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Availability of Toxic Metals and Its Transfer from Soil to Some Selected Edible Vegetables Consumed in Port Harcourt City, Nigeria.

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ABSTRACT

This study showed the distribution of trace metals in soil and some selected edible vegetables consumed in Port Harcourt City, Nigeria. Trace metal content investigated ranged from 0.001 ± 0.000 to 0.090 ± 0.001, 0.100 ± 0.002 to 2.010 ± 0.001, 0.001 ± 0.000 to 0.010 ± 0.001, 0.001 ± 0.000 to 0.001 ± 0.750 ± 0.200, 0.100 ± 0.002 to 2.600 ± 0.003, 0.400 ± 0.030 to 3.400 ± 0.004, 0.040 ± 0.100 to 1.700 ± 0.002, 18.910 ± 0.200 to 260.700 ± 1.090, 0.060 ± 0.003 to 1.550 ± 0.003, 2.100 ± 0.005 to 13.900 ± 0.004, 7.000 ± 0.030 to 12.500 ± 0.002 and 0.050 ± 0.001 to 0.160 ± 0.040 for arsenic, mercury, nickel, chromium, cobalt, lead, cadmium, iron, zinc, copper, magnesium and manganese respectively in sample A. Vanadium was not detected in all the sample. Sample B had concentration of metals that ranged from 0.001 ± 0.000 to 0.300 ± 0.020, 0.600 ± 0.210 to 1.900 ± 0.010, 1.000 ± 0.030 to 3.200 ± 0.070, 0.001 ± 0.000 to 1.030 ± 0.001, 12.500 ± 0.850 to 89.300 ± 1.300, 0.200 ± 0.010 to 3.700 ± 0.020, 1.800 ± 0.201 to 16.400 ± 0.700, 0.020 ± 0.000 to 1.980 ± 0.003 for mercury, nickel, cobalt, lead, iron, zinc, copper, magnesium, and manganese respectively. Arsenic, vanadium and chromium was not detected in all the samples. The vegetables investigated were good accumulator of cadmium and copper with transfer factor values ranged from 11.764 to 53.529 and 24.390 to 67.986 respectively.
KEYWORDS: Bioavailability, vegetables, toxic metals, transfer factors.

INTRODUCTION

Heavy metals in natural environment are present in various chemical forms and exhibits different behavior in term of chemical interactions, mobility, biological availability and potential toxicity. Vegetables can become contaminated with heavy metals if they are grown on contaminated soils by vehicular exhaust, industrial activities and other agricultural activities. Levels of heavy metals in vegetables and soils and their risk to people are of great public concern [1,2]. Some species of plants disappear from such soil, while others, on the contrary, are stimulated by these elements. On soils containing metals, some plant species (metalophytes) have developed tolerance towards metals, and others (hyper-accumulators) are characterized by the capacity to accumulate high quantities of metals in their tissues.

Heavy metals are involved in series of complex chemical and biological interactions [5]. Some of these metals in soil would be persistent because of their immobile nature. Other metals however would be more mobile therefore the potential of transfer either through soil profile down to ground water aquifer or via plant root uptake is likely. It has been noticed that cadmium accumulates mostly in lettuce, spinach, cereal, cabbage, rather than in tomatoes, corn, or sweet pea [3]. The process governing the migration and plant availability of trace metals in soils is essential for predicting the environmental impact of spreading metal containing wastes on agricultural land. The adverse effect of heavy metals is inseparably related to the soil's ability to adsorb and retain these metals. The pH of the soil solution maintained at neutral to slightly alkaline condition showed low mobility of all heavy metals. Mobility of heavy metals increased as the pH of the soil solution is lowered. The solubility of Pb in soil solution was pH dependent, increasing as the pH was adjusted from 6 to 3. At near neutral pH, the activity of Pb^{2+} showed no clear relationship to pH and a small but significant increase resulting from changing organic matter content. In the near neutral pH range, higher Soil Organic Matter (SOM) increases the Dissolved Organic Matter. [6]. Sulfate reduction in contaminated soils may mobilize Cu, Pb, and Cd through the formation of Cu-rich sulphide colloids. The solubility product of most heavy metalsulphides is very low, so that even a moderate output of sulphide can remove metals from solution [5].

