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Heavy metals concentration in soil and *Amaranthus retroflexus* grown on irrigated farmlands in the Makera Area, Kaduna, Nigeria

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This study was conducted to determine the heavy metals concentration in soil and *Amaranthus retroflexus* grown on irrigated farmlands along the Makera Drain, Kaduna, Nigeria. The objectives were mainly to detect the presence of heavy metals in soil and vegetable grown in the study area, compare seasonal variation in concentration of metals, identify the transfer factors for heavy metals, compare the concentration of heavy metals in soil and vegetable in sample and control site, compare the concentration of heavy metals in soil/bioaccumulation in vegetable in sample site and control site in relation to the permissible limits specified by WHO/FAO, NAFDAC, FEPA and E.U Standards. Samples of soil and *Amaranthus retroflexus* were collected in the rainy and dry season for the year 2013 from upstream and downstream portion of the Sample site and control site. Analysis for the concentration of these heavy metals; Cu, Cr, Cd, Fe, Pb and Zn was conducted by the use of AAS (by Atomic Absorption Spectrometry) method. The transfer factor was identified and determined by the use of the formular TF=Mp/Ms. The difference between concentrations of heavy metals in portions of drain, seasons and sites was done by the use of T-test statistical analysis. Results from this study indicate that concentration value of Cr and Fe in the soil samples were generally higher than the FEPA maximum permissive limits while the concentrations of Pb (0.87-1.41), Cd (0.0014-8.02), Cu (13.21-14.25), and Zn (10.10-112.04 in soil samples were generally lower than the maximum permissive limits (Pb; 1.6, Zn; 300-400; Cu; 70-80mg/kg), except for samples from control site. On the other hand, in vegetables, the mean concentrations of Cd (0.013-2.12), Cr (0.058-2.80) and Fe (331.6-1252) in sample site were higher than the WHO/FAO maximum permissive limits (Cd - 0.2, Cr - 1.3, Fe - 425mg/kg), while in control site vegetables, concentration for all heavy metals was found below the maximum permissive limit. Furthermore, the study revealed that some areas of the sample site were more polluted by a particular metal than the other due to the prevailing anthropogenic activities in the area, and that all areas of the site run the risk of pollution by Cd, Cr and Fe in vegetables.

Key words: *Amaranthus retroflexus*, Makera Drain, soil/bioaccumulation, transfer factors, vegetable.

INTRODUCTION

Urban agriculture is defined as food and fuel grown within the daily rhythm of the city or town produced directly for the market and frequently processed and marketed by the farmers or their close associates. It includes aquaculture, livestock, orchards, vegetables and other crops. About 800 million people are engaged in urban and pheri-urban agriculture worldwide and contribute about 30% to the worlds food supply (UNDP, 1996).

Agriculture, which is the backbone of most economy, has also been adversely affected by upsurge in the indiscriminate dumping and disposal of wastes into land and water courses. The continuous pollution of both surface and underground water sources has reduced the quality and quantity of water needed for general agricultural requirements such as meeting crop water requirement during insufficient rainfall (Sangodoyin, 1991). Nonetheless, urban agriculture using wastewater for irrigation provides for food, incomes, and employment of thousands of people in Kaduna and other cities in Nigeria (Samaila et al., 2011).

Industrialization is considered vital to the nation's socio-economic development as well as its standing in the international community. Ideally, the citing of industries should achieve a balance between socio- economic and environment considerations. Relevant factors are availability and access to raw materials, the proximity of water sources, a market for the products, the cost of effective transportation, and the location of major settlement, labour and infrastructural amenities. In developing countries such as Nigeria, the location of industries is determined by various criteria, some of which are environmentally unacceptable and pose serious threats to public health (WHO/UNEP, 1997). Most of the environmental pollution problems arise from anthropogenic sources mainly from domestic and industrial activities. Though water pollution is an old phenomenon, the rate of industrialization and consequently urbanization has exacerbated its effect on the environment (Javeed, 1999; Asonye et al., 2007). As long as localization of industry could be an advantage for economic purposes, it also carries along the hazard of environmental pollution with it (Ogedengbe and Akinbile, 2004).

