EVALUATION OF HEAVY METAL STATUS, QUALITY AND SAFETY OF VEGETABLES SOLD IN MARKETS LOCATED IN MAKURDI METROPOLIS, NIGERIA FOR HUMAN CONSUMPTION

BY

BEMGBA ANJEMBE[1] AND NGUVEREN TYAVKASE[2]

[1&2] Department of Soil Science, College of Agronomy, Federal University of Agriculture, Makurdi, Nigeria

[1] Author for correspondence email address: bemgbanjembe@gmail.com

ABSTRACT

Studies were carried out to evaluate the quality of some common vegetables sold in markets located within Markurdi metropolis in terms of their heavy metal status and safety for human consumption. Five markets (Makurdi Modern Market, Wadata, High Level, Wurukum and North bank) where vegetables are sold in large quantities were selected. Four common vegetables sold and consumed in very large quantities were sampled for twelve weeks. The vegetables include Cabbage, Pumpkin, Okra and Amaranthus. Collected samples were subjected to Laboratory Analysis and concentrations of five heavy metals were determined. These metals were Zinc, Copper, Lead and Selenium. These concentrations were compared with the FAO/WHO safety limits for heavy metals in vegetables and food. It was observed that metal concentration in the samples were lower than the safety limits of FAO/WHO and are thus safe for human consumption. Concentration of the metals in Cabbage was consistently higher than the other vegetables while the concentration in Amaranthus was mostly lower across the selected Markets. Samples from North Bank market had considerably lower concentration of these metals while samples from High level market contained the highest concentration. It was concluded that Amaranthus from North Bank market is of best quality for human consumption. Monitoring of heavy metal concentration in vegetables sold in these markets would be necessary as these vegetables have the capacity to phytoremedy contaminated substrates. This is necessary for preservation of human health and environmental protection.

KeyWords: *Heavy metals, safety, quality, vegetables, environment*

INTRODUCTION

Metals with a specific density of more than 5 gcm^{-3} and atomic weight greater than that of iron (55.5 $gmol^{-1}$), are generally known as Heavy metals (Anjembe *et al.,* 2018). They are persistent and non-biodegradable, can neither be removed by normal cropping nor easily leached by rain water. They might be transported from soil to ground waters or may be taken up by plants, including agricultural crops. For this reason, the knowledge of metal plant interactions is also important for safety of the environment (Divrikli *et al.*, 2006).

There has been increasing interest in heavy metal levels in public food supplied. However, their concentration in bio-available form is not necessarily proportional to the total concentration of the metal. Heavy metal pollution of agricultural soil and vegetables is one of the most severe ecological problems on a world scale (Ahmad and Goni, 2010) because of their toxicity for plant, animal and human beings, and their lack of biodegradability (Li *et al*., 2006; Huang *et al*., 2007; Zhang *et al*., 2005). They pose potential threats to the environment and can damage human health through various absorption pathways such as direct ingestion, dermal contact, diet through the soil-food chain, inhalation and oral intake (Park *et al*., 2004; Al-Saleh *et al.*, 2004; Komárek *et al*., 2008; Lu *et al*., 2011). The food chain contamination is the major pathway of heavy metal exposure for humans. Excessive accumulation of trace elements in agricultural soils through wastewater irrigation may not only result in soil contamination but also affect food quality and safety (Sharma *et al*., 2006; Ahmad and Goni, 2010).

Occurrence of uncontrolled urban sewage farming is a common site in African cities which exposes consumers of such produce to poisoning from heavy metals. Open dumps are a source of various environmental and health hazards. In Makurdi, the Benue State capital, Nigeria, vegetables are commonly grown on dumpsites, along the Benue River Bank and subsequently sold in Markets around the town. These dumpsites are no doubt loaded with both domestic and industrial waste whose composition is not determined. The vegetable crops are expected to benefit from these waste which is supposed to serve as manure to the crops.

Soil is the most important component of the environment, but it is the most undervalued, misused and abused of the earth's resources. Soil contamination has become a serious problem in all industrialized areas of the country. Soil is equally regarded as the ultimate sink for the pollutants discharged into the environment.

