Heavy Metal Content in Vegetables from an Irrigated Farmland in Kaduna Metropolis, Nigeria.

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ABSTRACT

A total of 17 vegetable samples were collected; 7 pumpkin leaves **(***Telferia occidentalis***)**, 6 bitter leaves *(Vernonia amygdalina*) and 4 pumpkin leave from control site. Concentration ranges of pumpkin leaves were 0.1-0.30 mg/kg, 1.5-6.20 mg/kg, 1.3-3.10 mg/kg, 4.0-15.30 mg/kg and 4.1-10.20 mg/kg dry weight for Cd, Cr, Cu, Pb and Zn respectively while for bitter leave the concentration ranges from 0.3-1.00 mg/kg, 2.0-9.50 mg/kg, 0.8-3.40 mg/kg, 4.4-7.50 mg/kg and 5.8-12.70 mg/kg dry weight for Cd, Cr, Cu, Pb and Zn respectively. The mean concentrations of pumpkin leave samples studied were found to follow the decreasing orders; Pb > Zn > Cr > Cu > Cd respectively. However, for bitter leave the mean concentration decreases in this order; Zn, Pb, Cr, Cu and Cd. There is correlation between some metals in both vegetable samples. The concentrations of heavy metals are within tolerable levels except Pb in pumpkin leaves that have values which are higher than the WHO/EU recommended values. The slightly high level of Pb in the pumpkin vegetable could be attributed to deposits of the metal from vehicle emissions.

Key words: Heavy metals; leafy vegetables; irrigated farmlands;

Introduction

The problem of environmental pollution due to heavy metals is causing a lot of concern in most major urban and rural cities. The heavy metals entering the ecosystem may lead to geoaccumulation, bioaccumulation and biomagnifications [1].The contamination of food chain by heavy metals has become an issue of interest in recent years 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 are taken up by the roots or foliage. The term heavy metal refers to any metallic chemical element that has a relatively high density and is toxic or poisonous at low concentrations. Examples of heavy metals include Mercury (Hg), Cadmium (Cd), Arsenic (As), Chromium (Cr), Thallium (Tl), and Lead (Pb). Heavy metals like Cr, Cu, Zn, and other trace elements are important for proper functioning of biological systems and their deficiency or excess could lead to a number of disorders [2]

The metal, cadmium is well known for its toxico-logical effects [3]. Cd is not essential for plant growth but it's rather toxic to it; a concentration of 6mgL^{-1} Cd or higher are lethal to E. coli cells [4]. Effect of Cd toxicity in plants include; leaf discoloration and necrosis, reduction in growth and wilting. For animals and humans, food is the major source of Cd intake for non-occupationally exposed people and the principal food sources of cadmium are grains (i.e. wheat and rice), potatoes, marine molluscs and crustaceans [5].

Chromium is a micronutrient, which is essential for carbohydrate metabolism in animals. Introduction of chromium into animal's feeds could lead to its bioaccumulation in meat by-products such as skin bone and meat meals, and finally into soils and crops fertilized with animal manure and finally into humans through food chain [6].

Copper content of normal plant tissues varies according to species but is usually within the range 1-25 mg/Kg dry matter [7]. It is toxic to man at concentration of 250 mg/day. In soils copper reduces the enzymatic activities and it is particularly toxic to lower organism and has been used as an algaecide in lakes [8].

Lead is toxic to plants at concentration range of 3-20 ppm depending on plant species, to animals at a concentration of 1 mg/day, and human at 10 g/day [8]. Accurate and adequate food composition data are invaluable for estimating the adequacy of intakes of essential nutrients and assessing exposure risks from intake of toxic non essential elements [9].

Zinc is an essential element involved in metabolic functions, and is important for both man and plant health growth [10]. Although, sludge treatment usually results in elevated zinc levels, plants do not accumulate zinc to a degree that would be toxic to animals or humans [10]. The zinc content of normal plant tissues varies according to species, but, it is usually within the range of 5-300 mg/kg dry matter [7].

Vegetables constitute essential diet components by contributing protein, vitamins, iron, calcium and other nutrients, which are usually in short supply [11]. They also act as buffering agents for acidic substances produced during the digestion process. However, they contain both essential and toxic elements over a wide range of concentrations. Metal accumulation in vegetables may pose a direct threat to human health [12]. Vegetables take up metals by absorbing them from contaminated soils, as well as from deposits on different parts of the vegetables exposed to the air since vegetable growing areas are often situated in, or near sources of atmospheric deposits, and thus have an elevated risk of potential contamination from polluted environments [13]. Furthermore, studies have shown that vegetables, especially leafy crops grown in heavy metals contaminated soils are likely to have higher concentrations of heavy metals than those grown in uncontaminated soil [14], [15].

