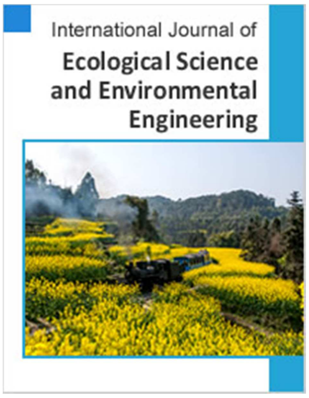
International Journal of Ecological Science and Environmental Engineering
2016; 3(1): 10-19
Published online February 24 2016 (http://www.aascit.org/journal/ijesee)
ISSN: 2375-3854

American Association for Science and Technology



Keywords
Carrots,
Health Benefits,
Contamination,
Toxicological Risk

Received: December 27, 2015
Revised: January 14, 2016
Accepted: January 16, 2016

Evaluation of the Toxicological Implication of Consuming Carrots (*Daucus carota L*) Cultivated Along River Galma Basin Around Dakace Industrial Layout, Zaria, Nigeria

Udofia Udeme U.[1], Udiba U. U.[2, *], Bate G. B.[3], Lydia E. Udofia[1], Agbon T. D. T[1]

[1]Dept of Zoology and Environmental Biology, University of Calabar, Calabar, Nigeria
[2]Environmental Technology Division, National Research Institute for Chemical Technology, Zaria, Nigeria
[3]Department of Environmental Science, Federal University Dutse, Jigawa State, Nigeria

Email address
udiba.udiba@yahoo.com (Udiba U. U.)

Citation
Udofia Udeme U., Udiba U. U., Bate G. B., Lydia E. Udofia, Agbon T. D. T. Evaluation of the Toxicological Implication of Consuming Carrots (*Daucus carota L*) Cultivated Along River Galma Basin Around Dakace Industrial Layout, Zaria, Nigeria. *International Journal of Ecological Science and Environmental Engineering.* Vol. 3, No. 1, 2016, pp. 10-19.

Abstract
Carrot (*Daucus carota L*), is a root vegetable rich in bioactive compounds having significant health-promoting properties. The enormous health benefits of the vegetable notwithstanding, consumption of contaminated edible portion of the plant could pose serious toxicological risk. In this study, Lead (Pb), Chromium (Cr), Nickel (Ni) and Manganese (Mn) contents of edible carrots roots from River Galma basin around Dakace industrial area, Zaria were thoroughly assessed to evaluate the potential risk of consuming root vegetables from the area and by implication, the impact of Dakace industrial area on the environment. The assessment was carried out by atomic absorption spectrophotometry using Shimadzu atomic absorption spectrophotometer (model AA-6800, Japan) after wet digestion. The overall mean concentrations of the metals were: 1.05±0.5 mg/kg for lead, 1.51±0.9 mg/kg for chromium, 3.74±1.89 mg/kg for nickel and 1.21±2.72 mg/kg for manganese. Lead and chromium concentrations were found to be above WHO/FAO permissible levels. Average values of Estimated Daily Intake (EDI) were higher compared to Recommended Daily Intake (RDI) and Upper Tolerable Daily Intake (UL) for all the metals. Target Hazard Quotient (THQ) for lead and nickel were found to be above the safe limit of unity. Hazard Index (HI) used to evaluate the potential risk to human health due to the combined effect of the four heavy metals was 2.84. The relative contributions of these metals to the aggregated risk were 59.86%, 0.21%, 38.03% and 1.76% for Pb, Cr, Ni, and Mn respectively. Consumption of edible carrots roots from the study area thus poses a serious toxicological risk. Average values of the contaminants in the study area were found to be significantly ($p < 0.05$) higher than the control suggesting that the industrial estate exerts a significant adverse impact on the environment. Implications of these findings to public health are fully discussed.

1. Introduction

Nutrition is the cornerstone of good health. There are so many illnesses that could be prevented with better nutrition. Vitamin supplements for instance are not normally necessary when there is balanced diet. Vegetables play an important role in meeting the food requirements of people world-wide, because they are a very important source of various essential components of food (Ogle *et al*., 2001; Mukerji, 2004). They are sources of vitamins, minerals, and fibers in abundance and also have beneficial anti-oxidative effects. Research has proven that getting the proper level of antioxidants into the human bloodstream will reduce the risk of cancer and many other diseases (Arai, 2002). Vegetables are also potential source of essential nutrients which constitutes functional food components thereby providing protein, iron and calcium which have noticeable health effects (Arai, 2002).

Carrot (*Daucus carota L*), a root vegetable, is an economically important horticultural crop that has gained popularity due to increased awareness of its nutritional value. Orange carrots are highly regarded with admiration and deep respect due to their high content of hydrocarbon carotenoids, a class of phytochemicals that are often precursors to vitamin A. The domestic carrot has been selectively bred for its greatly enlarged and more palatable, less woody-textured edible taproot. The carrot gets its characteristic and bright orange colour from β-carotene, and lesser amounts of α carotene and γ- carotene. α and β-carotenes are partly metabolized into vitamin A in humans (Strube and OverDragsted 1999; Noontny *et al*., 1995). The storage root of carrot is the most commonly consumed portion of the plant, although the tender young foliage is occasionally used as herb and in salads (Rubatzky *et al.,* 1999). Carrots supply nutrition in the form of phytochemicals, such as carotenoids, anthocyanins, and other phenolic compounds. The greatest nutritional interest in carrots stems from their phytochemical content. They are also a good source of potassium, vitamins B, vitamin C, copper, folic acid and thiamine. The enlarged and palatable edible taproot also contain fibre, vitamin K, potassium, folate, manganese, phosphorous, magnesium, vitamin E and zinc (Rodriguez-Concepcion and Stange (2013)).

Carrots are credited with many medicinal properties. It's been reported that they can enhance the quality of breast milk as well as improve the appearance of the skin, hair and nails. Potassium present in carrots is an important component of cell and body fluids that help control heart rate and blood pressure by countering effects of sodium (Rubatzky *et al.,* 1999). When taken daily, carrots can lower cholesterol and blood pressure. Raw carrots contain beta-carotene, a strong antioxidant that can prevent cancer. Carrots juice when taken every day prevents body infections and is claimed to be valuable for the adrenal glands. Carrots can help improve eye health and increase menstrual flow. They can regulate blood sugar and promote colon health, because they are rich in fiber. Carrots are also beneficial in the following cases: Obesity, poisoning of the blood, gum disease, insomnia, inflamed kidney, liver, gallbladder, Alzheimer's disease, colitis, ulcer and painful urination.

