



## Concentration of Pb, Fe, Zn, Cu and Cd in Soil, Vegetable and Irrigation Water in Bwari Abuja, Nigeria

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**ABSTRACT** The concentration of some selected heavy metals (Cd, Fe, Cu, Zn, and Pb) in water, soil and plant (*Telfaria Occidentalis*) grown in two different farmlands located in Bwari, Abuja, Nigeria was investigated using an Atomic Absorption Spectroscopy (AAS). The results obtained indicated the following mean concentration for the heavy metals in water (mg/l): Farm A: Cd (0.005±0.0003), Cu (0.076±0.0005), Pb (0.745±0.0001), Fe (23.460±0.0009) and Zn (1.415±0.0017); Farm B: Cd (0.008±0.0002), Cu (0.083±0.0003), Pb (0.608±0.0001), Fe (10.925±0.0005) and Zn (1.193±0.0006). Soil (mg/kg): Farm A: Cd (0.040±0.0001), Cu (0.263±0.0003), Pb (0.134±0.0001), Fe (16.404±0.0199) and Zn (22.207±0.0010); Farm B: Cd (0.042±0.0002), Cu (0.445±0.0002), Pb (0.131±0.0001), Fe (239.471±0.0050) and Zn (25.385±0.0008). Plant (mg/kg): Farm A: Cd (0.031±0.0003), Cu (0.187±0.0005), Pb (0.00±0.0001), Fe (9.400±0.0004) and Zn (0.732±0.0002); Farm B: Cd (0.030±0.0002), Cu (0.189±0.0002), Pb (0.00±0.0002), Fe (8.901±0.0004) and Zn (1.169±0.0003). The concentration of iron metal analyzed in water, soil and plant samples from the two different farmlands were high compared to other selected metals. The value of Cd, Pb and Fe obtained in water sample from Farm A and B exceeded the WHO/FAO permissible limits.

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Heavy metals in the environment has greatly increased because of urbanization and the presence of industries. These industries pollute the soil, plants, rivers and stream. These rivers carry toxic metals such as Cu, Cd, Zn, Cr, Ni, Pb, and Mn and this creates an unsafe water that are used for irrigation purposes when farms are located at the river bank. The resultant effect of the excessive trace elements in the soil and water is on the quality and safety of food produced (Oladebeye, 2017). Surveys have shown that continuous consumption of concentrations of heavy metals through foodstuffs lead to large accumulations of the metals in the kidney and liver of humans causing disruption of numerous body processes, leading to cardiovascular, nervous, and kidney and bone diseases (Sabina Braun 2015, Oladebeye, 2017). Vegetables serve as a source of protein, calcium, vitamins and iron in the human body, thereby making it important (Chiroma *et al.*, 2014; Akpan *et al.* 2015). They are also very rich in fiber which aids digestion, increases appetite and prevent constipation (Uka, *et al.*, 2012). They are usually inexpensive to purchase making it affordable to a wide populace. Most times, vegetables are cultivated around the homestead usually because the farmers see it as a way to curb poverty, meet the ever-increasing demand for food, and provide a source

of livelihood for the family. Also, the availability of waste products used as organic manure, surface and underground water makes it easier for farmers to farm vegetables all year round. Although Some of the metals present in the environment are essential for the growth and development of the vegetable plants, other metals, such as Cd and Pb are not. These elements have negative impact on both human and animals. They can be harmful to plants, animals and humans if present in sufficient concentration (Sabina Braun, 2015; Uka *et al.*, 2012). However, farmers pay less attention to the associated environmental hazards as they are more interested in making high yields and profit from the harvest. In polluted areas, the vegetable takes up pollutants such as toxic heavy metals from contaminated soils and water, as well as from deposits on different parts of the vegetables exposed to the air. The vegetables store these heavy metals in both the edible and non-edible parts in large quantities (Uka, *et al.*). Different plants and vegetables have different tendency of heavy metal absorption (Hamid *et al.* 2016). Leafy vegetables are said to be high accumulators of heavy metals compared with other vegetables (Kalagbor, 2015; Surukite *et al.*, 2013). Fluted pumpkin is a tropical vine plant vegetable belonging to the family of *Curcubitaceae* with