Kaduna metropolis has not been left out from the aftermath effect of industrialization. Studies by Nwaedozie (1998) and Federal Ministry of Environment Report (2002) on the River Kaduna have shown considerable increase in load of pollutants. River Kaduna is a major source of water supply to the Kaduna city. The river basin is a booming crop farming area in both dry and raining seasons. The bank of River Kaduna is predominantly used for peasant vegetable crop farming of lettuce, cabbage and dry season fresh corns. Fertilizers, herbicides and insecticides are used on these crops – and are eventually washed into the river via surface run off. Most of the industries (Textile factories, NNPC Refinery and Peugeot Automobile Assembly Plants among others) located in the southern part of the city derive their water requirements from the river and discharge their wastes directly into the river (Federal Ministry of Environment, 2002). Trade wastes (from auto-mechanics, metal fabrication/finishing and abattoirs among others) are also directly or indirectly discharged into the river. Domestic sewage and refuse also found their way into the river from many settlements along the river via leaching, direct discharge and surface run off. These suggest that there is every possibility of contamination of water, sediments and fish of River Kaduna by heavy metals since industrial effluents and municipal wastes are known to contain high amounts of heavy metals (Federal Ministry of Environment, 2002).

Kaduna River receives over 500, 000 m^3/day of untreated effluent from various industries in Kaduna through 53 tributaries and Makera Drain is one of such. The Makera drain is located around the industrial area that is situated on the far East (Nnamdi Azikwe) western bye–pass road in Kaduna. Notable industries located there are United Nigeria Textiles Plc (UNT Plc), Changchangi oil depot, Nigerian Brewery Ltd (NBL) and Norspin (Ali, Oniye, Balarabe and Auta 2004). These industries drain into the Makera rivulet, that drains northwards and empties into Kaduna River, a 10th order river, which flows across Kaduna metropolis, it serves as a major source of water supply to its populace and many aquatic organisms (National Water Resources Institute, Kaduna, *ToT-IWRM2004 Program).* The drain is surrounded by the Nasarawa, Makera, Down quarters and Kinkinau communities. Activities common around include, farming, fishing, cattle-rearing and minor quarrying among others (Salami, 2013).

According to Kirkhan (1983), the use of polluted water in the immediate surroundings of big cities in most countries (Nigeria inclusive) for growing of vegetables is a common practice. Although this water is considered to be a rich source of organic matter and plant nutrients, it also contains sufficient amounts of soluble salts and heavy metals such as Iron (Fe), Copper (Cu), Zinc (Zn), Lead (Pb) Nickel (Ni), Selenium (Sn), Mercury (Hg), Chromium (Cr), Arsenic (As), and Aluminum (Al) among others. When such water is used for cultivation of crops for a long period, these heavy metals may accumulate in soil, become toxic to the plants and also cause deterioration of soil.

The rapid increase in domestic, agricultural, municipal and industrial wastes in developing world under the combined effects of increasing population, industries and urbanization has been reported by various researchers (Sangodoyin, 1991; NEST, 1991; Ongley, 1998; Osibajo, 2001; Nubi, 2002; Ogedengbe and Akinbile, 2004). They all remarked that developing countries (Nigeria inclusive) suffer from problems arising from effluent discharge into river courses and agricultural pollution in surface runoff and ground water sources. Chiroma et al. (2003) in their