The key to healthier vegetable produce is healthier growing medium (Soil and water). Vegetables grown decades ago have been reported to be much richer in vitamins and minerals than the ones obtained today (Davis *et al.,* 2004). The main reason for this disturbing nutritional trend is soil depletion: Modern intensive agricultural methods have stripped increasing amounts of nutrients from the soil in which the food we eat grows. Sadly, each successive generation of fast-growing, pest-resistant carrots are truly worse for human consumption than the one before (Davis *et al.,* 2004). Rapid population growth, industrialization and urbanization with insufficient environmental monitoring and planning have actually lead to large scale degradation the global environment. Untreated or poorly treated industrial waste and sewage are discharged into rivers and lakes which in turn have lead to gradual pollution of our water resources. Many times such wastewater is drained to the agricultural land where they are used for irrigating crops including vegetables. Many farmers in areas closer to urban localities are often compelled to use waste water to irrigate their crops, due to absence of better alternatives (Ghimire, 1994). Polluted effluent has been found to be rich not only in organic matter and nutrients but also in heavy metals that eventually reach the soil of agricultural area (Smith *et al*., 1996). Heavy metals play an important role in plant physiology since many of them are essential trace elements necessary for the optimal growth of the plants. The lack of them can result in different diseases (deficiency). On the other hand, above a certain concentrations, these heavy metals can have toxic effects on plants (Szabol and Czeller, 2009). The uncontrolled input of heavy metals in soils is an undesirable one because once in the soil, they are generally very difficult to remove (Smith *et al.,* 1996). Vegetable cultivated in soils with elevated metal levels have the potential to significantly uptake such metals to dangerous concentrations in its edible parts. The degree of uptake is largely a function of the soil chemistry, chemical form of the metals concern, species and age of the vegetable. According to literature sources, vegetables (such as carrot) can accumulate some heavy metals to such degree that can have toxic effects on humans (Szabol and Czellérm, 2009; Clemens *et al*., 2002; Yang *et al.,* 2009). Intakes of heavy metal-contaminated vegetable therefore have the potential of posing serious risk to the human health. It has been reported that prolonged consumption of unsafe concentrations of heavy metals through foodstuffs may lead to the chronic accumulation of the metals in the kidney and liver of humans causing disruption of numerous biochemical processes, leading to cardiovascular, nervous, kidney and bone diseases (Trichopoulos, 1997; Jarup, 2003). It follows therefore that, the enormous benefits of carrots notwithstanding, the consumption of heavy metal contaminated carrot could pose serious toxicological risk. This study was thus designed to assess the potential risk of consuming carrots from River Galma basin around Dakace industrial area, Zaria. River Galma is used as receptacle for domestic, agricultural and most importantly industrial waste. Previous studies have seriously implicated the surface water of River Galma around Dakace industrial layout for heavy metal pollution (Udiba *et al.,* 2014a, Udiba *et al.,* 2014b). The possibility of heavy metal contamination of River Galma basin and crops grown on it around Dakace industrial layout cannot be completely ruled out especially in the dry season when the contaminated water is used for irrigation. Carrot is reported to grow best in full sun with optimum temperature of about 16-21°C (Benjamin *et al*., 1997). In the study area the seeds are sown from mid February to early April corresponding to the peak of the dry season in the Northern Nigerian State. Monu *et al.,* (2008) cited in Szabol and Czellérm, (2009) reported that irrigation water from different sources have significant effect on the heavy metal uptake of 10 vegetables including carrot.

2. Materials and Methods

2.1. Sampling Area

Zaria, a city in Kaduna State, Northern Nigeria is located at latitude 11º3'N and longitude 7º40'E. The city is about 128 km Southeast of Kano and 64 km Northeast of Kaduna, the State capital (Nnaji *et al*., 2011). River Galma is the main drainage channel in Zaria since other rivers and streams discharge into it. The river is located at the southeastern part of Zaria and its source is the Jos Plateau. The Zaria dam is located on River Galma (Nnaji *et al* 2007). Dakace industrial area habours a number of wet industries such as oil mills, packaging, food and beverages industries. Effluents from these industries are discharged through drains and canal that empties into the River. The Galma river basin is a booming agricultural area. Crops are planted on both sides of the river bank throughout the year. The river is a major source of water supply to a number of communities located along its course. It is used for irrigation, fishing, bathing and even drinking. The river carries water throughout the year with its peak discharge in the month of July or August and least discharge in March or April (Thorp, 1970). The geology of the study area is basement of complex rock composed mainly of fine grain gneisses and migmatite with some coarse-grained granite outcrop in few places. The gneisses are moderately to weakly floated, primarily made up of quartz and oligoclase, depth of weathering is regular but thorough, the depth ranges from 10 meters to deep pocket, occasionally extending to about 60 meters. Due to poor conservation and land use practice like extensive vegetation clearance for agricultural and urban development purposes, intensive grazing, livestock tracks and human foot paths criss-crossing the area, overland flow, rilling and gullying have become the dominant mode of rain water disposal from the landscape.(Ologe, 1971; Bello, 1973; Iguisi, 1996). The catchment area lies in the natural vegetation zone known as the Northern Guinea Savannah. Unfortunately, this characteristic vegetation cover is hardly preserved due to urbanization, other anthropogenic activities and poor management practices, like cultivation, intensive grazing, fuel wood harvesting and annual bush burning (Ologe, 1971).

Rainfed agriculture and irrigation are the two major forms of agricultural activities practiced in the Galma catchment. The rainfed agriculture is a rainy season activity which takes place on the upland fields.

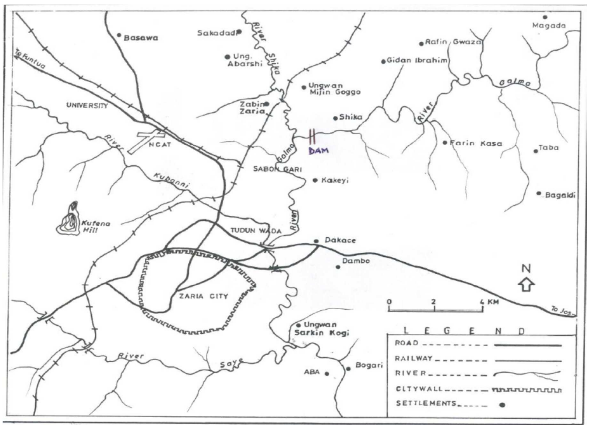


Fig. 1. *Zaria showing Rivers and Settlements (Nnaji et al., 2007).*

2.2. Collection, Preservation and Preparation Samples

Procedure for sample collection, preservation and preparation was adopted from Abida, (2009). Three sampling stations were established along Galma River basin around Dakace industrial layout after identifying effluent discharge points (point sources) from the industries. Sampling station 1 was at the first identified point source in industrial layout. Sampling station 2 was after the second and third identified effluent discharge points about 500 meters from sampling station 1. Sampling station 3 was 500 meters from sampling station 2. The control samples were collected along River Kubanni basin, about 1kilo meter from the confluence of River Galma and River Kubanni. Matured Carrots roots were harvested from three different points in farms around each of the four established sampling stations. The harvested crops were stored in black polythene bags and transported to the environmental laboratory of National Research Institute for Chemical Technology (NARICT), Zaria, Nigeria. The carrots roots from each sampling station were thoroughly washed so as to remove all adhered soil, cut into pieces and air dried for 5 days in the laboratory. The dried samples were pulverized, passed through 1 mm sieve and digested. The digestion of 1 g was carried out using 10ml of concentrated nitric acid according to Awofolu (2005).