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botanical name known as *Telfairia Occidentalis* (Oladebeye and Olasupo, 2017; Akpan *et al.* 2015). It is one of the most popular vegetables consumed in Nigeria. This plant is known as ubong in Efik/Ibibio, mfang ubre in Oron, Ugu in Igbo, iroko or aporoko in Yoruba, umee in Urhobo, and Umeke in Edo (Oladebeye and Olasupo, 2017; Akpan *et al.* (2015). *Telfairia Occidentalis* vegetable is a rich source of vitamin A, C and K used in the treatment of anaemia and a raw material in pharmaceutical industries in the preparation of blood tonics. (Kalagbor, 2015, Oladebeye and Olasupo, 2017, Akpan, 2015). According to Ehiagbonare (2008), the leaf extract is believed to serve as a remedy to anaemia, high blood pressure, convulsion, and diabetes. The seeds are also nutritious and rich in an oil and used for cooking and soap manufacture (Surukite *et al.*, 2013). Its affordability, availability and the mineral elements has made it a popular vegetable consumed more than other vegetables in people's diet.

The increasing awareness about the health hazards associated with environmental chemicals has brought about major global concern towards prevention of heavy metal accumulation in soil, water and vegetables (Syed *et al.*, 2012). The terrible effects caused by the uptake of these heavy metals has led to various countries passing laws regulating heavy metal level in soils and commissions such as The Codex Alimentarius Commission, set up by the UN Food and Agriculture Organization and the World Health Organization, as standards for the maximum permissible concentration of metals in food crops to improve food safety and safeguard human health (Makino *et al.*, 2010). Regular monitoring of these heavy metals from effluents, sewage, etc. in vegetables and other food materials is important to avoid excessive buildup of the metals in the food chain. Thus, it is necessary to analyze soils, water and vegetables to ascertain the level of these heavy metals. This research targets the levels of Pb, Fe, Zn, Cu and Cd in soil, vegetable and irrigation water in Bwari, Abuja, Nigeria.

## MATERIALS AND METHOD

*Study Area and Sample Collection:* The study areas are two farmlands located at Arab road (Farm A) (latitude 9°17'13.8650, longitude 7°22'26.1359 and Altitude 543m) and Zuma 2 (Farm B) (latitude 9°17'43.2225, longitude 7°24'46.6854 and Altitude 614m), Bwari. Soil and plant samples were all collected randomly in triplicates with polythene bags soaked in 10% HNO<sub>3</sub> solution for 24 hours, rinsed with deionized water and air dried. The water samples (river and ground water) used for irrigation in both farmlands was collected by immersion below water

level using a polyethylene bottle previously soaked in 10% HNO<sub>3</sub> from the same location.

*Pretreatment of Samples:* The soil samples were air dried for at least seventy-two hours, ground in a mortar and passed through a 2mm and 0.005mm sieve and stored in clean polyethylene bags.

Plant samples were washed with deionized water, air dried and dried to constant weight at about 105°C in an oven. Samples were ground into powder, passed through a 0.02mm sieve, mixed to homogenize and stored in acid treated polyethylene bags.

*Sample Preparation:* Plants-Method of 4:1 mixture of HNO<sub>3</sub> and HClO<sub>4</sub> by Kakulu and Jacob (2006) was used for plant digestion. The ground sample was re-dried at about 105°C for about 2 hours in the oven before each weighing and mixed to homogenize. 50ml of 4:1 mixture of HNO<sub>3</sub> and HClO<sub>4</sub> was added into 1g of sample and left to predigest for 24 hours. The sample was heated at about 100°C in a fume cupboard until the sample appeared a pale yellow or water white. The sample was transferred into 50ml volumetric flask and diluted with de-ionized water to mark and filtered into clean plastic sample bottle ready for AAS analysis. Reagent blank was prepared in similar manner. Soil-Tessier *et al.* total metal content procedure was used to determine the studied metals.

Total metal analysis procedure was carried out by digesting 1g (<0.05mm) of soil sample with a mixture of 10ml HF and 2ml HClO<sub>4</sub> to near dryness; a second addition of 10ml HF and 1ml HClO<sub>4</sub> was made and again the mixture was evaporated to near dryness.