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study on heavy metal contamination of vegetables and soils irrigated with sewage water in Yola, Nigeria reported high concentration of heavy metals (especially Fe, Zn, Cu, Mg, Mn and Pb) contamination in the soils irrigated with sewage water. Their study also found out that there is accumulation of these metals in different parts of plant cultivated on the soil. The study also shows that the heavy metal concentration vary in different parts of the plant with Fe shown to accumulate in roots and leaves while Zn accumulates in roots and translocates gradually to the leaves and Mn and Mg show greater accumulations in unwashed leaves. Arora et al. (2008) carried out a study in Rajasthan India to assess the level of different heavy metals such as iron, manganese, copper and zinc, in vegetables irrigated with water from different sources. The results indicated a substantial build-up of heavy metals in vegetables irrigated with wastewater. Vivan et al. (2011), in their study, analyzed the effect of Kaduna refinery effluent discharge on River Romi and concluded that the water in Romi River has been contaminated by effluent discharge from the refinery, it was found that there is difference in the concentration of the pollutants at the upstream, point of entry and downstream, despite the fact that the refinery has a waste water treatment plant.

In another Study carried out by Raphael and Kolawale (2011) on the River Benue within Makurdi town shows that out of the heavy metals considered, Zn, Cd, Pb and Mn show the highest contamination in the soil of area studied and stated that the heavy metal contamination was largely because of presence of Benue Brewery Limited (BBL), Fertilizer blending company, Agro miller industry, NNPC deport and other small scale industries like dyeing, metal work, printing, paints and fuel filling stations discharge their effluents into the river.

From the foregoing, it has been demonstrated that the use of industrial effluents and wastewaters for growing of vegetables have serious impacts in contamination of soils by heavy metals and subsequent accumulation of metals by vegetables. A number of research have been carried out on the concentration of heavy metals of certain crops around the Makera Drain (Ali et al., 2005; Dadi-Mamud et al., 2011; Etonihu and Lawal, 2011), but none have considered a leafy vegetable like *Amaranthus retroflexus*. There have been some earlier reports that leafy vegetables have greater potential for accumulating heavy metals in their edible parts than grains and fruit crops, due to their higher transpiration rate (Jacob 2010). The aim of this study is to assess the heavy metals concentration in Soil and *Amaranthus retroflexus* grown on irrigated farmlands along the Makera Drain, Kaduna, Nigeria.

Study area

Kaduna is the capital of Kaduna State, it lies within latitudes 10^0 23'N – 10^0 38'N of the equator, and longitudes 7^0 21'E – 7^0 31'E of the Greenwich Meridian. It is located in the central area of what used to be called the Northern Region of Nigeria. It has interstate boundaries with Niger state to the West, Zamfara, Katsina and Kano states to the North, Bauchi and Plateau states to the East while FCT and Nasarawa state to the South (Figure 1).

The climate of the study area is of tropical continental or Sudan type which is characterized by a well-defined wet and dry season. The wet seasons lasts from April to October with its highest peak in August. Rainfall is usually heavy with storms of high intensity and short duration occurring ranging between 1200-1500m. The dry season persist from October to March during which the harmattan winds usually void of moisture, pervade the large part of the Northern part of Nigeria. The temperature in Kaduna is relatively high throughout the year. The daily ranges are usually higher than the monthly ranges particularly in the dry season when temperatures could drop low as 18 degrees. The highest temperatures are normally recorded in March and April, which is about 37 degrees (NIMET, 2007). The Makera drain is predominantly a tributary to the Kaduna River. The river takes source from Kujama hills in the Jos Plateau and flows for 210 km, before reaching Kaduna town. The Kaduna River cuts across the city dividing it into north and south area. Beyond Kaduna, the river flows for about 100km into Shiroro Dam. Past Shiroro, there is another 200km flow length before it finally discharge into the River Niger (Takobi, 2004).