Most plants and animals depend on soil as a growth substrate for their sustained growth and development. In many instances the sustenance of life in the soil matrix is adversely affected by the presence of deleterious substances or contaminants. The entry of organic and inorganic form of contaminants result from disposal of industrial effluents. The contamination of soils with heavy metals in phytotoxic concentrations generate adverse effects not only on plants but also poses risks to human health (Montagne *et al.*, 2007). Afterwards, the consumption of contaminated vegetables constitute an important route of heavy metal exposure to animals and humans (Tsafe *et al.*, 2012).

Abandoned waste dumpsites have been used extensively as fertile grounds for cultivating vegetables, though research has indicated that the vegetables are capable of accumulating high levels of heavy metals from contaminated and polluted soils (Cao *et al.,* 2010; Benson and Ebong, 2005; Anjembe *et al.,* 2018).

WHO estimates that about a quarter of diseases facing mankind today occur due to prolonged exposure to environmental pollution (Pruss-Ustun and Corvalan, 2006; Kimani, 2007).Heavy metal pollution of environment, even at low levels and their resulting long term cumulative effects are among the leading health concerns all over the world. Heavy metals are non bio-degradable, and persist for long duration in aquatic as well as terrestrial environments. They might be transported from soil to groundwater or may be taken up by plants, including agricultural crops. In Makurdi, Nigeria, vegetables grown on dumpsite grow luxuriantly and are sold in large quantities in markets around the town. It is therefore important to investigate the heavy metal status of some common vegetables sold in these markets in order to ascertain their quality and safety for human consumption as they form important components of the daily human diet in this location. Consequently, this work was carried out to determine the concentration of heavy metals in some sampled vegetables from selected vegetable Markets located in Makurdi metropolis and to compare the status of these vegetables with the WHO/FAO safe limits in order to determine their suitability for domestic human consumption.

MATERIALS AND METHODS

Sample Collection and analysis

Five markets in Makurdi where vegetables are sold in large quantities were selected. These markets were the Makurdi Modern, Wadata, High Level, Wurukum and Northbank Markets. Four common vegetables sold and consumed in very large quantities were selected and sampled for twelve weeks across these markets. The vegetables include Cabbage, Pumpkin, Okra and Amaranthus. Two hundred and forty (240) samples of the edible vegetables (Spinach) were randomly collected during dry season of 2017. The edible portions of the samples were washed with tap water first and then followed by double washing with distilled water and then oven dried to constant weight. The dried samples were ground, sieved and digested as reported by Kudirat and Funmilayo (2011). 1.0g each of the samples were digested with 10ml of 98% nitric acid for 72 hrs. The digested solution was allowed to dry and the digest was made up to 25ml with distilled water. Triplicate digestion of each sample was carried out. Concentrations of Zinc, Copper, Lead and Selenium were determined using an Atomic Absorption spectrophotometer. These concentrations were compared with the FAO/WHO safety limits for heavy metals in vegetables and food (FAO/WHO, 2011)

RESULTS AND DISCUSSION

The Food and Agriculture Organisation of the United Nations together with the World Health Organisation FAO/WHO, (2011) guideline for metals in food and vegetables is presented on table 1. This indicates that food and vegetables containing less than 2.4 mg Kg^{-1} of Cadmium (Cd)would be safe for human consumption. For copper (Cu), lead (Pb), zinc (Zn), Selenium (Se), Iron (Fe) and Nickel (Ni), the safety limits are reported as 2.5, 0.50 – 30, 20-100, 5 – 19 and 400 – 500 mg kg^{-1} respectively.

Table 1: FAO/WHO Guideline for Metals in Foods and Vegetables

Metals	Normal Ranges in Plants (mg/kg)
Cd	<2.4
Cu	2.5
Pb	0.50-30
Zn	20-100
Se	5-19
Fe	400-500
Ni	0.02-50

Source: FAO/WHO (2011)