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MATERIALS AND METHODS

Sample collection and preparation

Soil and edible plant samples were collected from selected abattoirs in Port Harcourt City in the month of August, 2013. Soil samples were collected at different depth using soil augar. Edible vegetables were also collected from the same plant gardens. The soil samples were labeled A1, A2, A3, B1, B2 and B3. Where A and B represent the sampling sites; Rumuokoro slaughter and Chobaslaughter respectively and 1,2 and 3 represent the different depths; 0 – 10 cm , 10- 20 cm and 20 – 30 cm respectively. Plant samples were labeled a, b and c which represent the edible vegetables; *Vernoniaamydalina, Telferaoccidendalis*and *Amaranthusspinosus*respectively. The soil samples were air dried, ground into fine powder using pestle and mortar and sieved with 2mm mesh. The leaves of the plant samples were rinsed quickly with distilled water to remove the contaminant on the plant surfaces, blotted with tissue paper, and immediately weighed. The samples were airdried, chopped up, macerated and sieved using 2mm mesh.

Heavy metal analysis for the soil samples

The method of [4] was adopted. 2 g each was taken into 250 mL glass beaker and digested with 8 mL of aqua regia on a sand bath for 2 hours. After evaporation to dryness, the samples were dissolved with 10 mL of 2 % nitric acid, filtered and then diluted to 50 mL with distilled water. The filtrate was then used for heavy metals analysis using atomic adsorption spectrophotometer UNICAM SOLAAR 32.

Heavy metal analysis for the plant samples

Dry plant samples were wet- ashed using HNO_3: H_2SO_4: $HClO_4$ (10:1:4 v/v), filtered and then dilute to 50 mL with distilled water [10]. The filtrate was then used for heavy metals analysis using atomic adsorption spectrophotometer UNICAM SOLAAR 32

RESULTS AND DISCUSSION

Table 1. Distribution of heavy metals (mg/L) in soil of abattoir A.

Parameters	A 1	A2	A3
As	0.090 ± 0.001	0.001 ± 000	ND
Hg	0.100 ± 0.002	2.010 ± 0.001	ND
V	ND	ND	ND
Ni	0.010 ± 0.001	0.001 ± 0.000	ND
Cr	0.300 ± 0.001	0.001 ± 0.000	0.750 ± 0.200
Co	2.600 ± 0.003	0.400 ± 0.000	0.100 ± 0.002
Pb	3.400 ± 0.004	3.20 ± 0.005	0.400 ± 0.030
Cd	1.700 ± 0.002	0.500 ± 0.002	0.040 ± 0.100
Fe	260.700 ± 1.090	218.000 ± 1.040	18.910 ± 0.200
Zn	1.550 ± 0.003	0.115 ± 0.007	0.060 ± 0.003
Cu	13.900 ± 0.004	6.500 ± 0.020	2.100 ± 0.005
Mg	12.500 ± 0.002	7.000 ± 0.030	8.700 ± 0.010
Mn	0.100 ± 0.003	0.160 ± 0.040	0.050 ± 0.001

Table 2. Distribution of heavy metals (mg/L) in soil of abattoir B.

Parameters	B1	B2	B3
As	ND	ND	ND
Hg	0.300 ± 0.020	0.001± 0.000	ND
V	ND	ND	ND
Ni	1.900 ± 0.010	0.600 ± 0.210	0.900 ± 0.500
Cr	ND	ND	ND
Co	1.000 ± 0.030	3.200 ± 0.070	ND
Pb	0.60 ± 0.001	1.03 ± 0.001	0.001 ± 0.000
Cd	2.20 ± 0.100	ND	ND
Fe	89.30 ± 1.300	12.500 ± 0.850	17.800 ± 0.100
Zn	3.70 ± 0.020	0.90 ± 0.001	0.200 ± 0.010
Cu	16.40 ± 0.700	1.900 ± 0.130	1.800 ± 0.201
Mg	11.30 ± 0.890	7.000 ± 0.400	18.300 ± 0.020
Mn	1.980 ± 0.003	1.280 ± 0.070	0.020 ± 0.000