MATERIALS AND METHOD

For this research, two sites were chosen - the sample and control site. The sample site was the farmland along the Makera drain in the Makera area of Kaduna Metropolis. This area was chosen considering that the drain receives effluent from United Nigerian Textile Plc, Kaduna Textile Limited (KTL), Nigerian Brewery Limited and Chanchangi oil depots among others, and also for the fact that there was anthropogenic activities that contributed to pollution load of the Makera area. The sampling site was divided into the upstream and downstream portion with each portion having two sampling points each (Figure 2). The control site was a private garden located in Unguwan Television. This site was considered because it had minimal level of pollution, i.e it was not close to any dumpsite, contaminated water body, and neither have the land been cultivated with the use of fertilizers, pesticides and any other chemical that would have contaminated the soil in any way. More so, vegetables were grown with use of pipe borne water.

Soil and vegetable (*Amaranthus retroflexus*) samples were collected in the peak period of wet season (August) and dry season spell (December) from the upstream and downstream portion of the drain. Similarly, both soil and vegetable samples were collected from the control site. The collected samples were carefully packed and sent to the laboratory (National Geo-Science and Laboratory Research Center, Barnawa, Kaduna) for the testing of concentration of the selected six (6) heavy metals; Pb, Cd, Cr, Cu, Zn and Fe with the use of AAS (Atomic Absorption Spectrometry) machine. Atomic Absorption Spectrometry (AAS) is a susceptible means for the qualitative and quantitative measurement of more than 60 metals/ elements (Welz, 1999).

