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Investigation of some Heavy Metals in *Citrullus vulgaris, Cucumis sativus* and Soils obtained from Gardens being Irrigated with Wastewater in Maiduguri, Nigeria

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The levels of some heavy metals (As, Cd, Cr, Cu, Fe, Mn, Pb, Zn and Co) were determined in the edible portions of watermelon (*Citrullus vulgaris*) and cucumber (*Cucumis sativus*) irrigated with wastewater in Maiduguri, Nigeria. The metal levels in the vegetables as well as soils where the vegetables were cultivated were analyzed using Atomic Absorption Spectrophotometer. The metal levels in watermelon obtained from the Alau dam area ranged from 0.28 ± 0.05μgg^{-1} Cd to 46.03 ± 0.03 μgg^{-1} Cr. In the Gongulon area, the results ranged from 0.61 ± 0.03 μgg^{-1} Cd to 47.38 ± 2.85μgg^{-1} Cr. In cucumber obtained from the Alau dam area, the metal levels ranged from 0.06 ± 0.01μgg^{-1} Cd to 50.36 ± 0.96 μgg^{-1} Cr. In the Gongulon area, the results ranged from 0.14 ± 0.06 μgg^{-1} Cd to 53.75 ± 3.70μgg^{-1} Cr. The metal levels in the soils ranged from 0.56 ± 0.05μgg^{-1} Cd to 60.20 ± 0.70μgg^{-1} Fe. There were significant differences ($p < 0.05$) between the levels of the metals in the vegetables obtained from the sample areas and those of the controls which were not irrigated with wastewater. The differences in the levels of the metals in vegetables obtained from the sample areas and controls could be attributed to the use of wastewater in irrigating the soils, excessive usage of fertilizers and of course, the environmental factors in the areas. The levels of some of the heavy metals were lower than the established critical limits causing toxicity in plants and were lower than the FAO/WHO maximum limits (ML) of heavy metals in vegetables. However, the levels of highly toxic heavy metals like Cd, Pb and Cr were above the reported permissible limits. Consumption of these as food may constitute possible health hazards to the consumers at the time of the study.

Keywords: *Citrullus vulgaris*, *Cucumis sativus*, soil, heavy metals, wastewater, fertilizers, Atomic Absorption Spectrophotometry, Maiduguri.

INTRODUCTION

In recent years consumption of vegetables is gradually increasing due to increase awareness of their food values. Vegetables constitute an important part of the human diet since they contain carbohydrates, proteins, vitamins, minerals and trace elements (Abdola and Chmtelnicka, 1990). In the tropics, vegetables are described as the leafy (outgrowth) of plants used as food and they include those plants and parts used in making soup or served as integral parts of the main sources of our meal (Ihekoronye and Ngoddy, 1985). However, they contain both essential and toxic elements over a wide range of concentrations. Metal accumulation in vegetables may pose a direct threat to human health (Damek-Poprawa and Sawicka-Kapusta, 2003). Heavy metals are metallic elements with high atomic number and are poisonous to living organisms. They are defined as metals with density or specific gravity greater than 5g/cm^3. Heavy metals are referred to as trace metals because they are present at lower concentrations in water compared to major ions such as SO_4^{2-}, Cl^-, NO_3^-, Mg^{2+}, Ca^{2+} (Radojevic and Bashkin, 1999). Heavy metals are one of the important types of contaminants that can be found on the surface and in the tissue of fresh vegetables. Heavy metals, such as cadmium, copper, lead, chromium and mercury, are important environmental pollutants, particularly in areas under irrigation with wastewater (Mohsen and Mohsen, 2008). Heavy metal accumulation in soils is of concern in agricultural production due to the adverse effects on food quality (safety and marketability), crop growth (due to phytotoxicity) (Fergusson, 1990; Msaky and Calvert, 1990). Metals such as lead, mercury, cadmium and copper are cumulative poisons. These metals cause environmental hazards and are reported to be exceptionally toxic (Yargholi and Azimi, 2008).

Lead is a toxic element that can be harmful to plants, although plants usually show ability to accumulate large amounts of lead without visible changes in their appearance or yield. In many plants, Pb accumulation can exceed several hundred times the threshold of maximum level permissible for human (Wierzbicka, 1995). The introduction of Pb into the food chain may affect human health and thus, studies concerning Pb accumulation in vegetables have increasing importance (Coutate, 1992).

Maximum Zn tolerance level for human health established for edible parts of crops is 20 mg kg^{-1} by Chinese Department of Preventive Medicine. According to FAO/WHO, (2001) the permissible level for Zinc in vegetables is 100 mg kg^{-1}. Vegetables growing on heavy metal contaminated soils can accumulate high concentrations of Zinc to cause serious health risk to consumers.

Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on different parts of the vegetables exposed to the air from polluted environments (Zurera-Cosano *et al*., 1984). Nearly half of the mean ingestion of lead, cadmium and mercury through food is due to plant origin (fruit, vegetables and cereals). Heavy metals may enter the human body through inhalation of dust, direct ingestion of soil and consumption of food plants grown in metal contaminated soils (Cambra *et al*., 1999). Once in the body they compete with essential minerals such as Zn, Mg and Ca, and interfere with the function of the organs. In addition, people may come in contact with heavy metals in industrial work, pharmaceutical and agriculture. Children may be poisoned as a result of playing in contaminated soil. Symptoms vary, depending on the nature and the quantity of the heavy metal ingested. Patients may complain of nausea, vomiting, diarrhea, stomach pain, headache, sweating, and a metallic taste in the mouth. Depending on the metal, there may be blue-black lines in the gums (Nriagu, 1990). A number of studies have shown that vegetables are capable of accumulating high levels of metals from the soils. Investigation had shown that prolonged use of wastewater for irrigation of fields and farmland in Ghazvm, Iran had caused concentration of Lead, Copper, Cadmium and Zinc to exceed permissible limits several times over. Research results about the effects of excess Zinc on plant growth of three selected vegetables; cabbage, celery and Spinach showed that excess Zn in growth media caused toxicity to the three vegetable crops (Long *et al*., 2003). Yang *et al*., (2003) studied the response of three vegetables to Cu toxicity and found that Cu levels in both root and shoot increased, but root Cu concentration increased more sharply than shoot with increasing Cu levels in growth media. In another study, Xiong and Wang (2005) found that Cu concentration in the shoots was significantly influenced by Cu concentration in soil and increased markedly with an increase in the soil Cu concentration. Similarly, Chiroma *et al*., (2003) studied heavy metal contamination of vegetables and soils irrigated with sewage water in Yola, Nigeria and reported high concentration of the metals (Fe, Zn, Cu, Mg, Mn and Pb), and suggested heavy metal contaminations of the soils irrigated with sewage water and their accumulations in different parts of plants cultivated in the soils. In a related study, Uwah *et al*., (2011) investigated Levels of some heavy metals (As, Cd, Cu, Fe, Mn, Pb and Zn) in edible portions of spinach (*Amaranthus caudatus*) and lettuce (*Lactuca sativa*) grown in Maiduguri. They noted that the vegetables contained variable levels of the metals as a result of excessive usage of fertilizers and irrigating with all forms of wastewater. Watermelon (*Citrullus vulgaris*) and cucumber (*Cucumis sativus*) are among the various classes of vegetables grown in Northern Nigeria. In Borno State, Northeast Region of Nigeria, vegetables are heavily cultivated and consumed as food (Bokhari and Ahmed, 1985; Uwah, 2009). Maiduguri, the capital of Borno State lies between latitude 11° 51'N and longitude 30° 05'E at an altitude of 345 m above sea level (Alaku and Moruppa,1988). This area has a light annual rainfall of about 864mm and temperature ranging from 32 - 43℃, with mean daily maximum exceeding 40℃ between March and May before the onset of the rains in June (Adeleke and Leong, 1978). In this area, vegetables are irrigated with dam water and all kinds of available wastewater. To enhance the yield of the vegetables, fertilizers and manures are occasionally added to the soil. There are every possibilities of over applications of these fertilizers and manures. Hence, the uptake and storage of some heavy metal pollutants from these wastewater, fertilizers and manures by the vegetables are very likely since these heavy metals are soluble and mobile in ground water (Uwah, 2009).

The aim of this study is to investigate the levels of some heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Co) in *Citrullus vulgaris* and *Cucumis sativus* irrigated with wastewater in Maiduguri, with the view to ascertaining the suitability of the vegetables for human consumption.

