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Full Length Research Paper

Heavy metal levels in spinach (*Amaranthus caudatus*) and lettuce (*Lactuca sativa*) grown in Maiduguri, Nigeria

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Levels of some heavy metals (As, Cd, Cu, Fe, Mn, Pb and Zn) were investigated in edible portions of *Amaranthus caudatus* and *Lactuca sativa* grown in Maiduguri. These heavy metals were similarly investigated in the soils in which the vegetables were grown. The metals were analyzed using atomic absorption spectrophotometer. The levels of the heavy metals in the vegetable and soil samples obtained from the sample areas were higher than their corresponding levels in the control samples. The results ranged from 0.26 ± 0.02 μgg^{-1} Cd to 10.28 ± 0.61 μgg^{-1} Fe in *A. caudatus* and 0.34 ± 0.06 μgg^{-1} Cd to 40.11 ± 0.16 μgg^{-1} Fe in *L. sativa*. In the soils, the results ranged from 0.56 ± 0.05 μgg^{-1} Cd to 60.20 ± 0.70 μgg^{-1} Fe. The order of the metals contamination in the soils and vegetables was: Fe > Mn > Pb > Zn > As > Cu > Cd. The data were analyzed with t-test and ANOVA. There were significant differences ($p < 0.05$) between the levels of the heavy metals in the vegetables obtained from the sample sites and those of the controls. The elevated levels of the metals in the soils and vegetables 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. The results were however lower than the published threshold values considered toxic for mature plant tissue, except *L. sativa* in which the Fe level was higher. Consumption of these vegetables as food may not pose possible health hazards to humans at the time of the study.

Key words: *Amaranthus caudatus*, *Lactuca sativa,* soil, heavy metals, wastewater, fertilizers.

INTRODUCTION

Heavy metal concentrations in soil are associated with biological and geochemical cycles and are influenced by anthropogenic activities such as agricultural practices, industrial activities and waste disposal methods (Ndiokwere and Ezehe, 1990; Usman and Ayodele, 2002; Uwah et al., 2009). Contamination and subsequent pollution of the environment by heavy metals have become global concern due to their sources, widespread distribution and multiple effects on the ecosystem (Nriagu, 1990). Heavy metals are present in agricultural soils at low levels. Due to their cumulative behaviour and toxicity, they have potential hazardous effect not only on plants but on human health (Das et al., 1997).

The major uses of wastewaters are in agricultural irrigation, industrial activities and groundwater recharge. Long-term use of these wastewaters on agricultural lands often results in the build-up of elevated levels of heavy metals in soils (Rattan et al., 2001). The extent of build-up of metals in wastewater-irrigated soils depends on the period of its applications (Bansal et al., 1992). Crops cultivated on the metal contaminated soils accumulate metals in quantities excessive enough to cause clinical problems both to animals and human beings consuming these metal rich plants (Tiller, 1986).

Distribution of heavy metals in plants depends upon availability and concentrations of heavy metals as well as particular plant species and its populations (Punz and

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Abbreviations: CNS, Central nervous system; **CEC,** cation exchange capacity; **EC,** electrical conductivity; **TF,** transfer factor; **OC,** organic carbon; **OM,** organic matter.

Seighardt, 1993). Many researchers have shown that some common vegetables are capable of accumulating high levels of metals from the soils (Xiong, 1998; Cobb et al., 2000; Uwah et al., 2009). Certain species of Brassica (cabbage) are hyper-accumulators of heavy metals into their edible tissues (Xiong, 1998). Many people could be at risk of adverse health effects from consuming common vegetables cultivated in contaminated soil. Often the condition of the soil is unknown or undocumented; therefore, exposure to toxic levels can occur (Nirmal et al., 2007). Xu and Thornton (1985) suggested that there are health risks from consuming vegetables with elevated heavy metal concentrations. The populations most affected by heavy metal toxicity are pregnant women or very young children (Boon and Soltanpour, 1992). Neurological disorders, central nervous system (CNS) destruction, and cancers of various body organs are some of the reported effects of heavy metal poisoning (ATSDR, 1999a, b; 2000). Low birth weight and severe mental retardation of newborn children have been reported in some cases where the pregnant women ingested toxic amounts of heavy metal through direct or indirect consumption of vegetables (Mahaffey et al., 1981).

Heavy metals like Fe, Cu, Zn, and Ni are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders (Ward, 1995; Uwah, 2009). Food chain contamination by heavy metals has become a burning issue because of their potential accumulation in biosystems through contaminated water, soil and air. The main sources of heavy metals to vegetable crops are their growth media (soil, air, nutrient solutions) from which these heavy metals are taken up by the roots or foliage (Lokeshwari and Chandrappa, 2006).