2.3. Sample Analysis

Metal concentration in the digests was determined by Atomic Absorption Spectrophotometry, using shimadzu Atomic Absorption Spectrophotometer (model AA-6800, Japan) equipped with Zeaman background correction and graphite furnace at National Research Institute for Chemical Technology (NARICT), Zaria-Nigeria. The calibration curve was prepared by running different concentrations of standard solutions. The instrument was set to zero by running the respective reagent blanks. Average values of three replicates were taken for each determination and were subjected to statistical analysis.

2.4. Analytical Quality Assurance

In order to check the reliability of the analytical methods employed for metal determination, one blank and combine standards were run with every batch to detect background contamination and monitor consistency between batches. The result of the analysis was validated by digesting and analyzing Standard Reference Materials, Lichen coded IAEA-336 following the same procedure. The analyzed values and the certified reference values of the elements determined were compared to ascertain the reliability of the analytical method employed. The reagent used for sample preservation and digestion, viz. Nitric acid and perchloric acid (Riedel-deHaën, Germany), were of analytical grade.

2.5. Statistical Analysis

Data collected were subjected to statistical test of significance using the Analysis of Variance (ANOVA) test to assess significant variation in metal levels across the three sampling stations within the study area. Pearson products moment correlation coefficient was used to determine the level of association between metals in the study. The three statistical analyses (ANOVA, t- test and correlation) were done by SPSS software 17.0 for windows.

The estimated daily metals intake from carrots roots in this study was determined according to Addo *et al*., (2012) following equation (1)

$$EDI = \frac{CHM \times DAC}{BW} \quad (1)$$

Where CHM (mg/kg) is the concentration of heavy metals in contaminated carrots root; DAC represents the daily average consumption of carrots; and BW is the body weight. The DAC for this study was taken from Sharma *et al*., (2009) as 400g. An adult's average body weight of 70kg was used for the EDI evaluation.

An estimate of the potential hazard to human health (Target Hazard Quotient- THQ) through consumption of carrots grown along River Galma basin around Dakace industrial area was computed using equation (2).

$$\mathrm{THQ} = \frac{(Div) \times Cmetal}{RfD \times Bo} \quad (2)$$

Where *(Div)* is the daily intake of vegetables (kg per day), (Cmetal) is the concentration of metal in the vegetable (mg/kg), RfD is the oral reference dose for the metal (mg/kg) body weight per day), and Bo is the human body mass (kg). RfD is an estimate of a daily oral exposure for the human population, which does not cause deleterious effects during a lifetime. The methodology for estimation of target hazard quotients (THQ) was adopted from *USEPA Region III Risk-Based Concentration Table, January–June 1996 cited in G*uerra *et al*., (2012). Values of RfD for Cr (1.5 mg/kg per day), Ni (0.02 mg/kg per day) and Mn (0.14 mg/kg) were taken from Integrated Risk Information System (US EPA, 2010). The value of RfD for Pb (0.0035 per day) was taken from WHO (1993). The average Bo was taken as 70 kg for adults (WHO, 1993).

The hazard index (HI) was computed as the sum of the Target Hazard Quotients of the heavy metals under study (US EPA, 1989, Guerra *et al*., 2012) as described in Equation (3)

$$\mathrm{HI} = \Sigma\, \mathrm{THQ} = \mathrm{THQPb} + \mathrm{THQCr} + \mathrm{THQNi} + \mathrm{THQMn} \quad (3)$$

2.6. Results

To evaluate the accuracy and precision of the analytical procedure employed, standard reference material of Lichen coded IAEA -336 was analyzed in like manner to our samples. The analyzed values were within the range of certified reference values of the elements determined (Table 1), suggesting the reliability of the method employed.

Table 1. *Results of analysis of reference material (Lichen IAEA -336) compared to the certified reference value (mg/kg).*

Element (mg/kg)	Pb	Cd	Cu	Mn	Ni
A Value	5.25	0.140	4.00	55.78	1.20
R value	4.2-5.5	0.1-2.34	3.1-4.1	56-70	1.00 – 1.40

A Value = Analyzed value R Value = Reference value.

Results obtained from the determination of lead, chromium, manganese and nickel content of carrots roots from the four established sampling stations are presented in Table 2, while the spatial distribution of the Average metal concentrations of carrots roots across the different sampling stations in the study area is shown in Figure 2, 3, 4, and 5.

Result obtained from the determination of metal content of edible carrots *roots* across the different sampling stations (Table 4) indicates that the order of detection of lead was; Sampling Station 3 > Sampling Station 2 > Sampling Station 1. The concentration ranged between 0.91 mg/kg – 1.22 mg/kg. The lowest concentration (0.91 mg/kg) was recorded in Sampling Station 1 in the month of November and the highest concentration (1.22 mg/kg) in Sampling Station 3 in January (Figure 2). The mean lead levels of edible carrots *roots* from River Galma basin increased with increasing distance downstream throughout the sampling period. Statistical analysis shows that the difference in lead content of edible carrots *roots* across the sampling stations was not statistically significant (ANOVA, $p > 0.05$). The overall mean lead levels of edible carrots *roots* from River Galma basin (Study area) was found to be 1.05±0.5 mg/kg while the average lead level of edible carrots *roots* from River Kubanni basin (control) was 0.53±03 mg/kg with a range of 0.46 mg/kg - 0.58 mg/kg. The difference in lead levels of edible carrots *roots* between the study area and the control was found to be statistically significant ($P < 0.05$), the average lead levels of edible carrots *roots* from the study area being significantly higher than the control.