Table 3. Concentrations of heavy metals (mg.kg-1) in edible vegetables from Abattoir A

Parameters	Aa	Ab	Ac
Fe	8.400 ± 0.020	11.400 ± 1.040	6.540 ± 0.500
Zn	0.010 ± 0.001	0.100 ± 0.002	0.040 ± 0.0.001
Cd	0.300 ± 0.002	0.200 ± 0.002	0.910 ± 0.004
P b	0.100 ± 0.003	0.100 ± 0.001	0.030 ± 0.001
Cu	4.100 ± 0.300	8.550 ± 0.070	9.450 ± 0.210

Table 4. Concentrations of heavy metals (mg.kg-1) in edible vegetables from Abattoir B

Parameters	Ba	Bb	Bc
Fe	15.400 ± 0.100	3.450 ± 0.003	9.300 ± 1.300
Zn	0.700 ± 0.003	1.000 ± 0200	0.025 ± 0.002
Cd	0.400 ± 0.060	0.940 ± 0.002	0.900 ± 0.040
Pb	0.190 ± 0.020	0.082 ± 0.001	0.230 ± 0.010
Cu	8.600 ± 0.100	4.000 ± 0.070	11.010 ± 1.010

Table 5. Percentage transfer factors from soil to edible vegetables studied.

Heavy metals	A			B		
	a	b	c	a	b	c
Fe	3.231	4.385	2.515	17.245	3.863	10.414
Zn	0.645	6.452	2.581	18.919	27.027	0.676
Cd	17.650	11.764	53.529	18.182	42.727	40.909
Pb	2.940	2.941	0.882	31.667	13.667	38.333
Cu	29.490	61.511	67.986	52.439	24.390	67.134

The results of distribution of heavy metals in soil samples from different abattoirs in Port Harcourt city were presented in Table 1 and 2. The total concentration of heavy metals studied ranged between 0.001 ± 0.000 to 0.090 ± 0.001, 0.100 ± 0.002 to 2.010 ± 0.001, 0.001 ± 0.000 to 0.010 ± 0.001, 0.001 ± 0.000 to 0.001 ± 0.750 ± 0.200, 0.100 ± 0.002 to 2.600 ± 0.003, 0.400 ± 0.030 to 3.400 ± 0.004, 0.040 ± 0.100 to 1.700 ± 0.002, 18.910 ± 0.200 to 260.700 ± 1.090, 0.060 ± 0.003 to 1.550 ± 0.003, 2.100 ± 0.005 to 13.900 ± 0.004, 7.000 ± 0.030 to 12.500 ± 0.002 and 0.050 ± 0.001 to 0.160 ± 0.040 for arsenic, mercury, nickel, chromium, cobalt, lead, cadmium, iron, zinc, copper, magnesium and manganese respectively in sample A. Vanadium was not detected in all the sample. Sample B had concentration of metals that ranged from 0.001 ± 0.000 to 0.300 ± 0.020, 0.600 ± 0.210 to 1.900 ± 0.010, 1.000 ± 0.030 to 3.200 ± 0.070, 0.001 ± 0.000 to 1.030 ± 0.001, 12.500 ± 0.850 to 89.300 ± 1.300, 0.200 ± 0.010 to 3.700 ± 0.020, 1.800 ± 0.201 to 16.400 ± 0.700, 0.020 ± 0.000 to 1.980 ± 0.003 for mercury, nickel, cobalt, lead, iron, zinc, copper, magnesium, and manganese respectively. Arsenic, vanadium and chromium was not detected in all the samples. Cadmium was detected only in sample B1 and mercury in B3. The concentration (mg/L) of metals in vegetables from sample A were investigated (table 3) and ranged from 6.540 ± 0.500 to 11.400 ± 1.040, 0.010 ± 0.001 to 0.100 ± 0.001, 0.200 ± 0.002 to 0.910 ± 0.004, 0.030 ± 0.001 to 0.100 ± 0.003, and 4.100 ± 0.300 to 9.450 ± 0.210 for iron, zinc, cadmium, lead and copper respectively. Metals concentration (mg/L) in vegetable from sample B ranged from 3.450 ± 0.003 to 15.400 ± 0.100, 0.025 ± 0.002 to 0.700 ± 0.003, 0.400 ± 0.060 to 0.940 ± 0.002, 0.082 ± 0.001 to 0.230 ± 0.010 and 4.000 ± 0.070 to 11.010 ± 1.010 for iron, zinc, cadmium, lead and copper respectively (table 4).