MATERIALS AND METHODS

Samples and sampling

Collections of vegetable and soil samples were carried out from December, 2007 to May, 2008. Samples were collected using Radojevic and Bashkin (1999) techniques. Edible portions of the fresh samples of *Citrullus vulgaris* and *Cucumis sativus* were randomly collected from different vegetable farms of Alau dam and Gongulon which supply most of the vegetables consumed in Maiduguri. Only fresh vegetables in good condition were collected in order to produce good quality dried products (Audu and Lawal, 2005). A total of 10 samples each of *Citrullus vulgaris* and *Cucumis sativus* from each of the vegetable farms of Alau dam and Gongulon were collected. Samples from each of the two areas were pooled together to obtained two homogenous samples. The vegetable samples were collected in new, clean polyethylene bags using a clean small knife. Similarly, vegetable samples from experimental gardens cultivated on a piece of virgin land on the same terrain with the two sample areas, but in an isolated location in the Alau dam area, were collected to serve as controls. The experimental gardens were irrigated with unpolluted water and without the applications of fertilizers, manures, herbicides and pesticides. Top soil samples were collected from the immediate vicinity of the vegetable roots at depths of 0 – 20 cm. Samples were homogenized to obtain representative samples of bulk soil in each of the sample areas. About 40 g of the soil samples were collected in clean polyethylene bags using soil hand probe. Soil samples from the experimental vegetable gardens were similarly collected to serve as controls. Collected vegetable and soil samples were properly labelled and transported to the laboratory for subsequent analyses. Samples collections were made six (6) times during the period.

Digestion of samples

Soil and sliced vegetable samples were dried in an oven at 105°C for 24 h until they were brittle and crisp (APHA, 1992). A portion (1g) of dried, disaggregated and sieved vegetable and soil samples were placed separately in 50 cm^3, Teflon beakers and then digested with 10 cm^3 of a mixture of HNO_3-$HClO_4$-HF (in the ratio of 1:1:1) to near dryness at 80 – 90°C on a hot plate. The digests were filtered into a 50 cm^3 volumetric flask using Whatman No. 42 filter paper and the volumes made up to the marks with water (USEPA, 1996; Radojevic and Bashkin,1999; Umoren and Onianwa, 2005).

Determination of heavy metals

Levels of As, Cd, Cr, Cu, Fe, Mn, Ni, Pb, Zn and Co in the vegetable and soil samples were determined using an SP 1900 Pye Unicam Atomic Absorption Spectrophotometer (AAS) equipped with an air – acetylene burner. Concentrations of the metals in the samples were calculated using:

$$\text{Concentration } (\mu g g^{-1}) = \frac{\text{concentration } (mg l^{-1}) \times V}{M} \quad (1)$$

Where V = Final volume (50cm^3) of solutions after digestion, M = Initial weight (1g) of samples measured. The mean values of six determinations per sample were recorded.

Determination of some physicochemical parameters and particle fractions of the soils

Organic carbon was determined by means of a potassium dichromate back titration method as described by McCleod (1973). Cation exchange capacity (CEC) was determined by the silver thiourea method as described by Rayment and Higginson (1992). The soil pH (1:5 soil water extract), electrical conductivity (EC) (1:5 soil water extract) and the soil particle size fractions were equally determined using standard laboratory methods as described by Rayment and Higginson (1992).

Transfer factors (TF) for heavy metals from soil to vegetables

Transfer factor (TF) is the ratio of the concentration of heavy metal in a plant to the concentration of heavy metal in soil. The transfer factors for each heavy metal were computed based on the method described by Harrison and Chirgawi (1989), according to the following formula:

$$TF = Ps\ (\mu g g^{-1}) / St\ (\mu g g^{-1}) \quad (2)$$

Where Ps is the plant's metal content originating from the soil and St is the total metal contents in the soil.

Data analyses

Data collected were subjected to statistical tests of significance using the Student t-test and Analysis of Variance (ANOVA) at $p<0.05$ to assess pairs results in the vegetable and soil samples. That is, to assess significant variation in the levels of the heavy metals in the vegetables as well as in soils. Probabilities less than 0.05 ($p < 0.05$) were considered statistically significant. All statistical analyses were done by SPSS software for windows.

RESULTS AND DISCUSSION

Levels of some heavy metals in *Citrullus vulgaris*, *Cucumis sativus* and soil samples

The levels of heavy metals in *Citrullus vulgaris* and *Cucumis sativus* are as shown in Table 1. The levels of these heavy metals were lower in the control samples than their corresponding levels in sample areas. The order of the heavy metals contamination in the vegetables was:

Table 1: Levels in µgg^{-1} of some heavy metals in *Citrullus vulgaris* and *Cucumis sativus* obtained from Alau dam, Gongulon and the control sites.