Table 2. *Metal Contents of carrots roots from River Galma Basin around Dakace Industrial Area, Zaria, Nigeria (mg/kg).*

Element	Sampling Month	Sampling Station 1	Sampling Station 2	Sampling Station 3	River Kubanni (Control)
Lead	Nov.	0.91	0.94	0.98	0.46
	Dec.	1.01	1.04	1.08	0.54
	Jan.	1.12	1.116	1.22	0.58
	Mean ± SD	1.01±0.11	1.03±0.09	1.09±0.12	0.53±0.06
Chromium	Nov.	0.95	0.99	1.74	0.41
	Dec.	1.14	1.25	2.13	0.49
	Jan.	1.41	1.49	2.48	0.51
	Mean ± SD	1.17±0.23	1.24±0.25	2.12±0.37	0.47±0.05
Nickel	Nov.	2.04	4.42	4.38	0.64
	Dec.	2.06	4.41	4.44	0.67
	Jan.	2.14	5.02	5.15	0.79
	Mean ± SD	2.08±0.05	4.62±0.34	4.66±0.43	0.7±0.08
Manganese	Nov.	0.76	0.89	1.32	0.48
	Dec.	1.04	1.21	1.41	0.54
	Jan.	1.19	1.38	1.66	0.59
	Mean ± SD	0.10±0.22	1.16±0.25	1.46±0.17	0.54±0.56
Standards					

Table 2 shows that chromium concentration followed the order: Sampling Station 3 > Sampling Station 2 > Sampling Station 1. The concentration ranged between 0.95 mg/kg – 2.48 mg/kg. The lowest concentration (0.95 mg/kg) was recorded in Sampling Station 1 in the month of November and the highest concentration (2.48 mg/kg) in Sampling Station 3 in January (Figure 3). The mean chromium levels of edible carrots *roots* from River Galma basin increased with increasing distance downstream throughout the sampling period. Statistical analysis shows that the difference in chromium levels of edible carrots *roots* from the sampling stations was statistically significant (ANOVA, $p < 0.05$). The average chromium level of edible carrots *roots* from the sampling station 1 was significantly higher than sampling station 3. The difference in between sampling station 1 and sampling station 2 and, between sampling station 2 and sampling station 3 were not statistically significant t 95% confidence level. The overall mean chromium levels of edible carrots *roots* from River Galma basin (Study area) was found to be 1.51±0.9 mg/kg while the average chromium level of edible carrots *roots* from River Kubanni basin (control) was 0.47±07 mg/kg. The difference in chromium levels of edible carrots *roots* between the study area and the control was found to be statistically significant ($P < 0.05$), with the average chromium levels of edible carrots *roots* from the study area being significantly higher than the control.

Nickel concentrations obtained from the determination of metal content of edible carrots *roots* from the different sampling points along River Galma Basin, Zaria and the control River Kubanni basin, Zaria, Nigeria (Table 4) followed the trend: Sampling Station 3 > Sampling Station 2 > Sampling Station 1. The concentration ranged between 2.04 mg/kg – 5.15 mg/kg. The lowest concentration (2.04 mg/kg) was recorded in Sampling Station 1 in the month of November and the highest concentration (5.15 mg/kg) in Sampling Station 3 in January (Figure 4). The mean nickel levels of edible carrots *roots* from River Galma basin increased with increasing distance downstream throughout the sampling period. Statistical analysis shows that the difference in nickel levels of edible carrots *roots* from the sampling stations were statistically significant (ANOVA, $p < 0.05$). Nickel level of edible carrots *roots* from the sampling station 3 was found to be significantly higher than sampling station 1 and sampling station 2. The difference in nickel levels between sampling stations 2 and 3 was not statistically significant (ANOVA, $P > 0.05$) The overall mean nickel levels of edible carrots *roots* from River Galma basin (Study area) was found to be 3.74±1.89 mg/kg while the average nickel level of edible carrots *roots* from River Kubanni basin (control) was 1.31±0.76 mg/kg. The difference in nickel levels of edible carrots *roots* between the study area and the control was found to be statistically significant ($P < 0.05$), with the average nickel levels of edible carrots *roots* from the study area being significantly higher than the control.

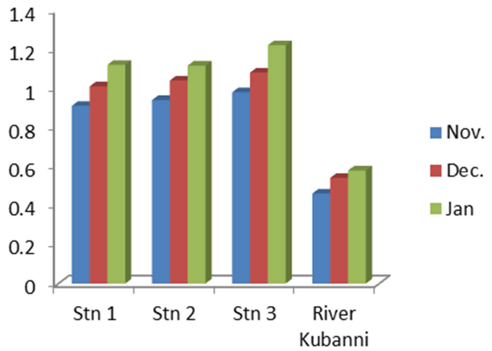


Fig. 2. *Spatial distributions of lead concentration in edible carrots tap roots across sampling stations.*

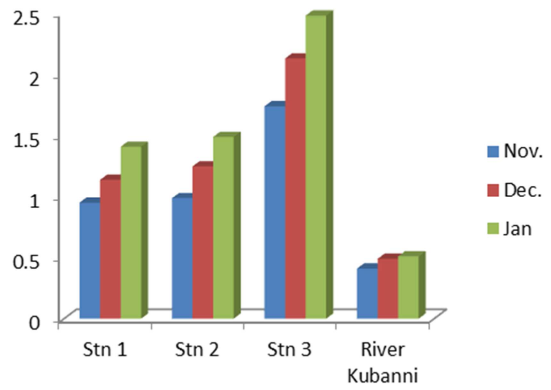


Fig. 3. *Spatial distributions of Chromium concentration in edible carrots tap roots across sampling stations.*

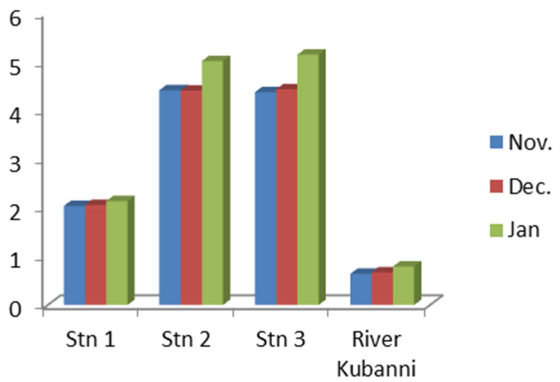


Fig. 4. *Spatial distributions of Nickel concentration in carrots tap roots across sampling stations.*

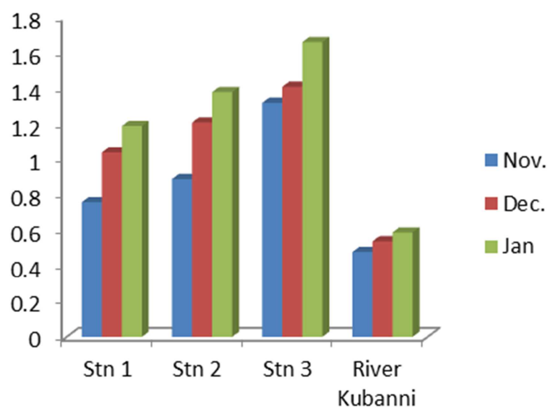


Fig. 5. *Spatial distributions of Manganese concentration in edible carrots tap roots across sampling statio.*

Manganese concentration (Table 4) followed the sequence: Sampling Station 3 > Sampling Station 2 > Sampling Station 1. The concentration ranged between 0.76 mg/kg – 1.66 mg/kg. The lowest concentration (0.76 mg/kg) was recorded in Sampling Station 3 in the month of November and the highest concentration (1.66 mg/kg) in Sampling Station 3 in January (Figure 5). Statistical analysis shows that the difference in manganese levels of edible carrots *roots* across the sampling stations were not statistically significant (ANOVA, $p > 0.05$). The overall mean manganese levels of edible carrots *roots* from River Galma basin (Study area) was found to be 1.21±2.72 mg/kg while the average manganese level of edible carrots *roots* from River Kubanni basin (control) was 0.53±05 mg/kg. The difference in manganese levels of edible carrots *roots* between the study area and the control was found to be statistically significant ($P < 0.05$), with the average manganese levels of edible carrots *roots* from the study area being significantly higher than the control.