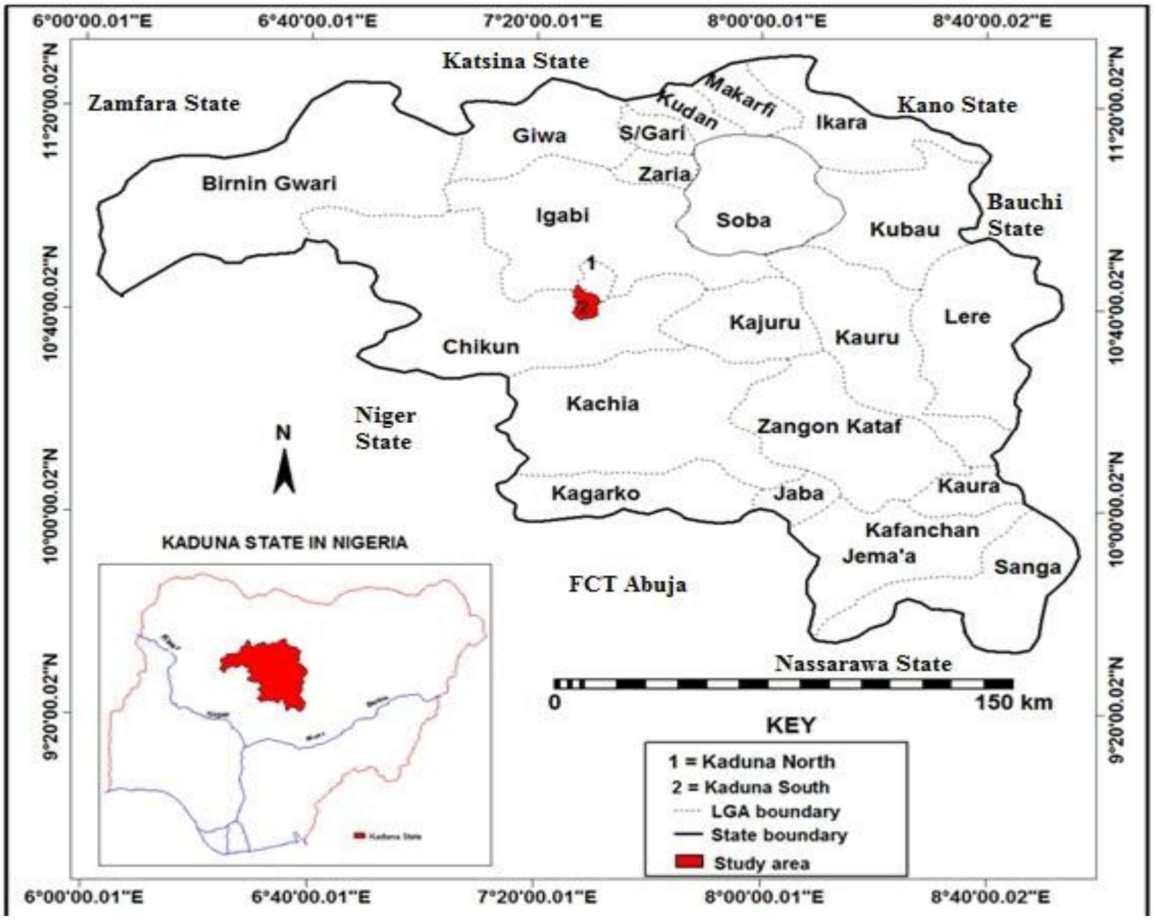

Figure 1. Location of the study area in Kaduna State. Source: Adapted and modified from Administrative Map of Kaduna State, 2014.

Table 1. Heavy metals concentration (upstream and downstream).

Heavy Metal	Concentration (mg/kg) Soil		Concentration (mg/kg) Vegetable	
	Upstream	Downstream	Upstream	Downstream
Pb	0.87-0.89	1.10-1.41	0.0014-0.0018	N.D
Cd	0.018-3.05	0.0014-8.02	0.035-1.014	0.013-2.12
Zn	10.10-81.88	22.38-102.04	18.25-53.68	14.19-69.07
Cr	21.35-103.48	27.77-358.0	0.058-2.80	1.19-1.72
Cu	13.21-42.15	35.89-41.93	0.77-8.65	0.58-3.04
Fe	1425-1871.2	1808.4-1981.6	1166-1839	331.6-1252.0

RESULTS AND DISCUSSION

The results obtained from the analysis of data from the sampling site to determine the heavy metals concentration in soil and vegetable upstream and downstream of the drain is shown in Table 1.

From Table 1, in vegetables, Pb showed a value of (0.0014-0.0018mg/kg) in the upstream and in downstream it was not detected. This indicates that, concentrations in the downstream were higher than in the upstream. And this could be explained by the fact that the downstream portion of the drain is some 60m from a motor bridge (Figure 2) where there is a considerable amount of vehicular emission which contributes to Pb concentration in the vegetable (Adeniyi, 1996; Okunola et al., 2007; Agunbiade and Fawale, 2009). Cd had a higher concentration in soil (0.035-1.014mg/kg) and vegetable (0.018-3.05mg/kg) in the upstream portion of the drain

