obtained by Hussain et al. (2017) in Pakistan. The concentration level of Pb was below while that of Cr was above that reported by Fosu-Mensah et al. (2017) in Accra Ghana. Cr was also below but Pb was above the concentrations reported by Hu et al. (2017) in the soil around Yangtze River Delta in China. The results show that Pb and Cr levels in the analysed soils though high are still below the Maximum permissible levels by WHO. The soils in the study area are therefore have heavy metals levels within permissible limits.

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

Table 2. Mean concentrations of heavy metals detected in fresh mango fruits.

Heavy metal	Mean concentration(mg/kg) ±SD			WHO (2017) MPL (mg/kg)	P-values
	Nyakiyumbu	Mubuku	MLTC		
Cd	-			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).

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 concentrations determined were based on sample dry weight. The results showed that the levels of Cd were not detected, Cr levels ranged from 0.3789 to 0.4265 mg/kg. Pb levels were lowest in Nyakiyumbu (0.2907±0.07 mg/kg) and highest in Mpondwe Lhubiriha Town council (0.3627 ± 0.09 mg/kg). 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 rampart 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 was 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.

ACKNOWLEDGEMENTS

REFERENCES

Ahmed F, Ishiga H (2006). Trace metal concentrations in street dusts of Dhaka city, Bangladesh. Atmospheric Environment 40:3835-3844.

Al-Saleh I, Al-Rouqi R, Elkhatib R, Abduljabbar M, Al-Rajudi T (2017). Risk assessment of environmental exposure to heavy metals in mothers and their respective infants. International Journal of Hygiene and Environmental Health 220(8):1252-1278.

Bahmanyar MA (2008). Cadmium, nickel, chromium, and lead levels in soils and vegetables under long-term irrigation with industrial wastewater. Communications in Soil Science and Plant Analysis 39(13-14):2068-2079.

Bambara LT, Kabore K, Derra M, Zoungrana M, Zougmoré F, Cisse O (2015). Assessment of heavy metals in irrigation water and vegetables in selected farms at Loumbila and Paspanga, Burkina Faso. IOSR Journal of Environmental Science Ver. II.

Banerjee D, Bairagi H, Mukhopadhyay S, Pal A, Bera D, Ray L (2010). Heavy metal contamination in fruits and vegetables in two districts of West Bengal, India. Electronic Journal of Environmental, Agricultural and Food Chemistry 9(9):1423-1432.

Bian B, Zhou LJ, Li L, Lv L, Fan YM (2015). Risk assessment of heavy metals in air, water, vegetables, grains, and related soils irrigated with biogas slurry in Taihu Basin, China. Environmental Science and Pollution Research 22(22):7794-7807.

Bigdeli M, Seilsepour M (2008). Investigation of Metals Accumulation in Some Vegetables Irrigated with Waste Water in Shahre Rey-Iran and Toxicological Implications. American-Eurasian Journal of Agriculture and Environmental Science 4(1):86-92.

Chojnacka K, Chojnacki A, Górecka H, Górecki H (2005). Bioavailability of heavy metals from polluted soils to plants. Science of the Total Environment 337(1-3):175-182.

Chronopoulos J, Haidouti C (1997). Variations in plant and soil lead and cadmium content in urban parks in Athens, Greece. Science of the Total Environment 196(1):91-98.

Clarke BO, Smith SR (2011). Review of 'emerging' organic contaminants in biosolids and assessment of international research priorities for the agricultural use of biosolids. Environment International 37(1):226-247.

Elbagermi MA, Edwards HGM, Alajtal AI (2012). Monitoring of Heavy Metal Content in Fruits and Vegetables Collected from Production and Market Sites in the Misurata Area of Libya. ISRN Analytical Chemistry pp. 1-5.

El-Kady AA, Abdel-Wahhab MA (2018). Occurrence of trace metals in foodstuffs and their health impact. Trends in Food Science and Technology 75:36-45.

FAO, WHO (2017). Report of the 11th session of the codex committee on contaminants in foods. Joint FAO/WHO Food Standards Programme Codex Alimentarius Commission 40th Session. CICG, Geneva, Switzerland. Codex pp. 1-69.

Fosu-Mensah BY, Addae E, Yirenya-Tawiah D, Nyame F (2017). Heavy metals concentration and distribution in soils and vegetation at Korle Lagoon area in Accra, Ghana. Cogent Environmental Science 3(1):1-14.

Habauzit V, Horcajada MN (2008). Phenolic phytochemicals and bone. Phytochemistry Reviews 7(2):313-344.

Hu B, Jia X, Hu J, Xu D, Xia F, Li Y (2017). Assessment of heavy metal pollution and health risks in the soil-plant-human system in the Yangtze river delta, China. International Journal of Environmental Research and Public Health 14(9):1042.

Hussain A, Gupta R, Hussain M, Srivastva A (2017). Comparative study of heavy metals in soil and selected medicinal plants. Biochemical and Cellular Archives 17(2):507-513.

ul Islam E, Yang XE, He ZLI, Mahmood Q (2007). Assessing potential dietary toxicity of heavy metals in selected vegetables and food crops. Journal of Zhejiang University Science B 8(1):1-13.