Farming through irrigation is generally practiced in the Northern part of Nigeria, especially in Kaduna State this could be attributed to the fact that there is always less rainfall in the Northern part compared to the Southern part of the Country. Fruits and vegetables are usually grown by irrigation where there is a source of water mostly at the bank of rivers. Vegetables mostly grown by irrigation are spinach, tomatoes, onion, pepper, pumpkin and bitter leaf. It is therefore necessary for a better understanding of heavy metal sources, their accumulation in the soil and the effect of their presence in water and soil on plant systems. The aim of this work therefore, is to determine the content of heavy metals in vegetables from a suspected contaminated site of irrigated farmlands around Barnawa area in Kaduna City.

Description of Study Area

Kaduna metropolis (Lat. 10.52_N, Long. 7.44_E) located in Kaduna state occupies central portion of Northern Nigeria [16]. Founded in 1917 as an administrative headquarters of Northern Nigeria, it is presently one of the most important cities in the country. As at 1991 census it had a population of 993,600 but projected to be about 1.56 million people [17].

Experimental

Materials and Methods

All the chemicals used for this work were of analytical grades obtained from BDH England. Double distilled water was used throughout the work. All glass wares used were soaked in 10 % HNO_3 over night and then washed with detergent, thoroughly rinsed with tap water and then with double distilled water.

Sampling Sites

The research was carried out on bitter leaf and pumpkin samples collected from irrigated farmlands in Barnawa around Kaduna metropolis between the months of June and July 2010. The sampling site was close to a source of water.

Sample Pre-Treatment

The vegetable samples were all collected in clean polythene bags and transported to the laboratory for further processing. The pumpkin and bitter leaf samples were cut into nearly uniform sizes. This was done to facilitate drying of the pieces at the same rate. The cut pieces were placed in clean acid-washed porcelain crucibles and labelled accordingly. The samples were oven-dried at 105°C for 24 hours until they were brittle and crispy. At this stage no micro-organisms can grow on it. The dried vegetable samples were grounded into fine particles using washed porcelain mortar and pestle. The powdered samples were placed in labelled Petri dishes and dried to constant weight in desiccators until they were digested. The same pre-treatment as mentioned above was carried out on the control samples.

Digestion of Vegetable Samples

0.5 g of dried sieved leave samples were weighed into 100 ml beaker. A mixture of 5ml concentrated trioxonitrate (IV) acid and 2ml of concentrated perchloric acid was added along with few boiling chips and this was digested at low heat using hot plate until close to dryness. The digested samples were allowed to cool, filtered into 50 ml standard flask using Whatman (110) filter paper and made up to the mark with 0.5M HNO_3. Triplicate digestion of each sample was carried out together with a blank digest which was incorporated in every batch of 5 triplicate samples. The blank was prepared using the same procedure as above with an exception of the samples [18].

Analysis of Vegetable Samples

Appropriate working standards were prepared for each of the metal solution by serial dilution of the stock solutions. Each of the sets of serial dilutions was then aspirated one after the other into the Atomic Absorption Spectrometry and their absorbance recorded.

The sample solutions were also aspirated one after the other and the absorbance recorded. Calibration curves were plotted for each of the trace metals standard using absorbance against concentrations (ppm) and the actual concentration of the metal extrapolated from the curves.