Studies on Cd, Cu and Ni levels in vegetables from industrial and residential areas of Lagos City, Nigeria were carried out by Yusuf et al. (2003) which revealed that the levels of Cd, Cu and Ni in different edible vegetables along with the soils on which they were grown were higher in industrial areas than those of the residential areas due to pollution. Also edible portions of five varieties of green vegetables, collected from several areas in Dar Es Salaam, Africa, were analyzed for Pb, Cd, Cr, Zn, Ni and Cu. It was reported that there was a direct positive correlation between Zn and Pb levels in soils with the levels in vegetables (Othman, 2001).

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) suggesting heavy metal contaminations of the soils irrigated with sewage water and their accumulations in different parts of plants cultivated in the soils.

Ebong et al. (2007) investigated the accumulation of some heavy metals by *Talinum triangulare* (water leaf) grown on waste dumpsites in Uyo Metropolis, Akwa Ibom state, Nigeria. Results obtained indicated higher levels of the metals in soils and plants from the dumpsites than the values recorded from the control samples.

Uwah et al. (2009) studied the levels of some agricultural pollutants in soils, and water leaf (*T. triangulare*) obtained in Maiduguri, Nigeria. The levels of the heavy metals in the soil and vegetable samples obtained in the two areas ranged from low to high depending on the metals. The values obtained were higher than their corresponding levels in the control samples for both the soil and the vegetable samples. In a related study, Uwah (2009) investigated the levels of some heavy metal pollutants in soils, and carrot (*Daucus carota*) obtained in Maiduguri, Nigeria. The levels of the heavy metals in the soil and plant samples equally ranged from low to high depending on the metals. The levels of the metals in both the vegetable and soil samples in the sample areas were equally higher than their corresponding levels in the control samples.

The use of polluted water in the immediate surroundings of big cities for growing of vegetables is a common practice in Nigeria. Although this water is considered a rich source of organic matter and plant nutrients, it also contains sufficient amounts of soluble salts and metals like Fe, Mn, Cu, Zn, Pb, Ni, Sn, Hg, Cr, As and Al. When such water is used for irrigation of crops for a long period, these heavy metals may accumulate in soil and may be toxic to the plants and also cause deterioration of soil (Kirkhan, 1983; Uwah, 2009). Various classes of vegetables are grown in many parts of Nigeria. In Borno State, Northeast Region of Nigeria, vegetables are heavily cultivated and consumed as food (Bokhari and Ahmed, 1985; Uwah et al., 2009). Maiduguri, a commercial nerve center in the Northeastern Region of Northern Nigeria 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 is known for its dryness, with Sudan type of climate, Savanna or tropical grasslands vegetation, light annual rainfall of about 864 mm and the temperature ranging from 32 - 41°C, with mean of the daily maximum exceeding 40°C 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. Similarly, to enhance the yield of these vegetables, fertilizers and manures are occasionally added to the soil. There are therefore, the 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 et al., 2009).

This study is aimed at investigating the levels of heavy metals (As, Cd, Cu, Fe, Mn, Pb and Zn) in edible portions of *A. caudatus* and *L. sativa* grown in Maiduguri, extrapolate the results and ascertained the suitability or otherwise of the vegetables for human consumptions.