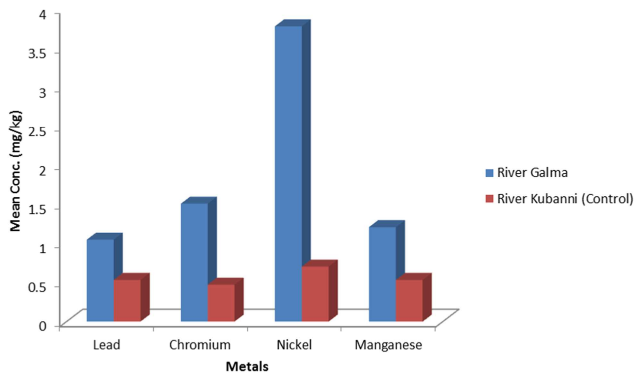


Fig. 6. *Spatial distribution of the Average metal concentrations of edible Carrot roots across the different sampling points in the study area.*

The spatial distribution of the Average metal concentration of edible carrots *roots* from the different sampling points in the study area (Figure 4) shows that the trend of occurrence of the heavy metals in the study area was nickel > chromium > manganese > Lead. Positive correlation was observed between lead and chromium ($r = 0.761$) and manganese ($r = 0.818$). Positive correlation was also observed between chromium and manganese ($r = 0.919$), chromium and nickel ($r = 0.573$), and between nickel and manganese ($r = 0.663$). The correlations between lead and manganese and, between chromium and manganese were statistically significant at 99% confidence level. The correlation between lead and chromium was significant at 95% confidence levels.

The estimated daily metal intake expressed as per unit body weight (mg/kg b.w. /day) calculated for carrots root from each of the three sampling station and the control is presented in table 3.

Table 3. *Estimated daily metal intake (mg/kg b.w. /day except otherwise stated) across sampling locations.*

Element	Lead	Chromium	Nickel	Manganese
Sampling Station 1	5.77	6.69	11.88	0.57
Sampling Station 2	5.94	7.09	26.40	6.63
Sampling Station 3	6.29	12.11	26.62	8.34
Average	6.00	8.65	21.63	5.18
River Kubanni (control)	3.06	2.69	4.00	3.09
UL (mg/ day)	0.240	130 µg/day	3-7	11.00 µg/day
RDI (mg/ day)	0.00	0.003-1.5	0.500	2.3 (1.8)

Figures in brackets () indicate the RDI for females

Table 3 revealed that the estimated daily metal intake from the consumption of carrots root from River Galma Basin around Dakace industrial area ranged from: 5.77 to 6.92 for lead, 6.69 to 12.11 for chromium, 11.88 to 26.62 for nickel and 0.57 to 8.34 for manganese.

The Target Hazard Quotient computed for the metals under study as presented in Table 4 revealed a range of 1.65 – 1.77, 0.004 – 0.008, 0.60 – 1.33, and 0.04 – 0.06 for lead, chromium, nickel and manganese respectively.

Table 4. *Target Hazard Quotient (THQ) of metals in Carrots root from River Galma Basin.*

Element	Lead	Chromium	Nickel	Manganese
Sampling Station 1	1.65	0.004	0.60	0.04
Sampling Station 2	1.68	0.005	1.32	0.05
Sampling Station 3	1.77	0.008	1.33	0.06
Average	1.7	0.006	1.08	0.05
River Kubanni (control)	0.87	0.002	0.2	0.02

3. Discussion of Results

Lead, chromium, nickel and manganese content of edible Carrots *roots* across sampling stations (Table 2) in the study area followed the order: sampling station 3 > sampling station 2 > sampling station 1. The order of these metals in soil and water used for irrigation was found to follow the same sequence (Udiba *et al*., 2014a; Udiba *et al*., 2014b; Udiba *et al*., 2015) suggesting uptake of the metals from the soil and water may be responsible for their presence at the concentration determined. The fact that no statistically significant (ANOVA, $P > 0.05$) difference was observed in metals level (chromium and nickel being the only exception) across the three sampling stations reflects the fact no significant difference in metals level across the sampling stations was displayed in growth medium (soil and water) as reported by Udiba *et al*., (2014a), Udiba *et al*., (2014b) and Udiba *et al*., (2015). The lowest concentration of each metal in the study was recorded in the month of November and the highest concentration in January. This observation could be explained on the basis of the water used for irrigation. The volume of water in River Galma used for irrigation was observed to decrease as the dry season progressed. The concentration of the contaminants in the water increases as the volume decreases. The use of a more concentrated water at the peak of the dry season for irrigation resulted to higher uptake by the plant. Metal content of edible carrots *roots* from River Galma basin was found to be higher than those from River Kubanni basin. The observation also followed the order of the metals concentrations in soil and water reported by Udiba *et al*., (2014a), Udiba *et al*., (2014b) and Udiba *et al*., (2015). Kubanni River originates in the precincts of the Ahmadu Bello University (ABU) Main Campus, Zaria (Northern Nigeria), as a trench in an undulating agricultural land and is fed by a number of tributaries (Uzairu *et al*., 2009). Kubanni River drains the northwest zone of the city of Zaria and receives effluents mainly from domestic activity and runoff from intense cropping in the adjoining land. On the other hand, River Galma basin around Dakace industrial layout receives untreated effluents from industries in addition to agricultural waste from heavily cultivated basin and domestic waste from communities along its course. The results of this study suggest possible adverse influence of Dakace industrial layout on the heavy metal status of the study area. It also indicates that crop grown in areas with less input of metals from anthropogenic sources accumulates lower amounts of the contaminants. The soil and water chemistry as well as the specie and age of plants play significant roles in the uptake of metals by plants. The order of detection of the metals was nickel > chromium > manganese > Lead. The significant positive correlation observed between lead and manganese ($p < 0.01$; $r = 0.818$), between chromium and manganese ($p < 0.01$; $r = 0.919$), and between lead and chromium ($p < 0.01$; $r = 0.761$) indicates that increase in lead contents of carrots from the study area is associated with increase in chromium and manganese content of the vegetable and that increase in chromium levels is also associated with increase in manganese levels suggesting same source may be responsible for the presence of the metals at the concentrations determined. The mean lead levels of edible carrots *roots* from the study area (1.05±0.5 mg/kg), was found to be higher than WHO/FAO limit of 0.3 mg/kg for lead in edible vegetable. Consuming carrots from the study area therefore poses toxicological risk. Lead concentration of edible carrot *roots* in the study was found to be lower than 41.6 - 84.6 mg/kg reported for carrots grown on peri-urban area of Lahore district of India (Ajmal *et al*., 2013). A range of 0.50 - 3.10 mg/kg with mean of value 1.61 mg/kg was reported for carrots from Baia Mare area, North-Western Romania (Miclean *et al*., 2000). Lead is one of the limited classes of element that can be described as purely toxic. Most other elements though toxic at high concentration are actually required nutrients at lower levels (Udiba *et al*., 2012 a). There is no exposure level below which lead appear to be safe. Lead is number 2 in the Agency for Toxic Substances and Disease Registry (ATSDR) Top 20 list, and account for most of the cases of pediatric heavy metal poisoning. It interferes with the normal development of a child's brain and nervous system; therefore children are at greater risk of lead toxicity. The effect on peripheral nervous system on the other hand, is more pronounced in adults. Lead absorption constitutes serious risk to public health. It induces reduced cognitive development and intellectual performance in children, increased blood pressure, and cardiovascular diseases in adult as well as liver and kidney dysfunction (Udiba *et al*., 2012a).