Vegetables/ Sample areas	Heavy Metals								
	As	Cd	Cr	Cu	Fe	Mn	Pb	Zn	Co
C. vulgaris									
Alau dam	1.52^{a} ±0.02	0.28^{a} ±0.05	46.03^{a} ±0.03	1.31^{a} ±0.01	19.75^{a} ±0.04	5.53^{a} ±0.03	2.23^{a} ±0.02	11.95^{a} ±0.03	2.49^{a} ±0.06
Gongulon	2.06^{b} ±0.30	0.61^{b} ±0.03	47.38^{a} ±2.85	1.79^{b} ±0.37	23.37^{b} ±0.51	6.09^{a} ±0.30	3.69^{b} ±0.34	14.66^{b} ±0.23	2.49^{b} ±0.06
Control	0.08^{c} ±0.03	0.03^{c} ±0.01	10.30^{b} ±0.21	0.05^{c} ±0.01	3.20^{c} ±0.20	1.54^{b} ±0.02	0.05^{c} ±0.03	3.00^{c} ±0.10	0.50^{c} ±0.12
C. sativus									
Alau dam	2.23^{a} ±0.03	0.06^{a} ±0.01	50.36^{a} ±0.96	1.38^{a} ±0.03	13.37^{a} ±0.21	7.03^{a} ±0.13	1.74^{a} ±0.24	7.33^{a} ±0.03	9.23^{a} ±0.02
Gongulon	2.82^{b} ±0.34	0.14^{b} ±0.06	53.75^{a} ±3.70	2.06^{b} ±0.42	16.01^{b} ±0.41	8.01^{a} ±0.37	2.77^{b} ±0.30	9.55^{a} ±0.32	11.61^{b} ±0.27
Control	0.30^{c} ±0.02	BDL	15.30^{b} ±0.32	0.06^{c} ±0.01	4.00^{c} ±0.22	2.10^{b} ±0.04	0.05^{c} ±0.01	2.15^{a} ±0.02	2.40^{c} ±0.06

The above values are means of replicate values (n = 6). Within column, means with different alphabets are statistically different (p<0.05). BDL = Below Detection Limit.

Cr > Fe > Zn > Mn > Co > Pb > As> Cu > Cd. Statistical test of significance using the Student t-test and analysis of variance (ANOVA), showed significant differences ($p < 0.05$) between the levels of the heavy metals in vegetables obtained from the sample sites and those of the controls. The elevated levels of the metals in the vegetables obtained from the sample areas could be attributed to excessive usage of fertilizers and other agro-chemicals, as well as the use of waste water in irrigating the soils and of course, the environmental factors in the areas. Accordingly, there were significant differences ($p < 0.05$) between the metal levels in vegetables from the two sample sites of Alau dam and Gongulon. The only exceptions were in Cr and Mn levels where there were no significant differences ($p > 0.05$) between the metal levels in vegetables from the two sample sites of Alau dam and Gongulon. The elevated levels of the metals in the vegetables obtained in the Gongulon area could be due to possible pollution as a result of the vast agricultural activities going on in the area, and downstream deposition of fertilizers and other agro - chemicals as the Alau dam water flows into the area.

The results were however, lower than the published threshold values considered toxic for mature plant tissues. The published threshold values are: As, 5 to 10 µgg^{-1}; Fe, 10-20.00 µgg^{-1}; Cu, 20 to 100 µgg^{-1}; Pb, 30 to 300 µgg^{-1}and Zn, 100 to 400 µgg^{-1} (Kabata-Pendias and Pendias , 1984). The critical values or values regarded as excessive are: Zn, >50-100 µgg^{-1}; Mn, >1000-4000 µgg^{-1}; Fe, >200-500 µgg^{-1}; Cu, >7-20 µgg^{-1}; Pb, >4-30 µgg^{-1} and Cd, >1-3 µgg^{-1}; depending on the plants (vegetables) in question (EC-UN/ECE, 1995). The results were equally lower than the FAO/WHO maximum permitted levels or limits of the respective metals in vegetables with the exception of Pb, Cd and Cr in the vegetables which were higher than maximum permitted levels. The FAO/WHO maximum permitted levels or limits of the respective metals in vegetables are: Pb, 0.3 µgg^{-1}; Cd, 0.1 µgg^{-1}; Fe, 425 µgg^{-1}; Cu, 73 µgg^{-1}; Mn, 500 µgg^{-1}; Zn, 100 µgg^{-1}; Ni, 67 µgg^{-1} and Co, 50 µgg^{-1} (FAO/WHO, 2001).

The levels of heavy metals in soil samples are as shown in Table 2. The values ranged from 0.56 ± 0.05 µgg^{-1} Cd to 76.18 ± 5.49 µgg^{-1} Cr. The metal levels in the control soil samples ranged from 0.15± 0.03 µgg^{-1} Cd to 26.10 ± 1.04 µgg^{-1} Cr.

The order of the metals contamination in the soils was similar to that noted for the vegetables. Statistical test of significance using the Student t-test and analysis of variance (ANOVA), showed significant differences ($p < 0.05$) between the levels of the heavy metals in soils obtained from the sample sites and those of the controls and there were significant differences ($p < 0.05$) between the metal levels in soils from the two sample sites of Alau dam and Gongulon with the exception of Mn and Zn which showed no significant differences($p>0.05$).