RESULTS AND DISCUSSIONS

The concentration of heavy metals in the two leafy vegetables studied is presented on Table 1 while the ranges is shown on Table 2 with pumpkin leaves having ranges of Cd (0.10- 0.30 mg/kg), Cr (1.5-6.20 mg/kg), Cu (1.3-3.10 mgkg), Pb (4.0-15.3 mg/kg) and Zn (4.1-10.20 mg/kg) and the mean concentration values of pumpkin leaves from the irrigated farmlands are Cd (0.16±0.09 mg/kg), Cr (3.14±1.98 mg/kg), Cu (2.06±0.57 mg/kg), Pb (7.47±3.99 mg/kg) and Zn (6.66±2.10 mg/kg). Furthermore, the concentration ranges of bitter leaves from the site had ranges of Cd (0.30- 1.00 mg/kg), Cr (2.0-9.50 mg/kg), Cu (0.8-3.40 mgkg), Pb (4.40-7.50 mg/kg) and Zn (5.8-12.70 mg/kg) and the mean concentration values of bitter leaves from the irrigated farmlands are Cd (0.52±0.29 mg/kg), Cr (5.22±3.27mg/kg), Cu (1.88±1.09 mgkg), Pb (6.08±1.08 mg/kg) and Zn (8.60±2.68 mg/kg). Levels of Cd obtained in this study for both leafy vegetables were lower than the than those reported by [19], [12] respectively. When further compared to other studies the concentration ranges of both leafy vegetables were lower and higher than 0.15 – 0.60mg/kg and 0.01 – 0.03mg/kg reported by [20], [21] respectively. Bitter leaf had higher level of Cd than pumpkin leaf while values of Cr in both vegetables were higher than that reported by [20]. The highest total mean concentration of Cr (7.87mg/kg) reported by [23] is higher than the mean concentration values found in both vegetables of this study. Furthermore, the mean values of Cr in both leafy vegetables were lower than the reported value of 6.4mg/kg by [20] but exceeded the 0.1mg/kg limits set by [24] but lower than world average of 100mg/kg reported by [25]. Bitter leaf had higher level of Cr than pumpkin leaf; this could be attributed to the possibility of bitter-leaf absorbing more of Cr from the soil than pumpkin leaf.

The values of Pb in both leafy vegetables are higher than the values of 3.24 and 1.20 reported by [26], [22] respectively in a similar study. The maximum concentration of Pb in leafy vegetables is much lower than the highest values of 42.00mgkg^{-1} reported by [20] and 375.0mg/ kg reported by [27] but higher than 0.015mg/kg reported by [5], the value is however close to 10mg/kg reported by [25].

Furthermore, the mean value of Pb is lower than that reported in plant samples analyzed by [28] in their study around battery factory in Nigeria. Although, pumpkin had higher level of Pb than that of bitter leaf, this could be attributed to the fact that the pumpkin leaves are closer to the road and as such much Pb particles were deposited on the leaves.

Table 1: Total Metal Contents (mg/kg) in Vegetables of Irrigated Farmland in Kaduna

Samples	Cd	Cr	Cu	Pb	Zn
Pumpkin leaf					
P1.	0.1	2.0	1.7	4.0	4.5
P2.	ND	1.5	1.3	4.0	6.9
P3.	0.2	3.5	2.2	5.2	7.2
P4.	0.1	5.5	3.1	8.2	7.9
P5.	0.3	6.2	1.9	9.3	10.2
P6.	0.1	1.5	2.3	6.3	5.8
P7.	ND	1.8	1.9	15.3	4.1
Bitter-leaf					
B1.	0.5	2.0	3.4	7.5	7.4
B2.	0.3	2.0	2.6	6.4	12.7
B3.	1.0	4.0	0.8	5.5	5.8
B4.	0.5	5.0	2.5	5.9	6.0
B5.	ND	8.8	0.9	6.8	9.9
B6.	0.3	9.5	1.1	4.4	9.8
Control Samples					
C1.	ND	0.6	0.1	2.5	3.3
C2.	0.1	2.5	0.3	3.9	4.0
C3.	ND	3.5	0.2	0.5	5.5
C4.	ND	3.0	0.1	0.8	4.0

ND = Not Detected, P = Pumpkin leaf, B = Bitter-leaf, Control Samples

Generally, Pb content was within the permissible limits given by [29], although higher than [24] limits. The high level of Pb in this study could be attributed to Pb batteries as waste dumped in the river which is subsequently used to irrigate the farmlands as well as deposits from vehicle exhaust. Although, the mean values of Cd, Cu, Pb and Zn are lower than the values of Cd 0.59±0.44 mg/kg, Cu 11±6 mg/kg, Pb 8±3 mg/kg and Zn 40±20 mg/kg reported by [30]. The concentration ranges of Cd, Cr and Pb in vegetables of this study are lower than the minimum and higher than the maximum concentration ranges of Cd, Cr and Pb reported by [23] in their study. However, the mean concentration values of 4.10±2.75 mg/kg Cr, 1.98±0.81 mg/kg Cu, 6.44±1.76 mg/kg Pb and 7.55±2.49 mg/kg Zn respectively in both leafy vegetables are higher than that reported by [31] in all the varieties of leafy vegetables studied. Furthermore, the concentration values of Cr, Pb and Zn are higher than the values of 0.005-0.4320 mg/kg Cr, 0.017-0.029 mg/kg Pb and 0.356-0.550 mg/kg Zn reported by [32] in a similar study. The value of Zn in bitter leaf was higher than that in pumpkin. In comparison to standard limits, mean concentration of Cd in the leaves revealed values below the limits of [24], [29], [33].