Finally, 1ml HClO<sub>4</sub> alone was added and the soil sample evaporated until the appearance of white fumes. The resulting solution was filtered into a plastic bottle ready for AAS. Blank samples were extracted as above. Water-Method of USEPA of evaporating with conc. HNO<sub>3</sub> was used to digest water samples. 6ml of conc. HNO<sub>3</sub> was added to 100ml sample volume and the sample was evaporated to near dryness, making certain the sample did not boil. The beaker was cooled and another 6ml of conc. HNO<sub>3</sub> was added. The temperature of the hot plate was increased for a gentle reflux.

The sample was evaporated to near dryness and the beaker cooled. 5ml of 1:1 HCL was added. The beaker was warmed and the sample pH adjusted to a pH of 4 with about 4.5-5M NaOH solution. The sample was then transferred to a volumetric flask and the volume diluted to 25ml with deionized water. The extract was analysed using AAS. Same procedure was carried out on blank sample.

## RESULTS AND DISCUSSION

The mean concentration of heavy metals in water, soil, and *T. Occidentalis* samples grown around Bwari in different farmlands are presented in figures 1 and 2. The heavy metal concentration showed variation in irrigation water, soil and *Telfairia Occidentalis*. All soil and water samples analyzed contained detectable concentrations of Cd, Cu, Pb, Fe, and Zn. Plant samples contained detectable levels of Cd, Cu, Fe, and Zn except Pb which was not detectable. Mean concentration of Cd, Cu, Pb, Fe, and Zn in water samples were  $0.005\pm 0.0003$ ,  $0.076\pm 0.0005$ ,  $0.745\pm 0.0001$ ,  $23.460\pm 0.0009$ ,  $1.415\pm 0.0017$  and  $0.008\pm 0.0002$ ,  $0.083\pm 0.0003$ ,  $0.608\pm 0.0001$ ,  $10.925\pm 0.0005$ ,  $1.193\pm 0.0006$ , for soil samples were  $0.040\pm 0.0001$ ,  $0.263\pm 0.0003$ ,  $0.134\pm 0.0001$ ,  $16.404\pm 0.0199$ ,  $22.207\pm 0.0010$  and  $0.042\pm 0.0002$ ,  $0.445\pm 0.0002$ ,  $0.131\pm 0.0001$ ,  $239.471\pm 0.0056$ ,  $25.385\pm 0.0008$  and for *Telfairia Occidentalis* leaves were  $0.031\pm 0.0003$ ,  $0.187\pm 0.0005$ ,  $0.000\pm 0.0001$ ,  $9.400\pm 0.0004$ ,  $0.732\pm 0.0002$  and  $0.030\pm 0.0002$ ,  $0.189\pm 0.0002$ ,  $0.000\pm 0.0002$ ,  $8.901\pm 0.0004$ ,  $1.169\pm 0.0003$  from farm A and B respectively. Metallic levels in plant soil and water were generally low except for Fe and Zn. The result indicates that the load of heavy metals increases in order  $Fe > Zn > Pb > Cu > Cd$  for water in farm A and B respectively. The heavy metal with the lowest concentration was Cd ( $0.005\pm 0.0003$ ) mg/kg in farm A and Cd ( $0.008\pm 0.0002$ ) mg/kg in farm B. Fe had the highest concentration of Fe ( $23.460\pm 0.0009$ ) mg/kg in farm A and Fe ( $10.925\pm 0.0005$ ) mg/kg in farm B.

The order of heavy metal loading  $Zn > Fe > Cu > Pb > Cd$  in farm A observed for soil samples (shown above) was different from soil sample loading  $Fe > Zn > Cu > Pb > Cd$  in farm B. The heavy metal with the highest concentration was Fe ( $239.471\pm 0.0056$ ) in farm B, while the heavy metal with the lowest concentration was Cd ( $0.040\pm 0.0001$  and  $0.042\pm 0.0002$ ) in farm A and B respectively.

The heavy metal load for *T. Occidentalis* increases in order  $Fe > Zn > Cu > Cd > Pb$  in Farm A and B respectively. Fe had the highest concentration Fe ( $9.400\pm 0.0004$  and  $8.901\pm 0.0004$ ) while Pb had the lowest concentration of Pb ( $0.00\pm 0.0001$  and  $0.00\pm 0.0002$ ) in farm A and B respectively.