The transfer factor factors (%) for Fe, Zn, Cd, Pb, and Cu for the vegetables studied were presented in table 5 above. The results varied greatly between plant species and soil. The transfer factor values for Cd varied from 17.650 to 18.182 (*Verniniaamydalina)*, 11.764 to 42.727 (*Telferaoccidendalis)* and 40.909 to 53.529 (*Amarathusspinosus).* The transfer factor for Pb varied from 2.940 to 31.667 (*Verniniaamydalina*), 2.941 to 13.667 (*Telferaoccidendalis*) and 0.882 to 38.333 (*Amarathusspinosus*). The values for the transfer factor for Zn ranged from 0.645 to 18.919 (*Verniniaamydalina*), 0.652 to 27.027 (*Telferaoccidendalis*) and 0.676 to 2.581 (*Amarathusspinosus*). The transfer factor for Fe varied from 3.231 to 17.245 (*Verniniaamydalina*), 3.863 to 4.385 (*Telferaoccidendalis*) and 2.515 to 10.414 (*Amarathusspinosus*). The transfer factor for Cu varied from 29.490 to 52.439 (*Verniniaamydalina*), 24.390 to 61.511 (*Telferaoccidendalis*) and 67.986 to 62.134 (*Amarathusspinosus*). Zinc and iron had the lowest transfer factor values for all the vegetables studied. copper had the highest transfer factorvalues ranging from 67.986 to 67.134 (*Amarathusspinosus*). This results agree to the results obtained by [11]. Heavy metal transfer from soil to plant depends on plant bio-disponibility and chemistry of the metal. Most plants act as a barrier for accumulation of pollutants in the food chain. Metal distribution in plants is heterogeneous and is controlled by genetic factors, environment and toxic factors [7].

The transfer factor of heavy metal from soil to plant is mostly expressed as activity in plant/activity in soil. They are used as parameter for transfer models for predicting the concentration of heavy metals in food-stuffs and for estimating their impact on man. Soil to plant transfer factors expresses the relative uptake of a heavy metal through the plant root system. Transfer factor is defined as follows, TF = activity of metal in plant dry weight/ activity of metal in soil dry weight. Higher transfer factor reflects relatively poor retention in the soil or greater efficiency of vegetables to absorb metals. Low transfer factor reflects the strong sorption of metals to the colloids [8]. Plants take heavy metals from soils through different reactions such as: absorption, ionic exchange, redox reactions and precipitation- dissolution which depends on the minerals in the soil (carbonates, oxides, hydroxides etc.); soil organic matter (humic acid, fulvic acids, polysaccharides and organic acid), soil pH, soil temperature and humidity [9]. The high level of Pb in these samples indicates the disposal of Pb batteries, roasting of cattle or goat with tyers, Pb-based paints and pipes at the site.

Conclusion

The distribution of the metals in the various fractions confirms differences in transfer factors. Of the metals studied, Cd, Pb and Cu appeared to be the most readily solubilized, thus, making the metal the most potentially bioavailable. This may posed a threat as Cd, Pb and Cu were transferred into the vegetables from soil contaminated by these metals. The values of the transfer factor showed that the vegetables studied are good accumulator of Cd, Pb and Cu. These high exceeding of the maximum admitted values for heavy metals in the vegetables studied impose the prohibition from eating vegetable products obtained on these soils.

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