Heavy Metals Concentration on Some Selected Crops from five Markets

The concentration of Zinc in the vegetables across the five selected Markets is shown in Table 2. The highest value for Amaranthus was 0.016 mg kg^{-1} found with samples from High level market. This was followed by 0.014 mg kg^{-1} found with samples from Makurdi Modern market, 0.012 mg kg^{-1} for Wadata market while the least value of 0.010 mg kg^{-1} was found with samples taken from North Bank and Wurukum markets. Okro samples from High Level had the highest zinc concentration of 0.016 mg kg^{-1}, this was followed by samples from Makurdi Modern Market that had a zinc concentration of 0.015 mg kg^{-1}, 0.014 mg kg^{-1} for Wadata market, 0,013 mg kg^{-1} for Wurukum market while the least value of 0.012 mg kg^{-1} was found in samples from North Bank market.For fluted pumpkin (commonly called ugwu) the highest Zn concentration of 0.020 mg kg^{-1} was again found in samples taken from High level market, this was followed by 0.017 mg kg^{-1} with samples taken from Makurdi Modern market, 0.015 mg kg^{-1} with samples from Wadata market, 0.014 mg kg^{-1} for samples from Wurukum market while the least value of 0.013 mg $kg^{-1}$was found with samples from North Bank market.The highest value of Zn in cabbage samples was again found in samples taken from High level market. The value was established at 0.023 mg kg^{-1}.This was followed by 0.021 mg $kg^{-1}$for samples from Makurdi Modern market, 0.018 mg kg^{-1} for samples from Wurukum market while the least value of 0.016 mg kg^{-1} was found for samples from North Bank market.

Generally, vegetables from high level market contained the highest levels of Zn while the least concentration was found in samples from North Bank market. These concentrations were however below the safety limits established by FAO/WHO. Highest Zn concentrations were found in cabbage. This was followed by Pumpkin, Okra while the least concentrations were found in Amaranthus. The variability in concentrations of Zn in the vegetables could have been due to differences in their ability to take up this metal from soils as well as the variability in terms of soil quality upon which the vegetables were grown These concentration are however lower than the values of 8.487 $mgkg^{-1}$ and 2.652 $mgkg^{-1}$ reported by Tasrina, *et al.*, (2015) for Amaranthus and Cabbage respectively. These values obtained show that the concentration of Zinc in the vegetables is within the safe limits reported for human consumption since the values fall below FAO/WHO safety limit. However, the safest vegetable in terms of Zinc concentration in the present study was found to be Amaranthus. The variability in terms of metal concentration along markets could probably be because of specific farmers growing their vegetables on particular soils and supplying specific customers in particular markets. Since the high level market appear to be the oldest market in the town and located centrally, vegetable growers within the town using domestic waste could be supplying their produce to this market. The other markets located outside the center of the town could probably be getting their supply from growers outside the town in rural areas neighboring the town. This variability could probably be responsible for the concentration of Zn in the samples.

Table 2: Concentration of Zinc (mg/kg) in Crops

Markets	Cabbage	Pumpkin	Okra	Amaranthus
Wadata	0.016	0.015	0.014	0.012
Northbank	0.014	0.013	0.012	0.010
High level	0.023	0.020	0.016	0.016
Modern	0.021	0.017	0.015	0.014
Wurukum	0.018	0.014	0.013	0.010

The concentration of Copper in the vegetables across the selected Markets is shown in Table 3. Amaranthus had the highest copper (Cu) concentration of 0.30 mg kg^{-1}. This was followed by 0.28 mg kg^{-1} with samples from High level and Wurukum markets while the least concentration of 0.26 mg kg^{-1} was recorded for samples from Makurdi Modern and North Bank markets. For the okra samples, the highest Cu concentration of 0.32 mg kg^{-1} was recorded for samples from Wurukum market, this was followed by 0.30 mg kg^{-1} for samples from Makurdi modern, High level and Wadata markets while the least concentration of 0.29 mg kg^{-1} was recorded for samples from North Bank market. For the fluted pumpkin samples, the highest concentration of 0.4 mg kg^{-1} was recorded with samples from Wadata market and was followed by 0.36 mg kg^{-1} for samples from Wurukum and North Bank markets while the least concentration of 0.31 mg kg^{-1} was recorded for samples from High level market. The cabbage samples had the highest concentration of 0.43 mg kg^{-1} for samples from Wadata market and was followed by 0.40 mg kg^{-1} with samples from Wurukum market, 0.38 mg kg^{-1} with samples from North Bank market, 0.36 mg kg^{-1} for samples from Markurdi Modern market while the least value of 0.34 mg kg^{-1} was recorded for samples from High level market. These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Copper are Okra and Amaranthus and the safest markets are North bank and Wurukum markets while cabbage and pumpkin are better at High level market. Sharma *et al.* (2006) reported the concentration of Cu (2.25–5.42 mg kg^{-1}) in vegetables grown in wastewater areas of Varanasi, India to be within the safe limit. This range is higher than the values that were obtained in the present study.