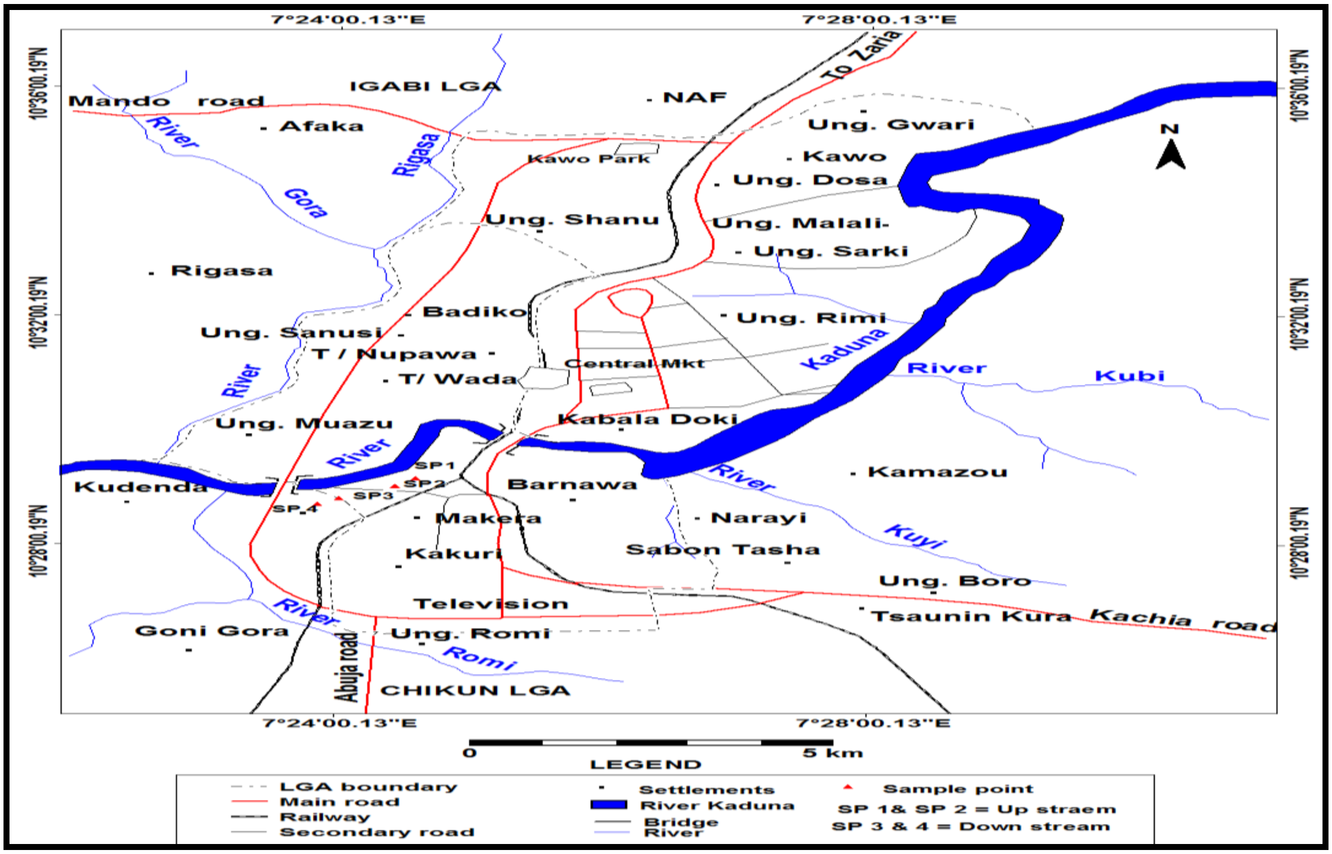

Figure 2. Kaduna metropolis showing the sampling points. Source: Adapted from Kaduna Street Guide Map, 2014.

Table 2. Heavy metals concentration (upstream and downstream).

Heavy Metal	Dry season		Wet Season	
	Concentration (mg/kg) (Soil)	Concentration (mg/kg) (Crop)	Concentration (mg/kg) (Soil)	Concentration (mg/kg) (Crop)
Pb	0.89-1.41	0.0018-0.001	0.87-1.10	0.0014-0.001
Cd	3.05-8.02	1.10-2.12	0.0014-0.018	0.013-0.035
Zn	81.88-112.04	53.68-69.07	10.10-22.38	14.19-18.25
Cr	103.48-358.00	1.72-2.80	21.35-27.77	0.058-0.772
Cu	13.21-41.93	3.04-8.65	35.89-42.15	0.582-0.772
Fe	1808.4-1871.2	331.6-1839	1425.0-1981.6	1166-1252

than in the downstream portion and this is largely because the upstream is point of entry for effluents into the drain. The effluents discharged had a considerable high amount of Cd and this also applies to Cu. Fe had a high level of high concentration in both portions of the drain and this is largely because the River Kaduna as a whole is known to be highly contaminated with Iron (Iguisi 2002; Sani, 1990).

Comparing the seasonal variation in the concentration of heavy metals in the sample site, the result is presented in Table 2.