Table 2: Levels in μgg^{-1} of some heavy metals in soil samples obtained from Alau dam, Gongulon and the control sites.

Sample areas	Heavy Metals								
	As	Cd	Cr	Cu	Fe	Mn	Pb	Zn	Co
Alau dam	3.42^a ±0.02	0.56^a ±0.05	65.58^a ±0.68	1.36^a ±0.68	51.02^a ±0.60	13.81^a ±0.01	2.95^a ±0.64	13.56^a ±0.38	9.65^a ±0.04
Gongulon	4.84^b ±0.04	0.81^b ±0.06	76.18^a ±0.68	3.78^b ±0.29	60.20^b ±0.70	15.12^a ±0.26	3.58^b ±0.08	16.72^a ±0.16	11.43^b ±0.16
Control	0.58^c ±0.20	0.15^c ±0.03	26.10^b ±1.04	0.30^c ±0.12	20.30^c ±0.30	4.80^b ±0.03	0.46^c ±0.20	5.40^b ±1.20	4.30^c ±0.32

The above values are means of replicate values (n = 6). Within column, means with different alphabets are statistically different ($p<0.05$).

The elevated levels of the metals in the soils obtained from the sample areas compared with the controls could be attributed to similar reasons given for the vegetables. Similarly, the elevated levels of the metals in the soils obtained from the Gongulon area could be due to possible pollution as a result of the vast agricultural activities going on in the area, and downstream deposition of fertilizers and other agro - chemicals as the Alau dam water flows into the Gongulon area. The values of the metals in soils obtained in this study were however below the guidelines for maximum limits (ML) of some metals in soil as adopted by Ewers (1991 and for Fe and Mn as adopted by FAO/WHO, 2001. These maximum limits (ML) of metals in soil included: Pb, 100 μgg^{-1}; Zn, 300 μgg^{-1}; Cd, 3 μgg^{-1}; Mn, 2000 μgg^{-1}; Fe, 50000 μgg^{-1}; Cu, 100 μgg^{-1}; Ni, 50 μgg^{-1}; Co, 50 μgg^{-1}; Cr, 100 μgg^{-1} and As, 20 μgg^{-1}.

Physicochemical Parameters of the Soils

The results for the determination of some physicochemical parameters in soils are as shown in Table 3. The results showed low organic carbon (OC) and organic matter (OM) in the study area. The values of OC (%) were 0.40 and 0.74 in Alau dam and Gongulon, respectively. Those of OM (%) were 0.69 and 1.28 in the two areas. Similarly, cation exchange capacity (CEC) in $meq100^{-1}g$ and the electrical conductivity (EC) in $\mu mhocm^{-1}$ were low. The values of the CEC ($meq100^{-1}g$) for the two areas were 5.33 ± 0.01 and 5.43 ± 0.10 and those of EC ($\mu mhocm^{-1}$) were 0.22 ± 0.03 and 0.24 ± 0.05. The soil pH values in the two areas were 6.23 ± 0.20 and 6.69 ± 0.04 respectively. The values of these parameters in the control samples were: OC (%) 0.22, OM (%) 0.35, CEC ($meq100^{-1}g$) 5.04± 0.15, EC ($\mu mhocm^{-1}$) 0.20 ± 0.12 and pH 6.67± 0.57. These low pH values of 6.23 ± 0.20 and 6.69 ± 0.04 in the two respective sample areas of Alau dam

Table 3: Physicochemical Parameters of the Soils

Sample Areas	Parameters				
	OC (%)	**OM** (%)	**CEC** ($meq100^{-1}g$)	**EC** ($\mu mhocm^{-1}$)	**pH**
Alau dam	0.40^a	0.69^a	5.33^a ± 0.01	0.22^a ± 0.03	6.23^a ± 0.20
Gongulon	0.74^b	1.28^b	5.43^a ± 0.10	0.24^a ± 0.05	6.69^a ± 0.04
Control	0.22^c	0.35^c	5.04^a ± 0.15	0.20^a ± 0.12	6.97^a ± 0.57

The above values are means of replicate values (n = 6). Within column, means with different alphabets are statistically different ($p<0.05$). OC = Organic carbon; OM = Organic matter; CEC = Cation exchange capacity; EC = Electrical conductivity and Gongulon are indicative of slightly acidic environment. These low pH values of 6.2 - 6.7 in the study area may be attributed mainly to the buffering effect of carbonate containing materials such as cement or bricks (Abulude , 2005; Uwah, 2009).The low pH values could also be attributed to the constant application of nitrogen containing inorganic and organic fertilizers and manures to the soils by the farmers to improve yields and as well as the decayed vegetable matters available in the soils. Statistical test of significance using the ANOVA, revealed significant differences ($p < 0.05$) between the values of organic carbon (OC), and organic matter (OM) in the soil samples obtained in the two areas with their corresponding values in the control samples. However, cation exchange capacity (CEC), electrical conductivity (EC) and pH values in samples obtained in the two areas did not show statistical differences ($p > 0.05$) with their corresponding values in the control samples.