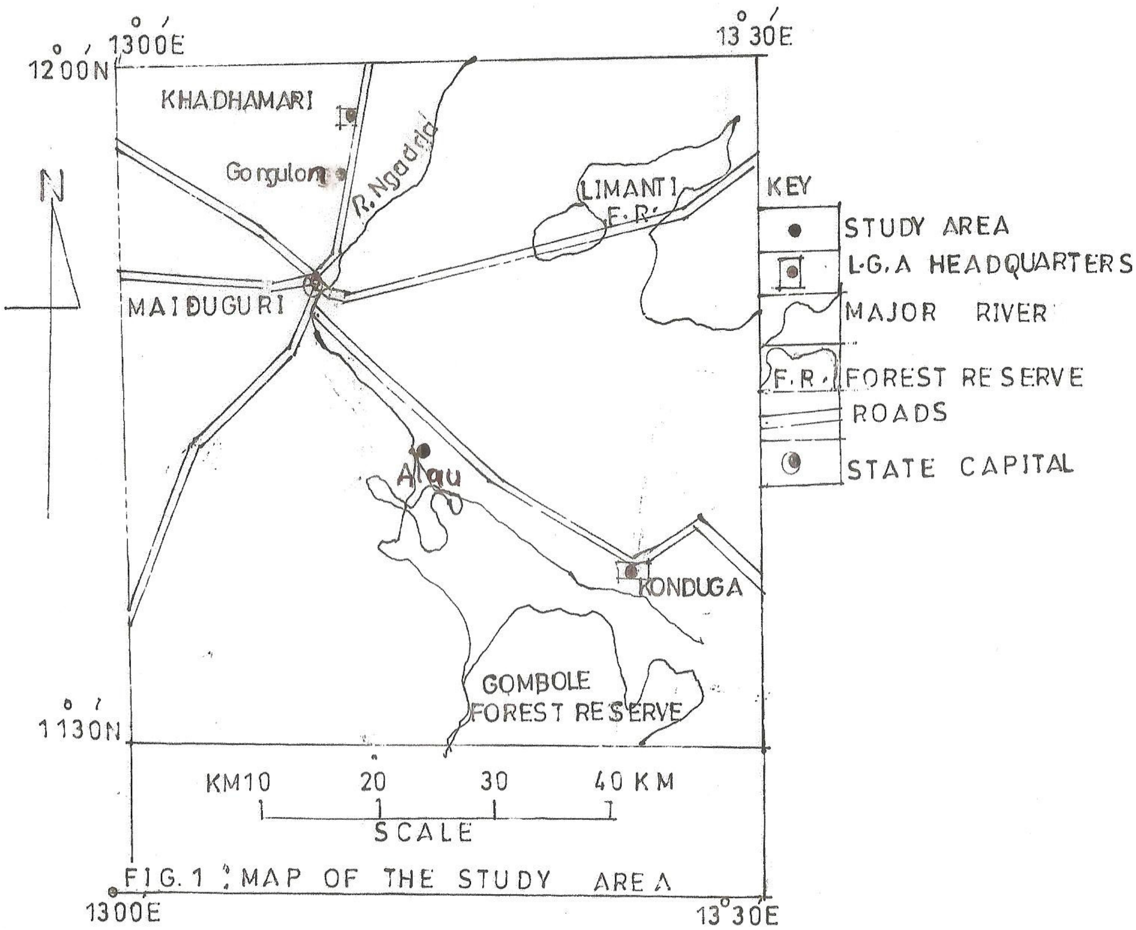

Figure 1. Map of study area.

This was carried out by analyzing spectrophotometrically the levels of the metals in the vegetable and soil samples.

MATERIALS AND METHODS

Samples and sampling

Sampling and collections of vegetable and soil samples were carried out from December, 2007 to May, 2008.

Collection of vegetable and soil samples

Vegetable and soil samples collection techniques were carried out as described by Radojevic and Bashkin (1999). Edible portions of the fresh samples of *A. caudatus* and *L. sativa* were randomly collected from different farms in the 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 *A. caudatus* and *L. sativa* 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. The samples were collected using a small knife.

Similarly, vegetable samples from experimental gardens cultivated on a piece of virgin land having 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. Samples were collected using soil hand probe. The soil samples were collected in clean polyethylene bags. Soil samples from the experimental vegetable gardens were similarly collected to serve as controls. Collected vegetable and soil samples were properly labeled and transported to the laboratory for subsequent analyses. Samples collections were made six (6) times during the period. The map of the study area is shown in Figure 1.

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 (1 g) of dried, disaggregated and sieved plant and soil samples were placed separately in 50 cm^3, Teflon beakers and then digested with

Table 1. Levels in $\mu g g^{-1}$ of some heavy metals in *A. caudatus* and *L. sativa* obtained from Alau dam, Gongulon and the control sites.