From the result presented above, there was a general reduction in heavy metals concentration in vegetables sampled during the rainy season when compared with those sampled during dry season. This may be due to the fact that during the rainy season, the gardens were not irrigated with the wastewater. There is also the possibility of rainwater leaching away parts of the metals that have accumulated in the soil, thus reducing the quantity of these metals available to plants in the soil. For Cd, in the dry season soil, it showed a concentration value of (3.05-8.02 mg/kg), while in wet season soil it showed a concentration value of (0.0014-0.018 mg/kg) showing dissimilarity between the concentration values in the dry

Table 3. Transfer factor of heavy metals in the study area.

Heavy Metal	Dry season		Wet Season	
	Upstream	Downstream	Upstream	Downstream
Pb	0.0019	0.0017	0.0017	0.0001
Cd	0.333	0.264	0.394	3.214
Zn	0.656	0.616	1.808	0.634
Cr	0.027	0.005	0.003	0.043
Cu	0.655	0.072	0.018	0.016
Fe	0.983	0.183	0.818	1.583

Table 4. Heavy metals concentration of soil and vegetable in sample and control site.

Heavy Metal	Sample Site		Control Site	
	Concentration of Heavy Metal in Soil (mg/kg)	Concentration of Heavy Metal in Vegetable (mg/kg)	Concentration of Heavy Metal in Soil (mg/kg)	Concentration of Heavy Metal in Vegetable (mg/kg)
Pb	0.87-1.41	0.0014-0.001	0.0012-0.0016	0.0001-0.0014
Cd	0.0014-8.02	0.013-2.12	0.0012-0.3720	0.0140-0.0500
Zn	10.10-112.04	14.19-69.07	10.070-12.320	6.8440-9.0400
Cr	21.35-358.00	0.058-2.80	0.2240-0.2820	0.0560-0.0860
Cu	13.21-42.15	0.582-8.65	0.2620-0.2820	0.0700-0.0780
Fe	1425.0-1981.6	331.6-1252	143.2-205.2	132.0-175.2

and wet season. This applies to Zn, Cd and Cu in both soil and vegetable sample, where concentrations were higher in the dry season.

Transfer factor is derived by the method described by Oyedele et al. (2008) and Harrison and Chirgawi, 1989) given in the equation below;

TF = Ps (mg/g) / St (mg/g)

Where Ps - plant metal content originating from the soil; St - total content in the soil.

Table 3 shows the results from the calculations. From the results, the highest transfer factor recorded was in Cd in the wet season downstream with value of 3.214 followed by Zn in wet season downstream with a value of 1.808. This implies that the bioaccumulation of heavy metals in vegetables was very high and consumption of the vegetables could lead to hypertension, arthritis, diabetes, anaemia, cancer, cardiovascular disease, cirrhosis, reduced fertility; hypoglycemia, headaches, osteoporosis, kidney disease, and strokes are its some odd long term results (Lokeshappa et al., 2012) as a result of Cd poisoning. Pb showed very low Tf values with the highest being 0.0019, indicating that vegetable from the study area did not have a high contamination by Pb and therefore, no fear of Pb related diseases. Zn showed a considerable high Tf value with almost all values surpassing 0.5 indicating that vegetables where largely contaminated with Zn form anthropogenic sources, and this is based on the suggestion that the greater the transfer coefficient value than 0.50, the greater the chances of vegetables for metal contamination by anthropogenic activities (Kloke, 1984).Zn showed a considerable high Tf value with almost all values surpassing 0.5 indicating that vegetables where largely contaminated with Zn form anthropogenic sources, and this is based on the suggestion that the greater the transfer coefficient value than 0.50, the greater the chances of vegetables for metal contamination by anthropogenic activities (Kloke, 1984).Fe had Tf values of 0.981, 0.183, 0.818 and 1.583 respectively and this is considered a high Tf value. Values close to or above 1 (one) are considered high Tf values (Uwah et al., 2009). The consistently high load of iron recorded in both site and season is not surprising considering the fact that iron is one of the constituents of rock materials found inside the drain. Calculating the mean for Tf values for Cu from table 4.3, Cu had a mean Tf value of 0.190, and this is considered low. The low Tf value may be due to its strong adsorption onto the organic matter which renders it less bio-available to plants (Alloway and Ayres, 1997).