There was no direct relationship between the soil, plant and water metallic levels. According to Adah *et al*, 2014, accumulation of heavy metals by plants and the transfer coefficient is a function of both soil and plant property and as such the total metal concentrations in soil do not necessarily correspond with metal bioavailability. They reported

bioavailability of heavy metals as depending on a number of physicochemical properties such as pH, organic matter contents, cation exchange capacity, redox potential, soil texture and clay contents. Also Syed *et al.*, (2012) reported factors such as concentration of heavy metals, climate, nature of the soil, atmospheric deposition and degree of plant maturity at the time of exposure influencing uptake and bioaccumulation of heavy metals in vegetables (Uka, 2015, Kakulu and Matthews-Amune, 2013). Other possible factors reported by Kakulu and Matthews-Amune (2013) that could have affected the metallic levels in this studies are, activities by farmers which could result in unequal mixing of soil in farmland top soil which depend on the mobilization pattern of the different elements and the physicochemical properties of the soil, various rates at which the heavy metal contaminants are assimilated by the vegetable plant and other non-crop plants which might change the heavy metal contaminants' distribution patterns (Kakulu and Matthews-Amune, 2013). All the metallic levels of the studied metals were lower in the vegetable plant than the soil. This observation indicates that only a fraction of the total metal content in the agricultural soil was taken up by the plants. Other factors listed above from other researchers could also be responsible.

The Bioaccumulation Factor (BCF) on Table 1 denotes the ability of *Telfairia Occidentalis* to extract heavy metals from the soil. Bio concentration factor is said to depend on vegetable species and nature of soil. As such human and environmental factors can cause changes. According to Hamid *et al* (2016) values greater than 1 shows efficient transfer system of plants while values higher than 0.5 show greater probability of metal accumulation attributed to human interventions. In this study, the BCF in farm A is in the sequence of  $Pb < Zn < Fe < Cd < Cu$  while that of farm B is  $Pb < Fe < Zn < Cu < Cd$ . The zero BCF value for Pb indicate limited movements of heavy metals from soil to plant. The concentrations of heavy metals in water samples were less than the permissible limit set by WHO, except for Pb, Cd and Fe which were higher. Researchers have reported pH as one of the main factors determining amount of soluble and plant-absorbed heavy metals and as such affecting the concentration level of heavy metals in the soil. Thus, the solubility as well as bioavailability of metals depends on the pH of the soil (Hamid *et al*, 2016, Danilcenko *et al*, 2016). Polluted irrigation water application can result in transformation of physicochemical characteristics of soil and heavy metals concentrations. This could reduce soil pH by 0.5 to 1 units and increase the level of heavy metals in the soil (Hamid *et al*, 2016). The elevated levels of Pb and Cd

observed in this study could be as a result of their usual constituents of industrial effluents, gaseous emissions and domestic wastes (Nnamonu *et al* (2015).

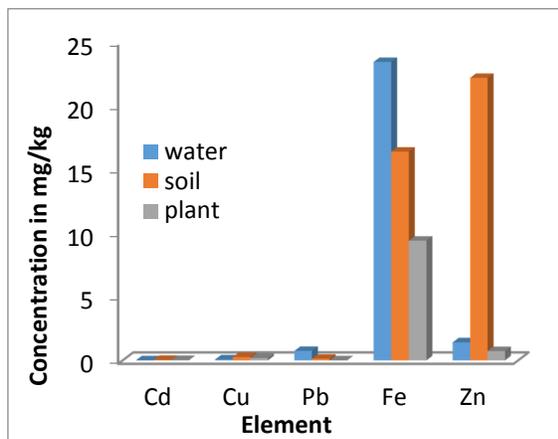


Fig 1: Concentration of heavy metals in farm A

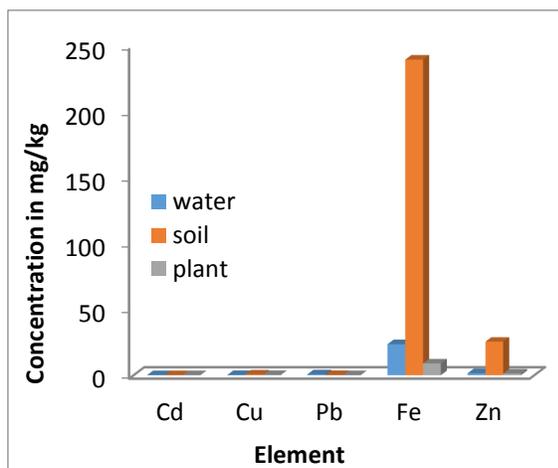


Fig 2: Concentration of heavy metals in farm B

Table 1. Bioaccumulation Factor

|              | Cd   | Cu   | Pb | Fe   | Zn   |
|--------------|------|------|----|------|------|
| BAF (Farm A) | 0.78 | 1.41 | -  | 0.57 | 0.03 |
| BAF (Farm B) | 0.71 | 0.43 | -  | 0.04 | 0.05 |