The mean chromium concentration (1.52±0.9 mg/kg) of edible carrots roots from River Galma basin was found to be higher than the WHO/FAO safe limit of 0.5 mg/kg for chromium in edible vegetable. Chromium levels in edible carrots *roots* recorded in this study were lower when compared to 13.9-35.8 mg/kg range reported for carrots grown on peri-urban area of Lahore district India by Ajmal *et al.,* (2013). Consuming carrots from the study area poses serious toxicological risk of chromium intoxication. Among the heavy metals, chromium is of great concern due to its high uptake rates in plants. It accumulates in plan's *roots* and the possibility of causing serious health problems is associated with the consumption of the heavy metal contaminated vegetable over a long period. Chromium is a toxic human carcinogen that causes or increases the rate of cancer; ingestion of high concentration often results in lung function and blood system problems, gastrointestinal burns, hemorrhage, generalized oedema, pulmonary oedema, liver damage and kidney damage. Symptoms are diarrhea, abdominal pain, indigestion and vomiting. Death may be the result of pulmonary or cardiac arrest. Skin contact causes a number of skin problems including rashes and sores (Udiba *et al.,* 2012b).

The mean nickel concentration (3.74±1.89 mg/kg) of edible carrots *roots* from River Galma basin was found to be lower than 67 mg/kg which is the WHO/FAO allowable limit for nickel in edible vegetable indicating that the carrots cultivated in River Galma basin is fit for consumption and does not pose any toxicological risk to public health with respect to nickel intoxication (Compare with literature). Small amount of nickel is needed by the human body to produce red blood cells, however, when the concentration exceeds a certain threshold, can cause decreased body weight, heart and liver damage, thyroid disease, cancer and skin irritation (Udiba *et al.,* 2012b). Other toxic effects of nickel observed following chronic exposure including bronchitis, emplysema, reduced vital capacity and asthma.

The overall mean concentration of manganese (1.21±2.22 mg/kg) in edible carrots *roots* from River Galma was found to be considerably lower than WHO/FAO standard of 200 mg/kg and as such safe for human consumption. A range of 50-125 mg/kg was reported for irrigated carrots grown on peri-urban area of Lahore, India (Ajmal, 2013) and 12.0-69.0 mg/kg for carrots irrigated with wastewater from different sources (Arora *et al*., 2008). These concentrations were found to be higher than the concentrations recorded in this study. Manganese toxicity may result in multiple neurological problems (Keen *et al*, 2001). The effects of early exposure may not appear until many years later. In its worst form, manganese toxicity can result in a permanent neurological disorder with symptoms similar to those of Parkinson's disease, including tremors, difficulty in walking and facial muscle spasms (udiba *et al*., 2012b).

3.1. Estimated Daily Intake (EDI)

In order to assess the health risk of any pollutant, it is absolutely necessary to estimate the level of exposure. One very significant aspect of such estimation is by the evaluation of the daily intake. The estimated daily intake (EDI) of heavy metals is widely used to describe safe levels of metallic intake through food consumed (Udiba *et al*., 2015; Querra *et al*., 2012; Lanre-Iyanda and Adekunle, 2012). It also combines data on the levels of heavy metals in foodstuff with quantities of food consumed on the daily basis (Querra *et al*., 2012). The EDI thus depend on both the metal concentration in edible portion of the food crops and the amount of the food crop consumed. In this study, the approximate daily lead, chromium, nickel and manganese intake for people living in Zaria and its environs through the consumption of edible carrots roots cultivated along River Galma basin around Dakace industrial area estimated were compared with the recommended daily intakes/or allowances and the upper tolerable daily intakes for the metals (UL) (Table 3). Tolerable Daily Intake (TDI) is an estimate of the amount of elements in air, food or drinking water that can be taken in daily over a lifetime without appreciable health risk. The average values of the estimated daily intake for lead, chromium, nickel and manganese were all above the recommended daily intakes for the metals (Table 3). The average values of the estimated daily intake for metals under study were also found to be above the upper tolerable daily intakes for the metals (UL) (Table 3). The estimated daily metal intake computed in this study were expressed per kilogram body weight (mg/kg b.w. /day) so that for an average adult of 70kg body weight, the average value of EDI of say manganese is equivalent to 9.58 multiplied by 70 which is equal to 670.6 mg per day. The results obtained from the estimation of daily intake (EDI) of lead, chromium, nickel and manganese in the study clearly implies that the perennial intake of edible carrots roots harvested from River Galma Basin around Dakace industrial layout is likely to induce serious adverse health effects.