It can be deduced from Table 4 above that concentration of heavy metals were higher in both soil and vegetable samples in the sample site than in the control site. The general higher concentration value observed in the sample sites as against the control site could be attributed to pollution of the sample areas due to excessive usage of fertilizers, herbicides and other agro-chemicals as well as the use of waste water in irrigating the soils and the environmental factors pertinent in the study area (Kirkhan, 1983; Lokeshwari and Chandrappa,

Table 5. Mean concentration of heavy metal in sample and control site and FEPA guidelines for heavy metals in soil.

Heavy Metal	Concentration of Soil in Sample Site (mg/kg)	Concentration of Soil in Control Site (mg/kg)	FEPA Guidelines for Heavy Metals in Soils (mg/kg) (Threshold Values)	E.U Standards for Heavy Metals in Soils (ppm) (Threshold Values)
Pb	0.87-1.41	0.0012-0.0016	1.6	300
Cd	0.0014-8.02	0.0012-0.3720	Not Fixed	3.0
Zn	10.10-112.04	10.070-12.320	300-400	-
Cr	21.35-358.00	0.2240-0.2820	Not Fixed	150
Cu	13.21-42.15	0.2620-0.2820	70-80	140
Fe	1425-1981.6	143.2-205.2	400	-

Table 6. Concentration of heavy metal in sample and control site.

Heavy Metal	Concentration of Vegetable in Sample Site (mg/kg)	Concentration of Vegetable in Control Site (mg/kg)	WHO/FAO Safe limits for Heavy Metals in vegetables (mg/kg)	E.U Standards for Heavy Metals in Vegetable (ppm)
Pb	0.0014-0.001	N.D-0.0014	0.3	0.3
Cd	0.013-2.12	0.0140-0.0500	0.2	0.2
Zn	14.19-69.07	6.8440-9.0400	99.40	-
Cr	0.058-2.80	0.0560-0.0860	1.30	0.3

2006). From Table 5, it was observed that the values obtained for concentrations for heavy metals (except for Fe, Cr and Cd in certain instances) in soils for sample and control site are well within the permissible limits specified FEPA and other standards.

For Pb in soils for both sites, range value (<0.0001-1.41mg/kg) and this relatively below threshold value of 1.6mg/kg set by FEPA for heavy metals in soils. Whereas Cr in soil had concentration range value of (0.2240-358.00mg/kg), the high concentration of Cr observed in sample site likely reflects its association with parent granite and ultramafic rocks (Nafiu et al., 2008). Concentrations of Cu and Zn for soil in both sites fell within the set standards of FEPA.

As seen from Table 6 the concentrations of Cd (0.013-2.12), Cr (0.058-2.80) and Fe (331.6-1252) in sample site were higher than the WHO/FAO maximum permissive limits (Cd - 0.2, Cr - 1.3, Fe - 425mg/kg), while in control site vegetables, concentration for all heavy metals was found below the maximum permissive limit. This indicates that there is a likelihood of suffering from diseases associated with consumption of vegetable (in this case *Amaranthus retroflexus)* containing elevated levels of those heavy metals.

Conclusion

This study was conducted to determine the heavy metal concentration in soil and *Amaranthus retroflexus* grown on irrigated farmlands along the Makera Drain, Kaduna, Nigeria. The study revealed that the concentration of heavy metals considered are usually higher at upstream portions of drain which is normally the point of effluent discharge than the downstream if all variables and parameters remained same for both portions. Similarly, dry season samples showed higher levels of concentration of heavy metals than in wet season's samples. Furthermore, it was observed that agronomic practices such as application of fertilizers, use of wastes as manures, and use of waste water can affect bio-availability and crop accumulations of heavy metals. In addition, it was discovered that the consumption of vegetables grown along the drain, may in some instances constitute possible health hazards to humans.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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