The concentrations of heavy metals in *T. Occidentalis* samples were generally low and less than the permissible limit set by Codex Alimentarius Commission (FAO/WHO, 2011). Akpan *et al* (2015) reported Fe and Zn as having the highest values in *T. Occidentalis* plant. This was the same in the present study. The levels observed could possibly be affected by the method of sampling. Plant leaves are known to reflect the elements input for a known exposure time. According to Kakulu and Matthews-Amune, 2013, if vegetable leaves are sampled randomly irrespective of their growth stage there is a possibility that the relative proportion of mature and young leaves in the composite samples will be different from one

sampling point to another and this could affect the metallic levels. Heavy metals concentrations in soil samples were all below the recommended WHO/FAO standards. The mean concentration of Cd in *T. Occidentalis* leaves ( $0.031\pm 0.0003$  and  $0.030\pm 0.0002$  mg/kg) in this study was less than the maximum value of 0.0910mg/kg at Lagos (Ladipo and Doherty, 2011) and greater than 0.0043mg/kg at Makurdi (Adah *et al.*, 2014). In farm B the pumpkin plant assimilated more of Cd in its leaves than any other heavy metal. This finding is in agreement with the results of a similar study carried out by Echem (ECHEM, O G (2014) on the Determination of the levels of heavy metal uptake of pumpkin (*Telfairia occidentalis*) leaves cultivated on contaminated soil.

Sabina Braun, (2015) reported Cd as relatively easily available in the soil, compared to other metals. According to him between 10-40 % of the total Cd can be assumed to be available for ion exchange especially when the pH is low. It can increase in geochemical mobility during acid rain with the resulting acidification of soils and surface waters (ECHEM, O G (2014). Up take and use of other, essential, elements by plants may also be hindered by exposure to Cd (ECHEM, O G 2014). For example, Cd can substitute for Zn, an essential trace element, causing the malfunctioning of metabolic processes (Oladebeye and Olasupo, 2017; Kalagbor *et al.* 2014).

The high-level concentration of Cd in water is of great concern. It was reported by Hamid *et al* (2016) in their research on Heavy Metal Contamination in Vegetables, Soil and Water and Potential Health Risk Assessment that Cd buildup tends to be more in aerial parts compared to roots and thus recommended that such vegetables whose stems leaves are mostly consumed should not be grown in areas irrigated with heavy metal polluted waste water. Cd is known to affect several enzymes in the body responsible for reabsorption of proteins in kidney tubules causing renal damage. (Kalagbor *et al.* 2014; Oladebeye, A.O 2017). According to Hang Zhou *et al*, (2016) Cd exposure can be toxic to the liver and lungs, inducing nephrotoxicity and osteotoxicity, and impairing function of the immune system (Hang Zhou *et al* 2016). The presence of Cd can also cause toxic effects such abnormalities and inhibition of growth by inducing chlorosis, necrotic lesions, wilting, and disturbances in mineral nutrition and carbohydrate metabolism. Cadmium is reported to be present as impurity in products such as phosphate fertilizers, detergents and refined petroleum products.

The Concentration of Fe was found to be higher than all other elements in water, soil and plant. Except for

soil in farm A the iron level was higher than the WHO /FAO level for water and plant. Such finding has previously been reported by (Edem *et al.*, 2009). The high concentrations of Fe in the soil samples could be due to the presence of a high concentrated anthropogenic material source of Fe. The mean concentration of Fe in farm A and B in this study was greater than the concentration level of 3.14µg/g reported by (Edem *at al.*, 2009) for Cross river, but lower than the value of 1435mg/kg reported at Benin Metropolis (Ikhajiegbe *at al.*, 2013).

Excessive metal concentrations in contaminated soils is reported to cause decreased soil microbial activity, soil fertility, yield and difficulty in the removal of heavy metals from the soil which results in destruction of soil structure. These effects result in retarded growth, different growth rate and the yellowish - green color of plant leaves (ECHEM, O. G 2014).