Table 3: Concentration of Copper (mg/kg) in Crops

Markets	Cabbage	Pumpkin	Okra	Amaranthus
Wadata	0.43	0.41	0.30	0.30
Northbank	0.38	0.36	0.29	0.26
High level	0.34	0.31	0.30	0.28
Modern	0.36	0.32	0.30	0.26
Wurukum	0.40	0.36	0.32	0.28

The concentration of Lead in the vegetables across the selected Markets is shown in Table 4. The highest concentration of this metal in Amaranthus was 0.19 mg kg^{-1} for samples from Wurukum market. This was followed by 0.18 mg kg^{-1} with samples from High level market, Wadata and Makurdi Modern market had a concentration of 0.02 while the least concentration of 0.01 mg kg^{-1} was found with samples from North Bank market. For Okra, Pumpkin and cabbage, a lead (Pb) concentration of 0.02 mg kg^{-1} was recorded with samples across the markets. Higher values of 1.596 $mgkg^{-1}$ and 0.119 $mgkg^{-1}$ were reported by Tasrina, *et al.*, (2015) for Amaranthus and Cabbage respectively. Md Saiful Islam and Hoque (2014) reported concentration of Copper, Zinc and Lead in Pumpkin as 11.44 mg/kg, 46.10 mg/kg and 0.25 mg/kg respectively. In the present study Amaranthus samples from Wurukum had the highest concentration of Pb (0.19 mg kg^{-1}) and was followed by samples from High level market (0.18 mg kg^{-1}). The least concentration of Pb (0.01 mg kg^{-1}) was again found with Amaranthus samples from North Bank market.

Table 4: Concentration of Lead (mg/kg) in Crops

Markets	Cabbage	Pumpkin	Okra	Amaranthus
Wadata	0.02	0.02	0.02	0.02
Northbank	0.02	0.02	0.02	0.01
High level	0.02	0.02	0.02	0.18
Modern	0.02	0.02	0.02	0.02
Wurukum	0.02	0.02	0.02	0.19

The concentration of Selenium in the vegetables across the selected Markets is shown in Table 5. For Cabbage at Wadata Market, the concentration of Selenium was determined to be 0.14 $mgkg^{-1}$. This is below the FAO/WHO safety limit. For Pumpkin, Okra and Amaranthus, the concentrations were found to be 0.13, 0.12 and 0.01 $mgkg^{-1}$ respectively. These concentrations were also below the safety limit. For Cabbage at North bank Market, the concentration of Selenium was determined to be 0.13 $mgkg^{-1}$. This is below the FAO/WHO safety limit. For Pumpkin, Okra and Amaranthus, the concentrations were found to be 0.11, 0.08 and 0.07 $mgkg^{-1}$ respectively. These concentrations were also below the safety limit.

For Cabbage at High Level Market, the concentration of Selenium was determined to be 0.16 $mgkg^{-1}$. This is below the FAO/WHO safety limit. For Pumpkin, Okra and Amaranthus, the concentrations were found to be 0.14, 0.13 and 0.09 $mgkg^{-1}$ respectively. These concentrations were also below the safety limit. For Cabbage at Modern Market, the concentration of Selenium was determined to be 0.14 $mgkg^{-1}$. This is below the FAO/WHO safety limit. For Pumpkin, Okra and Amaranthus, the concentrations were found to be 0.01, 0.12 and 0.09 $mgkg^{-1}$ respectively. These concentrations were also below the safety limit. For Cabbage at Wurukum Market, the concentration of Selenium was determined to be 0.25 $mgkg^{-1}$. This is below the FAO/WHO safety limit. For Pumpkin, Okra and Amaranthus, the concentrations were found to be 0.24, 0.22 and 0.09 $mgkg^{-1}$ respectively. These concentrations were also below the safety limit.