Levels of Particle Size Fractions of the Soils

The levels of particle fractions of the soils are as presented in Table 4. Particle size analyses of the soils revealed the levels of clay (%) in the two respective areas to be: 9.00 and 8.50; sand (%) as 84.00 and 86.00 and silt (%) as 5.00 and 7.50. The levels of these parameters in the control samples were: clay (%) 8.80, sand (%) 84.00 and silt (%) 7.20. There were significant differences ($p > 0.05$) between the concentrations of clay, silt in soil samples obtained in the two sample areas of Alau dam and Gongulon with their corresponding levels in the control samples. In general, the results revealed the soils to be loamy sand in texture and slightly acidic with low organic matter contents. The dominance of sand in the soils and small amount of clay, does not only contribute to low heavy metal levels, but also lead to low retention of anthropogenically introduced metals.

Table 4: Particle Size Fractions of the Soil

Sample Areas	**Particle size**		
	Clay (%)	**Sand** (%)	**Silt** (%)
Alau dam	9.00^{a}	86.00^{a}	5.00^{a}
Gongulon	8.50^{b}	84.00^{a}	7.50^{b}
Control	8.80^{c}	84.00^{a}	7.20^{c}

The above values are means of replicate values (n = 6). Within column, means with different alphabets are statistically different ($p<0.05$).

Transfer factors (TF) of the Heavy Metals from Soil to Vegetables

The transfer factors of the heavy metals from soil to vegetable are as presented in Table 5. Transfer factors were computed for the heavy metals to quantify the relative differences in bioavailability of metals to vegetables or to identify the efficiency of a vegetable species to

Table 5: Transfer Factors (TF) of some of the Heavy Metals from Soil to *Citrullus vulgaris* and *Cucumis sativus*

Vegetable / Sample area	Heavy Metals								
	As	Cd	Cr	Fe	Mn	Cu	Pb	Zn	Co
C. vulgaris									
Alau dam	0.44	0.50	0.70	0.39	0.40	0.96	1.43	0.88	0.26
Gongulon	0.43	0.75	0.62	0.39	0.40	0.43	1.87	0.87	0.32
C. sativus									
Alau dam	0.65	0.07	0.77	0.26	0.51	1.01	0.59	0.54	0.96
Gongulon	0.58	0.21	0.71	0.27	0.53	0.54	0.77	0.57	1.02

accumulate a heavy metal. These factors were based on the roots uptake of the metals and discount the foliar absorption of atmospheric metal deposits (Lokeshwari and Chandrappa, 2006; Awode *et al*., 2008). The values of TF obtained for the metals in the vegetables were below one (1) except for Pb in *Citrullus vulgaris* obtained from the two areas, Cu in *Cucumis sativus* obtained from Alau dam and Co in *Cucumis sativus* obtained from Gongolon. The rate of metal uptake by the plant could have been affected by other factors such as plant age, plant species, soil pH, nature of soil and climate. Many metals act as biological poisons even at parts per billion (ppb) levels. Elevated levels in crops may have certain health hazards to humans and animals consuming the plants. For instance, chronic Cd exposures result in kidney damage, bone deformities, and cardiovascular problems. Since phosphate fertilizers can contain significant Cd concentrations, Cd can accumulate in crops, and human health problems could result from crop Cd contamination (Alloway, 1995b). Toxicological effects of lead on man include; inhibition of haemoglobin formation, sterility, hypertension and mental retardation in children (Amdur *et al*., 1991). High levels of Fe can cause vomiting, upper abdominal pain, pallor, cyanosis, diarrhea, dizziness, shock, haemochromatosis, diabetes, diseases of liver, lungs and kidney, haepatoma and cardinomyopathy (Duppler, 2001).