3.2. Target Hazard Quotients (THQ)

Risk to human health by the intake of metal-contaminated edible carrots roots was also characterized using Target Hazard Quotient (THQ). THQ is the ratio between exposure and the reference oral dose (RfD). When the ratio is lower than one (1), there is no obvious risk. THQ-based risk assessment method indeed provides an indication of the risk level due to exposure to pollutants (Chary *et al*., 2008 cited in Querra *et al*., 2012). THQ method employed in this study considered only exposure to the selected heavy metals through consumption of edible carrots roots, without taking into account other exposure routes like dermal contact, soil ingestion, and other factors such as the presence of agrochemicals and herbicide molecules. The average THQs for individual metals across the study area were all below 1.00, lead (Pb) being the only exception. Table 3 shows that the THQ for lead across the three sampling stations were all above 1.00 with the highest value recorded at sampling station 3. THQ for nickel at sampling station 2 and 3 were also found to be above 1.00. THQ-based risk assessment in this study thus indicates that, the consumption of edible carrots roots from the study area poses serious toxicological risk with respect to lead and nickel intoxication.

3.3. Hazard Index (HI)

To evaluate the potential risk to human health through more than one heavy metal, the hazard index (HI) has been developed (US EPA, 1989 cited in Querra *et al*., 2012). It assumes that the magnitude of the adverse effect will be proportional to the sum of multiple metal exposures. It also assumes similar working mechanisms that linearly affect the target organs (Querra *et al*., 2012). There is serious concern for potential health effects when the Hazard Index is greater than 1. Even though there was no apparent risk when each metal was analyzed individually, the potential risk could be multiplied when all metals are considered together. The hazard index for a typical adult of body weight 70 kg considered in this study was found to be 2.84. The relative contributions of Pb, Cr, Ni, and Mn to the aggregated risk were 59.86%, 0.21%, 38.03% and 1.76% respectively. Consumption of edible carrots roots from the study area therefore poses serious course for concern.

4. Conclusion

Carrots are credited with many nutritional and medicinal properties. Despite the enormous benefits of this important root crop, the findings of this study reveal that Carrots cultivated along River Galma basin round Dakace industrial area has lead and chromium concentrations above WHO/FAO standards for consumed vegetables. The average values of the estimated daily metal intake were all above recommended daily intakes and upper tolerable daily intakes for the metals. The average THQs for lead and nickel across the study area were above 1.00. The hazard index for a typical adult of body weight 70 kg computed was found to be 2.84. The relative contributions of Pb, Cr, Ni, and Mn to the aggregated risk were 59.86%, 0.21%, 3.0% and 1.76% respectively. It was therefore concluded that consumption of edible carrots roots from the study area poses serious toxicological risk. Average values of the contaminants in the study area were found to be significantly ($p < 0.05$) higher than the control suggesting that the industrial estate exerts a significant adverse impact on the environment.

References

[1] Abida, B., Ramaiah, M., Harikrishna, Khan I. and Veena, K. (2009). Analysis of Heavy Metals concentration in Soil and Lichens from various Localities of Hosur Road, Bangalore, India *Journal of Chemistry*6 (1) 13 – 22.

[2] Addo M. A., Darko, E. O., Gordon, C., Nyarko B. J. B. (2013), *e-Journal of Science & Technology, 3 (8), 71-83*.

[3] Ajmal, K., Javed, S., Muhmood, A., Tahir, M., Naiz, A., and Abdul, M. (2013). Heavy Metal Status of Soil and Vegetables Grown on Peri Urban area of Lahore District. *Soil Environ* 32 (1): 49-54.

[4] Arai S (2002). Global view on functional foods: Asian perspectives. Brit. J. Nutr. 88: pp.139-143.

[5] Arora, M.; Kiran, B,; Rani, A.; Kaur B. and Mittal, N. (2008). Heavy Metal Accumulation in Vegetables irrigated with water from different sources, *Food Cheem.*, 111: 811-815.

[6] Awofolu, O. R. (2005). A Survey of trace metals in vegetation, soil and lower animals along some selected major roads in Metropolitan City of Lagos. *Environmental Monitoring and Assessment*, *105*, 431-447.

[7] Bello, A. L. (1973). The Morphology of an Erosional Scarp, South of Ahmadu Bello University, Zaria. Unpublished B. A Dissertation, Department of Geography, ABU, Zaria.

[8] Benjamin, L. R. Mc Garry A and Gray D. (1997), "The vegetables, beets, carrots, parsnips and tumips" *The physiology of vegetable crops, Wallingford, UK, CAB, international, 553-580*

[9] Chary, N. S.; Kamala, C. T.; Raj, D. S. S. 2008. Assessing risk of heavy metals from consuming food grown on sewage irrigated soils and food chain transfer. Ecotoxicology and Environmental Safety 69: 513-24.

[10] Davis D. R., Epp M. D., and Riodan H. D., (2004) Changes in USDA food composition data for 43 garden crops, 1950 to 1999. *Journal of the American College of Nutrition,* 23 (6): 669-82.

[11] Davis, D. R. (*2006*) *Commentary on: 'Historical variation in the mineral composition of edible horticultural products'* J. Hort. Sci. Biotechnol. *81*: *553–554*.

[12] Ekholm, P., Reinivuo, H., Mattila, P., Pakkala, H., Koponen, J., Happonen, A., Hellström, J., Ovaskainen, M.-L. *(2007) Changes in the mineral and trace element contents of cereals, fruits and vegetables in Finland. J. Food Compos. Anal. 20: 487–495.*

[13] Ghimire SK (1994). Evaluation of industrial effluents toxicity in seed germination and seedling growth of some vegetables, M. Sc. Dissertation, Central Department of Botany Tribhuvan University, Kirtipur, Kathmandu, Nepal.

[14] Iguisi, E. O. (1996). "Variation of Soil loss in two Sub-basin near Zaria, Nigeria.: Unpublished Ph.D Thesis, Department of Geography, ABU, Zaria.

[15] Jarup L (2003). Hazards of heavy metal contamination. Br. Med. Bull., 68: pp.167–182.

[16] Keen, C. L., (2001), Manganese As Essential And Possibly Toxic Mineral, Linus Pauling Institute, Oregun, *lpi@oregonstate. Edu.*

[17] Lanre-Iyanda T. Y. and Adekunle, I. M. (2012). " Assessment of heavy metals and their estimated daily intakes from two commonly consumed foods (Kulikuli And Robo) found In Nigeria", African J. Food, Nutrition and Development, Vol. 3, No. 12, 6157-6169

[18] Lugwisha Esther Hellen, Othman Chande Othman (2014). Levels of Selected Heavy Metals in Soil, Tomatoes and Selected Vegetables from Lushoto District-Tanzania. *International Journal of Environmental Monitoring and Analysis.* 2 (6), 313-319.

[19] Miclean M., Roman, C., Levei, E., Senila, M., Abraham, B. & Cordos, E. (2000). *Heavy metals availability for plants in a mining area from North-Western Romania*. Romania: INCDO-INOE press.

[20] Monu, A., Bala, K., Shweta, R., Anchal, R., Barinder, K., Neeraj, M. (2008): Heavy metal accumulation in vegetables irrigated with water from different sources. *Food Chemistry* 111: 811–815

[21] Mukerji KG (2004). Fruit and vegetable diseases. Hingham, MA, USA: Kluwer Academic. Pp. 145.