Table 5: Concentration of Selenium (mg/kg) in Crops

Markets	Cabbage	Pumpkin	Okra	Amaranthus
Wadata	0.14	0.13	0.12	0.01
Northbank	0.13	0.11	0.08	0.07
High level	0.16	0.14	0.13	0.10
Modern	0.14	0.011	0.12	0.09
Wurukum	0.25	0.24	0.22	0.09

The concentration of Selenium in the vegetables attained highest value of 0.140 $mgkg^{-1}$ (Cabbage) and lowest value of 0.010 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Selenium is Amaranthus. The concentration of Zinc in all the vegetables in Northbank Market attained the highest value of 0.014 $mgkg^{-1}$ (Cabbage) and the lowest was determined to be 0.010 $mgkg^{-1}$ (Amaranthus). These values obtained shows that the concentration of Zinc is safe for human consumption since the values fall below FAO/WHO safety limit. However, the safest vegetable in terms of Zinc concentration is Amaranthus. The concentration of Copper in the vegetables attained highest value of 0.38 $mgkg^{-1}$ (Cabbage) and lowest value of 0.26 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Copper is Amaranthus. Concentration of Lead in the vegetables attained highest value of 0.021 $mgkg^{-1}$ (Cabbage) and lowest value of 0.014 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Lead is Amaranthus. Concentration of Selenium in the vegetables attained highest value of 0.13 $mgkg^{-1}$ (Cabbage) and lowest value of 0.07 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Selenium is Amaranthus. Zinc in all the vegetables in High Level Market attained the highest value of 0.023 $mgkg^{-1}$ (Cabbage) and the lowest was determined to be 0.016 $mgkg^{-1}$ (Okra and Amaranthus). These values obtained shows that the concentration of Zinc is safe for human consumption since the values fall below FAO/WHO safety limit. However, the safest vegetable in terms of Zinc concentration are Okra and Amaranthus. Copper in the vegetables attained highest value of 0.34 $mgkg^{-1}$ (Cabbage) and lowest value of 0.28 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Copper is Amaranthus. Lead in the vegetables attained highest value of 0.022 $mgkg^{-1}$ (Cabbage) and lowest value of 0.018 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Lead is Amaranthus. Selenium in the vegetables attained highest value of 0.16 $mgkg^{-1}$ (Cabbage) and lowest value of 0.10 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Selenium is

Amaranthus. Zinc in all the vegetables in Modern Market attained the highest value of 0.014 $mgkg^{-1}$ (Cabbage) and the lowest was determined to be 0.021 $mgkg^{-1}$ (Amaranthus). These values obtained shows that the concentration of Zinc is safe for human consumption since the values fall below FAO/WHO safety limit. However, the safest vegetable in terms of Zinc concentration is Amaranthus. Copper in the vegetables attained highest value of 0.36 $mgkg^{-1}$ (Cabbage) and lowest value of 0.26 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Copper is Amaranthus. Lead in the vegetables attained highest value of 0.024 $mgkg^{-1}$ (Cabbage) and lowest value of 0.020 $mgkg^{-1}$ (Okra and Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Lead are Okra and Amaranthus. Selenium in the vegetables attained highest value of 0.14 $mgkg^{-1}$ (Cabbage) and lowest value of 0.090 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Selenium is Amaranthus. Zinc in all the vegetables in Wurukum Market attained the highest value of 0.018 $mgkg^{-1}$ (Cabbage) and the lowest was determined to be 0.010 $mgkg^{-1}$ (Amaranthus). These values obtained shows that the concentration of Zinc is safe for human consumption since the values fall below FAO/WHO safety limit. However, the safest vegetable in terms of Zinc concentration is Amaranthus. Copper in the vegetables attained highest value of 0.40 $mgkg^{-1}$ (Cabbage) and lowest value of 0.28 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Copper is Amaranthus. Lead in the vegetables attained highest value of 0.023 $mgkg^{-1}$ (Cabbage) and lowest value of 0.018 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Lead is Amaranthus. Selenium in the vegetables attained highest value of 0.25 $mgkg^{-1}$ (Cabbage) and lowest value of 0.090 $mgkg^{-1}$ (Amaranthus). These values fall below the FAO/WHO safety limit. However, the safest of the vegetables in terms of the concentration of Selenium is Amaranthus. Soil and vegetables polluted with Pb and Cd can lead to decrease of human life expectancy within the affected areas. Pruvot *et al.* (2006), Bosso and Enzweiler (2008) showed that children living around a former smelter had high blood Pb levels in France and Brazil. Although Zn and Cu are essential elements, their excessive concentration in food and feed plants are of great concern because of their toxicity to humans and animals. When concentrations exceed their safe threshold values, Cu and Zn can cause non-carcinogenic hazardous effects such as neurologic involvement, headache and liver disease. Soil pollution has negative impacts on humans and the environment, especially for the ubiquitous and non-biodegradable heavy metals, the negative effects persist for several decades and even longer. Therefore, it is important to get information about heavy metal concentrations in food products and their dietary intake, and heavy metal pollution of soil and its impact on food security are receiving more attention (Akhtar, 2013; He *et al.*, 2013; Römkens *et al.*, 2009).