CONCLUSION

Considering the health risks encountered in diets as a result of high levels of heavy metals in vegetables, the maximum allowable levels of these metals in vegetables should not exceed levels that reflect good agricultural practices. There is therefore every need to educate the farmers on the problems associated with excessive usage of fertilizers and other chemicals, as well as irrigating the crops with waste and all sorts of polluted water and of course, the needs to grow crops with safe levels of pollutant indicators. Based on the analyses, it is concluded that: Watermelon (*Citrullus vulgaris*) and cucumber (*Cucumis sativus*) and indeed soil where the vegetables were cultivated, contain the investigated heavy metals (As, Cd, Cr, Cu, Fe, Mn, Co, Pb and Zn) at variable levels. The heavy metal levels were lower than the published threshold values considered toxic for mature plant tissues; similarly, the levels of some of the heavy metals were lower than the established critical limits causing toxicity in plants. The results were lower than the FAO/WHO maximum limit (ML) of heavy metals in vegetables. However, the levels of highly toxic metals like Cd, Pb and Cr were above the reported permissible limits. Interaction of soil-plant roots-system plays important roles in regulating heavy metals movement from soil to the edible parts of crops. Agronomic practices such as application of fertilizers and use of waste water can affect bioavailability and crop accumulation of heavy metals. Finally, consumption of watermelon (*Citrullus vulgaris*) and cucumber (*Cucumis sativus*) irrigated with wastewater in the study area as food may constitute possible health hazards to the consumers at the time of the study. The results obtained in this study would go a long way in providing baseline data for the investigation of heavy metals in watermelon (*Citrullus vulgaris*), cucumber (*Cucumis sativus*) and other vegetables cultivated in Maiduguri.

REFERENCES

Abdola M, Chmtelnicka J (1990). New Aspects on the Distribution and Metabolism of Essential Trace Elements after Dietary Exposure to Toxic Metals. *Biol. Trace Element Res*., 23: 25-53.

Abulude OF (2005). Trace Heavy Metals contamination of Soils and Vegetation in the vicinity of livestock in Nigeria. *EJEAFChe*., *4* (2): 863 – 870.

Adeleke BO, Leong GC (1978). *Certificate Physical and Human Geography.* WestAfrican Ed; Oxford University Press Nigeria, pp.171 – 173.

Alaku SO, Moruppa SM (1988). Organ Weight Loss in Goats during long Dry Season in the Sahel Region of West Africa. *J. Arid Zone Agric.,* 1: 23 – 24.

Alloway BJ (1995b).Cadmium In, *Heavy Metals in Soils*. 2nd Ed (B.J.Alloway,ed). Blackie, New York, pp.122 –151.

Amdur MO, Doull J, Classen CD (1991). The Basic Science of Poisons. *J. Soil Sci*., 49**:** 639-643.

APHA (American Public Health Association) (1992). *Standard Methods for the Examination of Water and Wastewater.* 16th Ed. APHA. New York, pp. 75 –86.

Audu AA, LawaL AO (2005). Variation in Metal contents of Plants in Vegetable Gardens Site in Kano Metropolis. *J. Appl. Sci. Environ. Manage*., 10(2): 105 – 109.

Awode UA, Uzairu A, Balarabe ML,Okunola OJ, Adewusi SG (2008). Levels of some Trace Metals in the Fadama Soils and Pepper (*Capsicum annuum*) along the bank of River Challawa, Nigeria. *Asian J. Sci. Res*. ISSN 1992 – 1454, pp.1 – 6.

Bokhari MH, Ahmed MS (1985). *Food Plants in Borno State, Nigeria*. Ghulamdi Publishers, Lahore, pp. 1 – 46.

Cambra K, Martínez T, Urzelai A, Alonso E (1999). Risk analysis of a farm area near a lead- and cadmium-contaminated industrial site. *J. Soil Contam*., 8(5): 527-540.

Chiroma TM, Hymore FK, Ebawele RO (2003). Heavy Metal Contamination of and Soils Irrigated with Sewage Water in Yola. *NJERD*, 2(3): 25 – 31.

Coutate TP (1992). *Food, the Chemistry of Component*. 2nd Edn. Cambridge: Royal Society of Chemistry, pp. 265.

Damek-Poprawa M, Sawicka-Kapusta K (2003). Damage to liver, kidney and teats with reference to burden of heavy metals in yellow-necked mice from areas around steelworks and zinc smelters in Poland. *Toxicol*., 186(1-2): 147-158.

Duppler D (2001). Heavy Metals Poisoning. *Gale Encyclopedia of Aiternative Medicine,* Farmington Hills, pp. 23 – 26.

EC-UN/ECE (Economic Commission – United Nations) (1995). Foliar Expert Panel,Symposium Paper ICP-Forest, Wien, 6-8 Nov. 1995.