Vegetables/ Sample sites	Heavy metals						
	As	Cd	Cu	Fe	Mn	Pb	Zn
A. audatus							
Alau dam	$0.90^a \pm 0.10$	$0.26^a \pm 0.02$	$0.88^a \pm 0.07$	$10.28^a \pm 0.61$	$10.50^a \pm 0.90$	$2.40^a \pm 0.16$	$6.10^a \pm 0.12$
Gongulon	$1.30^b \pm 0.26$	$0.34^b \pm 0.02$	$0.93^a \pm 0.06$	$15.96^b \pm 0.18$	$10.50^a \pm 0.90$	$4.67^b \pm 0.22$	$6.35^a \pm 0.1$
Control	$0.15^c \pm 0.10$	$0.02^c \pm 0.01$	$0.04^b \pm 0.02$	$1.40^c \pm 0.03$	$2.80^b \pm 0.06$	$0.23^c \pm 0.10$	$1.42^b \pm 0.05$
L. sativa							
Alau dam	$1.10^a \pm 0.16$	$1.54^a \pm 0.42$	$1.28^a \pm 0.16$	$40.11^a \pm 0.16$	$5.23^a \pm 0.06$	$3.10^a \pm 0.12$	$7.47^a \pm 0.12$
Gongulon	$1.73^b \pm 0.20$	$1.81^b \pm 0.09$	$1.66^a \pm 0.09$	$42.84^b \pm 0.27$	$5.65^a \pm 1.13$	$5.88^b \pm 0.06$	$7.80^a \pm 0.34$
Control	$0.20^c \pm 0.01$	$0.16^c \pm 0.02$	$0.15^b \pm 0.20$	$10.50^c \pm 0.21$	$1.62^b \pm 0.04$	$0.33^c \pm 0.02$	$1.70^b \pm 0.10$

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

10 cm^3 of $HNO_3^-HClO_4^-HF$ 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 (USEPA, 1996; Radojevic and Bashkin, 1999; Umoren and Onianwa, 2005).

Determination of heavy metals

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

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

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 vegetable and soil samples

The levels of heavy metals in *A. caudatus* and *L. sativa* are as shown in Table 1. In *A. caudatus* obtained from Alau dam, the metal levels were: As, 0.90 ± 0.26; Cd, 0.26 ± 0.02; Cu, 0.88 ± 0.07; Fe, 10.28 ± 0.61; Mn, 10.50 ± 0.90; Pb, 2.40 ± 0.16 and Zn, 6.10 ± 0.12 µgg-1. In those obtained from Gongulon, the metals were: As, 1.30 ± 0.26; Cd, 0.34 ± 0.02; Cu, 0.93 ± 0.06; Fe, 15.96 ± 0.18; Mn, 11.75 ± 1.04; Pb, 4.67 ± 0.22 and Zn, 6.35± 0.10 µgg-1. In *L. sativa* obtained from Alau dam, the metal levels were: As, 1.10 ± 0.16; Cd, 1.54 ± 0.42; Cu, 1.28 ± 0.16; Fe, 40.11 ± 0.16; Mn, 5.23 ± 0.06; Pb, 3.10 ± 0.12 and Zn, 7.47 ± 0.12 µgg-1. In those obtained from Gongulon, the metals were: As, 1.73 ± 0.20; Cd, 1.81 ± 0.09; Cu, 1.66 ± 0.09; Fe, 42.84 ± 0.27; Mn, 5.65 ± 1.13; Pb, 5.88 ± 0.06 and Zn, 7.80 ± 0.34 µgg-1. The levels of these heavy metals were lower in the control samples than their corresponding levels in sample areas. On the other hand, the results were lower than the published threshold values considered toxic for mature plant tissue, except *L. sativa* in which the Fe level was elevated.

The published threshold values are: As, 5 to 10 mg kg-1; Fe, 10-20.00 mg kg-1; Cu, 20 to 100 mg kg-1; Pb, 30 to 300 mg kg-1 and Zn, 100 to 400 mg kg-1 (Kabata-Pendias and Pendias, 1984). The critical values or values regarded as excessive are: Zn, >50-100 µg/g; Mn, >1000-4000 µg/g; Fe, >200-500 µg/g; Cu, >7-20 µg/g; Pb, >4-30 µg/g and Cd, >1-3 µg/g; depending on the plants (vegetables) in question (EC-UN/ECE, 1995). The order of the metals contamination in the vegetables was: Fe > Mn > Pb > Zn > As> Cu > Cd. Statistical test of

Table 2. Levels in µgg^{-1} of some heavy metals in soils obtained from Alau dam, Gongulon and the Control Sites.