Järup L (2003). Hazards of heavy metal contamination. British Medical Bulletin 68(1):167-182.

Ju H, Arumugam P, Lee J, Song JM (2017). Impact of Environmental Pollutant Cadmium on the Establishment of a Cancer Stem Cell Population in Breast and Hepatic Cancer. ACS Omega 2(2):563-572.

Kachenko AG, Singh B (2006). Heavy metals contamination in Vegetables grown in Urban and Metal Smelter Contaminated Sites in Australia. Water, Air and Soil Pollution 169(1):101-123.

Kacholi DS, Sahu M (2018). Levels and Health Risk Assessment of Heavy Metals in Soil, Water, and Vegetables of Dar es Salaam, Tanzania. Journal of Chemistry 2018.

Kay CD, Kris-Etherton PM, West SG (2006). Effects of antioxidant-rich foods on vascular reactivity: Review of the clinical evidence. Current Atherosclerosis Reports 8(6):510-522.

Krueger WS, Wade TJ (2016). Elevated blood lead and cadmium levels associated with chronic infections among non-smokers in a cross-sectional analysis of NHANES data. Environmental Health: A Global Access Science Source 15(1):1-13.

Kushwaha N, Rajeev V, Jose S (2018). Human Health and effects of heavy metals. International Journal of Applied Chemistry5(1):4-5.

Lokeshwari HCG (2006). Impact of heavy metal contamination of Bellandur Lake on soil and cultivated vegetation. Current Science pp. 622-627.

Mahdavian SE, Somashekar R (2008). Heavy Metals and Safety of Fresh Fruits in Bangalore City, India - A Case Study. Kathmandu University Journal of Science, Engineering and Technology 4:17-27.

Mishra S, Bharagava RN (2016). Toxic and genotoxic effects of hexavalent chromium in environment and its bioremediation strategies. Journal of Environmental Science and Health - Part C Environmental Carcinogenesis and Ecotoxicology Reviews 34(1):1-32.

Mousavi SR, Balali-Mood M, Riahi-Zanjani B, Yousefzadeh H, Sadeghi M (2013). Concentrations of mercury, lead, chromium, cadmium, arsenic and aluminum in irrigation water wells and wastewaters used

for agriculture in mashhad, northeastern Iran. International Journal of Occupational and Environmental Medicine 4(2):80-86.

Nagajyoti PC, Lee KD, Sreekanth TVM (2010). Heavy metals, occurrence and toxicity for plants: A review. Environmental Chemistry Letters 8(3):199-216.

Säumel I, Kotsyuk I, Hölscher M, Lenkereit C, Weber F, Kowarik I (2012). How healthy is urban horticulture in high traffic areas? Trace metal concentrations in vegetable crops from plantings within inner city neighbourhoods in Berlin, Germany. Environmental Pollution 165:124-132.

Shaheen N, Irfan NM, Khan IN, Islam S, Islam MS, Ahmed MK (2016). Presence of heavy metals in fruits and vegetables: Health risk implications in Bangladesh. Chemosphere 152:431-438.

Slavin JL, Lloyd B (2012). Health Benefits of Fruits and Vegetables. Advances in Nutrition 3(4):506-516.

Smedley PL, Kinniburgh DG (2002). A review of the source , behaviour and distribution of arsenic in natural waters. Applied Chemistry 17(5):517-568.

Sterrett SB, Chaney RL, Gifford CH, Mielke HW (1996). Influence of fertilizer and sewage sludge compost on yield and heavy metal accumulation by lettuce grown in urban soils 18(4):135-142.

Thompson LA, Darwish WS (2019). Environmental Chemical Contaminants in Food: Review of a Global Problem. Journal of Toxicology 2019.

UN-HABITAT (2004). The State of the World's Cities: Globalization and Urban Culture. https://mirror.unhabitat.org/pmss/listItemDetails.aspx?publicationID=1163

US-EPA (2000). Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures. https://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=20533

Wang Q, Liu J, Cheng S (2015). Heavy metals in apple orchard soils and fruits and their health risks in Liaodong Peninsula, Northeast China. Environmental Monitoring and Assessment P 187.

Wang Y, Qiao M, Liu Y, Zhu Y (2012). Health risk assessment of heavy metals in soils and vegetables from wastewater irrigated area, Beijing-Tianjin city cluster, China. Journal of Environmental Sciences 24(4):690-698.

World Health Organization (WHO) (2017). Guidelines for drinking water: fourth edition incorporating the first addendum. https://www.who.int/publications/i/item/9789241549950

Wong JW (2010). Heavy Metal Contents in Vegetables and Market Garden Soils in Hong Kong, pp. 37-41.

Xin Z, Wenchao Z, Zhenguang Y, Yiguo H, Zhengtao L, Xianliang Y, Xiaonan W, Tingting L, Liming Z (2015). Species sensitivity analysis of heavy metals to freshwater organisms. Ecotoxicology 24:1621-1631.

Zhou H, Yang WT, Zhou X, Liu L, Gu JF, Wang WL, Zou JL, Tian T, Peng PQ, Liao BH (2016). Accumulation of heavy metals in vegetable species planted in contaminated soils and the health risk assessment. International Journal of Environmental Research and Public Health 13 p.