Although iron is very important for blood building when in excess it becomes toxic and could cause iron overload (Adepoju-Bello, 2013). This results in interaction of ferrous oxide with peroxide in the blood to produce free radicals which are highly reactive (Adepoju-Bello, 2013). According to Oladebeye, and Olasupo (2017), Fe acts as a catalytic center for a broad spectrum of metabolic functions. It is a component of various tissue enzymes, such as the cytochromes, that are critical for energy production, and necessary for immune system functioning. Increased body stores of iron in human has also been shown to increase the risk of several estrogen-induced cancers. In furtherance iron is reported to be capable of damaging cells in the heart, liver and elsewhere, which could result in coma, metabolic acidosis, shock, liver failure, coagulopathy, adult respiratory distress syndrome, long-term organ damage, and even death. The mean concentration of Zn in *T. Occidentalis* leaves ( $0.732\pm 0.0002$  and  $1.169\pm 0.0003$ ) in this study, was greater than the maximum concentration of 0.04µg/g at Cross river (Edem *et al.*, 2009), and less than 60.0mg/kg at Benin Metropolis (Ikhajiegbe *et al.*, 2013). The observed level could be due to high metal content of soils at sampling sites. The high level of zinc in soil and the lower level in *T. Occidentalis* leaves could be as a result of the fact that most zinc in soil exist in unavailable forms. This is because zinc is held on soil particles and by chelation (process by which certain metals are held with the structure of large organic molecules), it does not move through the soil and is not leached under most conditions (Schult, 2004).

Zn is an essential element for humans and animals but high level of Zn can reduce immune function and

levels of high-density lipoproteins (Hang Zhou et al 2016; Oladebeye, and Olasupo 2017) Zn is also reported as capable of causing anaemia, nervous system disorders, damage to the pancreas and low levels of “good” cholesterol. (Surukite *et al.*, 2013)

Pb was not detected in the plant *T. Occidentalis* leaves. This could be as a result of the far distance of the study farms from areas such as busy high ways (Hang Zhou, 2016). Similar result was reported by Akpan *et al* (2015) while Oluwole *et al* (11) reported insignificant level. This agrees with Sabina Braun report that Pb form strong bonds with organic material and the concentration in the soil solution is therefore usually low. In furtherance increase in total zinc content of the soil could lower fluted pumpkin lead accumulation (Orubite 2015). The level of Pb in soil and water were high. According to Kakulu and Matthews-Amune (2016) Pb has high affinity for soils and it stabilizes through hydrolysis reactions on soil surface. Sabina Bruma reported similar high level of Pb in soil. High concentration of Pb in soil (farm A) and water could be as a result of industrial wastes pollution around the selected locations. The result in this research disagrees with Adah *et al.*, (2014) report that there is a positive relationship between atmospheric metal deposition and elevated concentrations of heavy metals in plants and top soil.

The high level of Pb in soil and water used for irrigation is of great concern to the health of humans and livestock. Pb is a neurotoxin that severely affect the central nervous system. Pb has been reported to adversely influence the intelligence development of children, cause excessive lead in blood, and induce hypertension, nephropathy and cardiovascular disease. (Oladebeye and Olasupo; Hang Zhou *et al.*, 2016).

The concentration of Cu in *T. Occidentalis* is less than the limit (73.3mg/kg) set by codex alimentarius commission (FAO/WHO, 2001). The mean concentrations of Cu in *T. Occidentalis* leaves ( $0.187\pm 0.0005$  and  $0.189\pm 0.0002$ ), was less than the 0.77mg at Lagos (Ladipo and Doherty, 2011) and that at Benin (Ikhajiegbe *et al.*, 2013). Although Cu is an important nutrients for humans, high toxicity of Cu can cause adverse health effects such as acute stomach and intestine aches, and liver damage (Oladebeye and Olasupo 2017, Hang Zhou *et al* 2013; Hang Zhou *et al* 2016).

**Conclusion:** The determination of levels of Pb, Fe, Zn, Cu and Cd in soil, vegetable and irrigation water in Bwari, Abuja, Nigeria showed tolerable levels. Although the levels of these metals are not presently high, it is however important to keep in mind that their

concentration might increase in future and there could be a risk for contamination. It is suggested that there should be regular monitoring of these metallic levels.

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