Sample areas	Heavy metals						
	As	Cd	Mn	Cu	Fe	Pb	Zn
Alau dam	$3.42^{a} \pm 0.02$	$0.56^{a} \pm 0.05$	$13.81^{a} \pm 0.01$	$1.36^{a} \pm 0.28$	$51.02^{a} \pm 0.60$	$2.95^{a} \pm 0.64$	$13.56^{a} \pm 0.38$
Gongulon	$4.84^{b} \pm 0.04$	$0.81^{b} \pm 0.06$	$15.12^{a} \pm 0.26$	$3.78^{b} \pm 0.29$	$60.20^{b} \pm 0.70$	$3.58^{b} \pm 0.08$	$16.72^{a} \pm 0.16$
Control	$0.58^{c} \pm 0.20$	$0.15^{c} \pm 0.03$	$4.80^{b} \pm 0.03$	$0.30^{c} \pm 0.12$	$20.30^{c} \pm 0.30$	$0.46^{b} \pm 0.20$	$5.40^{b} \pm 1.20$

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

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. Accordingly, there were significant differences ($p < 0.05$) between the metal levels in vegetables from the two sample sites of Alau dam and Gongulon with the exception of Cu, Mn and Zn which showed no significant differences ($p > 0.05$). The elevated levels of the metals in the vegetables 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. Similarly, 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 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 60.20 ± 0.70 µgg^{-1}Fe. The metal levels in the control soil samples ranged from 0.15± 0.03 µgg^{-1} Cd to 20.30 ± 0.30 µgg^{-1} Fe. As noted for the vegetables, the order of the metals contamination in the soils was: Fe > Mn > Pb > Zn > 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 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 ($p > 0.05$). The elevated levels of the metals in the soils could be attributed to similar reasons given for the vegetables. The elevated Fe content followed by other micronutrients in the vegetable and soil samples obtained in this study might be due to high content of micronutrients in the waste water used in irrigating the soils.

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, CEC in meq100^{-1}g and the EC in µmhocm^{-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 (µmhocm^{-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 (µmhocm^{-1}) 0.20 ± 0.12 and pH 6.97± 0.57. The pH values of 6.23 ± 0.20 and 6.69 ± 0.04 in the two respective sample areas of Alau dam and Gongulon are indicative of slightly acidic environment. This 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 OC, and OM in the soil samples obtained in the two areas with their corresponding values in the control samples. However, CEC, 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

Table 3. Physicochemical parameters of the soils.

Sample areas	Parameters				
	OC (%)	**OM (%)**	**CEC (meq100^{-1}g)**	**EC (µmhocm^{-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

Table 4. Particle size fractions of the soils.

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).

Table 5. Transfer factors of the heavy metals from soils to vegetables.

Sample areas	Heavy metals							
	Vegetables	**As**	**Cd**	**Mn**	**Pb**	**Cu**	**Fe**	**Zn**
Alau dam	Spinach	0.26	0.46	0.76	0.81	0.74	0.20	0.45
Gongulon	«	0.27	0.42	0.78	1.30	0.25	0.27	0.38
Alau dam	Lettuce	0.32	2.75	0.38	1.05	0.95	0.79	0.55
Gongulon	«	0.36	2.23	0.37	1.64	0.44	0.71	0.47

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 (Abulude, 2005; Uwah, 2009).

Transfer factors (TF) of the heavy metals from soils to vegetables

The FT of the heavy metals from soils to vegetables are as presented in Table 5. FT 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 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 Cd in lettuce (*L. sativa*) and Pb in spinach (*A. caudatus*) whose values higher than one (1). The TF values of Zn, Cu, Pb and Cd are found to be significant and support the findings that accumulation of As and Ni is comparatively less while that of Cd, Cu and Zn is more in plants (Olaniya et al., 1998).

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 (Alloway and Ayres, 1997; Uwah, 2009). Some of the results recorded in this study were in agreement with those obtained in related studies by various researchers: like the study on water leaf by Ebong et al. (2007) and the low levels of Cd in vegetables reported by Alloway and Ayres (1997). 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). Hg causes brain damage, chest pain, stomach and cough (Alloway, 1990). 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

Taking 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. Farmers should be educated 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 the needs to grow crops with safe levels of heavy metals. The following conclusions were arrived at based on the analyses:

1. The vegetables and soils contained variable levels of heavy metals (As, Cd, Cu, Fe, Mn, Pb and Zn).
2. With the exception of those of Fe, the metal levels were lower than the published threshold values considered toxic for mature plant tissue. Similarly, the levels of some of the metals were lower than the established critical limits causing toxicity in plants.
3. Interactions of soil-plant roots-system play important roles in regulating heavy metal movement from soil to the edible parts of crops.
4. Agronomic practices such as application of fertilizers and use of waste water can affect bioavailability and crop accumulations of heavy metals.
5. Consumption of these vegetables as food may not constitute possible health hazards to humans at the time of the study.
6. The results obtained in this study would go a long way in providing a baseline data for the assessment of the distribution of these metals in spinach (*A. caudatus*) and lettuce (*L. sativa*) grown in Maiduguri, Nigeria.

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