Conclusion

The concentrations of heavy metals namely Zinc, Copper, Lead and Selenium were determined for Cabbage, Pumpkin, Okra and Amaranthus obtained from Wadata, Northbank, High Level, Modern and Wurukum Markets. It was observed that the heavy metal concentration determined in the samples were lower than the safety limit of FAO/WHO. However, the concentration of all the heavy metals in Cabbage was consistently higher than the concentration in the other vegetables while the concentration of heavy metal in Amaranthus was mostly lower than the concentration in those of other vegetables across the selected Markets. Since the concentrations of heavy metal is in all the vegetables were lower than the safety limit of FAO/WHO, therefore, all the vegetables are safe for human consumption. The concentration of these metals was also lower in samples from North Bank market while samples from High level market contained the highest concentration of these metals.

It was concluded that all the vegetables are safe for human consumption, Amaranthus from North Bank market would be the safest vegetable to be consumed since the concentration of heavy metals therein was mostly lower than others. Monitoring of heavy metals concentration vegetables sold in these markets would be necessary as these vegetables have the capacity to phytoremedy contaminated substrates. This is necessary for the preservation and protection of human health and the environment.

RFEFERENCES

Al-Saleh, I., Shinwari, N., El-Doush, I., Biuedo, G., Al-Amodi, M., & Khogali, F. (2004).

Comparison of Mercury Levels in Various Tissues of Albino and Pigmented Mice Treated with Two Different Brands of Mercury Skin-Lightening Creams. Biometals, 2, 167-175.

Benson, N.U and G.A Ebong (2005). Heavy metals in vegetables commonly grown in a tropical

garden Ultisol. J. sustainable Tropic. Agric. Res. 16: 77-80

Bemgba Anjembe, T.R. Gesa and N.B. Ibrahim (2018). Effect of fertilizer sources on Heavy metal accumulation in soils and quality of Amaranth grown in Makurdi Nigeria. Nigerian Journal of soil and tillage research 4:25-35

FAO/WHO (2011); Joint FAO/WHO food standards programme codex committee on contaminants in foods, fifth session pp 64-89

Jasim Uddin Ahmad and Md Abdul Goni (2010). Heavy metal contamination in water, soil and vagatables of the industrial areas in Dhaka, Bangladash. Environmental monitoring and Assesment 166 (1-4): 347-57

Kimani, N.G. (2007). Implications of the Dandora Municipal Dumping Site in Nairobi, Kenya. Environmental Pollution and Impacts on Public Health. kenya: United Nations Environment Programme.

Komárek, M., Chrastny, V., & Mihaljevic, M. (2008). Lead Isotopes in Environmental Sciences: A Review. Environment International, 34, 562-577.

Ladipo Margaret Kudirat and Doherty Victoria Fumilayo (2011); Heavy metal levels in vegetables from selected markets in Lagos, Nigeria African Journal of Food Science and Technology (ISSN: 2141-5455) Vol. 2(1) pp. 018-021, January, 2011

Md Saiful Islam and Hoque, M. F. (2014). Concentrations of heavy metals in vegetables around the industrial area of Dhaka city, Bangladesh and health risk assessment. International Food Research Journal 21(6): 2121-2126

Park, R. M., Bena, J. F., Stayner, L. T., Smith, R. J., Gibb, H. J., & Lees, P. S. (2004). Hexavalent Chromium and Lung Cancer in the Chromate Industry: A Quantitative Risk Assessment. Risk Analysis, 24, 1099-1108.