[22] Nnaji C. J., Uzairu A., Harrison G. F. S. and Balarabe M. L. (2011). Effect of Pollution on the Physico-Chemical Parameters of Water and Sediments of River Galma, Zaria, Nigeria. Research *Journal of Environmental and Earth Sciences 3 (4): 314-320*

[23] Nnaji, J. C., Uzairu, A, Harrison, G. F. S. And Balarabe, M. L., (2007) Evaluation of Cadmium, Chromium, Copper, Lead And Zinc Concentrations in the Fish Head/Viscera of Oreochromis Niloticus and Synodontis Schall of River Galma, Zaria, Nigeria, *Ejeafche, 6 (10), 2007.* 2420-2426

[24] Noontny J A., Dueker, S. R, Zech LA, Cliford A. J, (1995). Compartmental analysis of the Dynamics of B- carotene metabolism in an adult volunteer. Journal of Lipids Research 36 (8), 1825-1838

[25] Ogle BM, Hung PH, Tuyet TT (2001). Significance of wild vegetables in micronutrient intakes of women in Vietnam: An analysis of food variety. Asia. Pacific. J. Clinic. Nutr. 10: pp. 21-30.

[26] Ologe, K. O. (1971). Gully Development in the Zaria Area, Northern Nigeria (with particular reference to the Kubanni Basin). Unpublished Ph.D Thesis University of Liverpool.

[27] Pandey, J., and Pandey, U., Accumulation of heavy metals in dietary vegetables and cultivated soil horizon in organic farming system in relation to atmospheric deposition in a seasonally dry tropical region of India. *Environ. Monit. Assess.* 148, 2009, p. 61-74.

[28] Querra F, Trevizam A, R., Muraoka3 T., Marcante N. C. Canniatti-Brazaca, S. G (2012), Heavy metals in vegetables and potential risk for human health. Sci. Agric. 69 (1), 54-60.

[29] Rodriguez-Concepcion M. and Stange C. (2013). Biosynthesis of carotenoids in carrot: An underground story comes to light, *Archives of Biochemistry and Biophysics* 539, 110–116).

[30] Sharma RK, Agrawal A., Mrshal FM (2009). Heavy metals in vegetable collected from production and market sites of a tropical urban area of india. Chem Toxicl. 47 (3), 582.

[31] Smith CJ, Hopmans P, Cook FJ (1996). Accumulation of Cr, Pb, Cu, Ni Zn and Cd in soil following irrigation with untreated urban effluents in Austriala. Environmental Pollution. 94 (3): pp. 317-323.

[32] Strube, M and OverDragsted L (1999), Naturally Occurring Antitumoungens *iv* carotenoids except B-carotene, Copenhagen: Nordic Council of Ministers, 48.

[33] Szabo1 G. and Czellérm K, (2009), Examination Of The Heavy Metal Uptake Of Carrot (*Daucus Carota*) In Different Soil Types, AGD Landscape and Environment 3 (2) 2009. 56-70.]

[34] Thorp, M. B. (1970). Landforms of Zaria in Mortomire, M. J. (ed) Zaria and its Region Occasional Paper 4, Department of Geography, ABU, Zaria.

[35] Trichopoulos D (1997). Epidemiology of cancer. In: DeVita, V. T. (Ed.), Cancer, Principles and Practice of Oncology. Lippincott Company, Philadelphia, WHO (1992). Cadmium. Environmental Health Criteria, Geneva 134: pp. 231-258.

[36] U.S. Department of Agriculture (*2008a*) *Vegetables and melons yearbook* (*U.S. Dept. Agr*, *Washington, DC*) *Tables 5 and 6*, *<http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1212>. 18 Sept. 2008*.

[37] U.S. Environmental Protection Agency [US EPA]. 1989. Risk Assessment Guidance for Superfund: Human Health Evaluation Manual [Part A]: Interim Final. U.S. Environmental Protection Agency, Washington, DC, USA [EPA/540/1-89/002].

[38] U.S. Environmental Protection Agency [US EPA]. 2010. Integrated risk information system. Available at: http://cfpub.epa.gov/ncea/iris/compare.cfm. retrieved Jan. 08, 2010.

[39] Udiba U. U., Anyanwu Stella, Gauje Balli, Dawaki S. I., Oddy-Obi I. C., Agboun T. D. T. (2015), Toxicity potential of *Allium cepa L.* as a bioindicator of Heavy Metal Pollution status of River Galma Basin around Dakace Industrial Layout, Zaria, Nigeria. International Journal of Biological Sciences and Applications (in press).

[40] Udiba U. U., Gauje Balli, Ashade N. O., Ade-Ajayi F. A., Okezie V. C., Aji B. M., Abashe H (2014). An Assessment of the Heavy Metal Status of River Galma around Dakace Industrial Layout, Zaria, Nigeria. *Merit Research Journal of Environmental Science and Toxicology,* 2 (8): 176-184.

[41] Udiba U. U., Inuwa Bashir, Akpan N. S., Ezike N. N., Zuru S. B., Anyanwu S. E., Saleh A. M (2014). The Influence of Industrial Effluents from Dakace Industrial Area on the Heavy Metal profile of River Galma, Zaria, Nigeria. *Advances in Applied Science Research,* 5 (6): 165-17.

[42] Udiba U. U., Ogabiela, E. E., Hammuel, C., Magomya, A. M., Yebpella, G. G., Ade-Ajayi, A. F., Odey, M. O. & Gauje, B. (2012a). Post Remediation Assessment of Contaminants Levels in Soil, Dareta Village, Zamfara, Nigeria. *Journal of Trends in Advanced Science and Engineering,* TASE 4 (1), 70-79.

[43] Udiba, U. U., Ogabiela E. E., C. Hammuel, Ade-Ajayi A. F., Odey M. O., Yusuf U., Abdullahi M., Gauje Bali,(2012b), Assessment Of Some Environmental Pollutants In Soil, Dareta Village, Zamfara, Nigeria, *Journal of Trends in Advanced Science and Engineering,* TASE 5 (1) pp 27-37.

[44] Uzairu A., Harrison, G. F. S., Balarabe, M. L. & Nnaji, J. C. (2009). Concentration Levels Of Trace Metals In Fish And Sediment From Kubanni River, Northern Nigeria. *Bull. Chem. Soc. Ethiop.* 23 (1), 9-17.

[45] World Health Organization [WHO]. 1993. Evaluation of Certain Food Additives and Contaminants. In: Forty-First Report of the Joint FAO/WHO Expert Committee on Food Additives, WHO, Geneva, Switzerland. (WHO Technical Series, 837).