Generally, the levels of Cd, Cr, Cu, Pb and Zn showed higher levels at the study area than those of the control samples which suggests that the investigated vegetables of study areas were slightly contaminated by these metals. Cd Cr and Zn showed higher levels in bitter leaves than pumpkin leaves this could be that the absorption rate of these metals by bitter leaf is higher than that of pumpkin leaf. Pumpkin had higher level of Pb than that of bitter leaf, this could be attributed to the fact that the pumpkin leaves were closer to the road and as such much Pb particles were deposited on the leaves. With Cu, almost similar ranges were observed in both vegetables. This could be that the absorption rate of Cu by both vegetables is similar.

The toxic doses of Cr and Pb to plants are 0.5-10mg/kg and 3-20mg/kg respectively while the toxic levels to man are Cr 200mg/kg and Pb 1.00mg/day [34].

Table 2: Summary of Total Metal Contents in Vegetables (mg/kg) of Irrigated Farmland in Kaduna

	Cd	Cr	Cu	Pb	Zn
Pumpkin Samples					
Mean	1.16	3.14	2.06	7.47	6.66
Median	0.10	2.00	1.90	6.30	6.90
SD*	0.09	1.98	0.57	3.99	2.10
Min	0.10	1.50	1.30	4.00	4.10
Max	0.30	6.20	3.10	15.30	10.20
Bitter-leaf Samples					
Mean	0.52	5.22	1.88	6.08	8.60
Median	0.50	4.50	1.18	6.15	8.60
SD*	0.29	3.27	1.09	1.08	2.68
Min	0.30	2.00	0.80	4.40	5.80
Max	1.00	9.50	3.40	7.50	12.70
Control Samples					
Mean	0.10	2.40	0.18	1.93	4.20
Median	0.10	2.75	0.15	1.65	4.00
SD*	0.00	1.27	0.10	1.58	0.93
Min	0.00	0.60	0.10	0.50	3.30
Max	0.10	3.50	0.30	3.90	5.50

SD* = Standard Deviation

Table 3 shows the correlation analysis results between heavy metals in both pumpkin leaf and bitter leaf plants. There was positive and significant correlation of Cd with Cr, Pb and Zn; positive and significant correlation of Cu with Cr and Pb. Furthermore, Cr correlated with Pb and Zn implying that these metals have the same source(s) in the pumpkin vegetables. In the bitter-leaves, there was negative correlation between Cd and all the other metals studied. Furthermore, Cu correlated positively and significantly with pb in the bitter leaf vegetables. This shows that they have the same source(s).

Table 3: Correlation between Heavy Metals in both Leafy Vegetables

Factor	Cd	Cu	Cr	Pb	Zn	
Cd	1					
Cu	-0.3750	1				
Cr	0.62987	0.519968	1			
Pb	0.517642	0.457169	0.601674	1		
Zn	0.806484	0.224596	0.746707	0.3566	1	**P**
Cd	1					
Cu	-0.43729	1				
Cr	-0.21244	-0.72253	1			
Pb	-0.00306	0.595842	-0.53666	1		
Zn	-0.72938	0.26516	0.101286	0.042814	1	**B**

P= Pumpkin leaf
B= Bitter-leaf

Conclusion

The results indicate that the vegetables had slightly high levels of Pb. However, the obtained mean values of heavy metals in the site studied are higher than that found in the control site. Though, the trace metal levels were close to the toxic levels for Pb in plants recommended by [34] joint limits but has not reached the toxicity level of Pb 30-300 mg/kg but is within the normal range of Cd (0.1-2.4 mg/kg) but higher than the value of Pb (5-10 mg/kg) [18]. .The slightly high levels of these toxic metals in vegetables could be ascribed to deposits from vehicle emission and deposits of all sorts of waste into the water used for irrigation. This put the consumers of these and other vegetable crop grown within this farmland at health risk with time and as such continues research of this farmland and the water used for irrigation is needed.

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