Prüss-Üstün, A. and Corvalán, C. (2006). Preventing disease through healthy environments. Towards an estimate of the environmental burden of disease. Geneva: World Health Organization

Sharma, R.K. Agrawal, M. and Marshall F.M. (2006). Heavy metals contamination in vegetables grown in wastewater irrigated areas of Varanasi, India. Bulletin of Environment Contamination and Toxicology, 77, pp. 311-318

Tasrina R. C, Rowshon A, Mustafizur A. M. Rafiqul, R, and Ali M. P. (2015) Heavy Metals Contamination in Vegetables and its Growing Soil. J Environ Anal Chem 2:142. doi: 10.4172/2380-2391.1000142 B.M

Tsafe A.I, Hassan L.G, Sahabi D.M, Alhassan Y, Bala B,M (2012) Evaluation of heavy metals uptake and risk assessment of vegetables grown in Yargalma of Northern Nigeria.J.Basic Appl. Sc. Res. 2 (7) 6708-6714

Umit Divrikli, Nesrin Horzum, Mustafa Soylak and Latif Elci (2006). Trace metal contents of some spices and herbal plants from Western Anatolia, Turkey. International journal of Food Science and Technology 41: 712-716

Akhtar, S. (2013). Food Safety Challenges—A Pakistan's Perspective.

Al-Saleh, I., Shinwari, N., El-Doush, I., Biuedo, G., Al-Amodi, M., & Khogali, F. (2004).

Comparison of Mercury Levels in Various Tissues of Albino and Pigmented Mice Treated with Two Different Brands of Mercury Skin-Lightening Creams. Biometals, 2, 167-175.

Bosso, S. T., & Enzweiler, J. (2008). Bioaccessible Lead in Soils, Slag, and Mine Wastes from an

Abandoned Mining District in Brazil. Environmental Geochemistry and Health, 30, 219-229.

Cao, H. B., Chen, J. J., Zhang, J., Zhang, H., Qiao, L., & Men, Y. (2010). Heavy Metals in Rice

and Garden Vegetables and Their Potential Health Risks to Inhabitants in the Vicinity of an Industrial Zone in Jiangsu, China. Journal of Environmental Sciences, 22, 1792-1799.

He, B., Yun, Z., Shi, J., & Jiang, G. (2013). Research Progress of Heavy Metal Pollution in

China: Sources, Analytical Methods, Status, and Toxicity. Chinese Science Bulletin, 58, 134-140.

Lu, Y., Yin, W., Huang, L. B., Zhang, G. L., & Zhao, Y. G. (2011). Assessment of

Bioaccessibility and Exposure Risk of Arsenic and Lead in Urban Soils of Guangzhou City, China. Environmental Geochemistry and Health, 33, 93-102.

Montagne, D., Cornu, S., Bourennane, H., Baize, D., Ratié, C., & King, D. (2007). Effect of

Agricultural Practices on Trace-Element Distribution in Soil. Communications in Soil Science and Plant Analysis, 38, 473-491

Park, R. M., Bena, J. F., Stayner, L. T., Smith, R. J., Gibb, H. J., & Lees, P. S. (2004).

Hexavalent Chromium and Lung Cancer in the Chromate Industry: A Quantitative Risk Assessment. Risk Analysis, 24, 1099-1108.

Pruvot, C., Douay, F., Herve, F., & Waterlot, C. (2006). Heavy Metals in Soil, Crops and Grass

as a Source of Human Exposure in the Former Mining Areas. Journal of Soils and Sediments, 6, 20-215.

Römkens, P., Guo, H. Y., Chu, C. L., Liu, T. S., Chiang, C. F., & Koopmans, G. F. (2009).

Prediction of Cadmium Uptake by Brown Rice and Derivation of Soil-Plant Transfer Models to Improve Soil Protection Guidelines. Environmental Pollution, 157, 2435-2444.