Ewers U (1991). Standards, guidelines and legislative regulations concerning metals and their compounds. In: Merian E, ed. *Metals and Their Compounds in the Environment:* Occurrence, Analysis and Biological Relevance. Weinheim: VCH, pp: 458-468.

FAO/WHO (Codex Alimentarius Commission) (2001). Food additives and contaminants. Joint FAO/WHO Food Standards Program; ALINORM 01/12A:1-289.

Fergusson JE (1990). *The Heavy Elements: Chemistry, Environmental Impact and Health Effects.*Oxford Press, pp: 382-399.

Harrison RM, Chirgawi MB (1989). The assessment of air and soil as contributors of some trace metals to vegetable plants I. Use of a filtered air growth cabinet. *Sci. Total Environ.* 83: 13–34.

Ihekoronye AI, Ngoddy PO (1985). *Integrated Food Science and Technology for the Tropics.* Macmillan Education Ltd, Oxford, London, pp: 270 – 281.

Kabata-Pendias A, Pendias A (1984). *Trace Elements in Soils and Plants*. CRC Press, Boca Raton, Forida, pp:321 – 337.

Lokeshwari H, Chandrappa GT (2006). Impact of Heavy Metal Contamination of Bellandur Lake on Soil and Cultivated Vegetation. *Curr. Sci.* 91 (5): 622 – 627.

Long XX, Yang XE, Ni WZ, Ye ZQ, He ZL, Calvert DV, Stoffella JP (2003). Assessing zinc thresholds for phytotoxicity and potential dietary toxicity in selected vegetable crops. *Soil Sci. Plant Anal*., 34(9 and 10): 1421-1434.

McCleod S (1973). Studies on Wet Oxidation Procedures for the Determination of Organic Carbon in Soil. In '*Notes on Soil Techniques'*. (CSIRO Division of Soils: Melbourne), pp: 73 – 79.

Mohsen B, Mohsen S (2008). Investigation of Metals Accumulation in Some Vegetables Irrigated with Waste Water in Shahre Rey-Iran and Toxicological Implications. *American-Eurasian J. Agric. & Environ. Sci*., 4 (1): 86-92.

Msaky JJ, Calvert R (1990). Adsorption behaviour of copper and zinc in soils: influence of p^H on adsorption characteristics. *Soil Sci*., 150(2): 513-522.

Nriagu JO (1990). Global Metal Pollution Poisoning the Atmosphere. *Environ*. 7**:** 87 - 93.

Radojevic M, Bashkin NV (1999). *Practical Environmental Analysis*. Royal Society of Chemistry and Thoma Graham House, Cambridge, pp: 180 – 430.

Rayment, G.E. and Higginson, F.R. (1992). 'Australian laboratory handbook of soil and water chemical methods.' Inkarta Press: Melbourne, pp.25 – 30.

Umoren IU, Onianwa PC (2005). Concentration and Distribution of some Heavy Metals in Urban Soils of Ibadan, Nigeria. *Pak. J. Ind.Res*., 48: 397 – 401.

USEPA (United States Environmental Protection Agency) (1996). Acid Digestion of Sediment, Sludge and Soils: Method 305B (USEPA: Washington), pp: 5 – 15.

Uwah EI (2009). Concentration Levels of some Heavy Metal Pollutants in Soil, and Carrot (*Daucus carota*) obtained in Maiduguri, Nigeria. *Continental J. Appl. Sci*., 4: 76 – 88.

Uwah EI, Ndahi NP, Abdulrahman F I, Ogugbuaja VO (2011). Heavy metal levels in spinach (*Amaranthus caudatus*) and lettuce (*Lactuca sativa*) grown in Maiduguri, Nigeria. *J. Environ. Chem. Ecotoxico.,* 3(10): 264-271.

Wierzbicka M (1995). How lead loses its toxicity to plants. *Acta Soc. Bot. Pol*., 64: 81-90

Yang X E, Long XX, Ni WZ (2003). Assessing copper thresholds for phytotoxicity and potential dietary toxicity in selected vegetables crops. *J. Environ. Sci. Health*, B 37(6): 625-635.

Xiong ZT, Wang H (2005).Copper toxicity and bioaccumulation in Chinese cabbage (*Brassica pekinensis* Rupr.). *Environ. Toxicol*., 20(2): 188-194.

Yargholi B, Azimi AA (2008). Investigation of Cadmium absorbtion and accumulation in different parts of some vegetables. *American Eurasian J. Agric and Environ. Sci*., 3(3): 357-364.

Zurera-Cosano G, Moreno-Rojas R, Salmeron-Egea J, Pozo LR (1984).Heavy metal uptake from greenhouse border soils for edible vegetables. *J. Sci. Food Agric*., 4