Seasonal variations in heavy metals concentrations in soils and *Telfairia occidentalis* grown around selected dumpsites in Uyo metropolis, Akwa Ibom State

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Abstract

This study was conducted to examine seasonal variations of heavy metals (Cr, Cd, Ni, Cu and Pb) concentrations in soils and Telfairia occidentalis grown around selected dumpsites in Uyo metropolis. Soil samples(0 – 30 cm depth) and plant samples were collected during the wet and dry seasons of 2020/2021. The samples were processed and analyzed in the laboratory by standard methods. The results show that the concentrations of the heavy metals in the soils during the wet and dry seasons were in the order: Cu (14.42)>Pb (6.92)>Cr (3.26)> Cd (2.23)>Ni (1.24) and Cu (12.31)>Pb (5.61) >Cr (2.39)> Cd (2.25) >Ni (1.30 mgkg^{-1}) respectively.The mean concentrations of the heavy metals in the dumpsite soils and Telfairia occidentalis were higher than those of the control samples. Generally, the levels of heavy metals in soils and Telfairia occidentalis were higher in the wet season than in the dry season, although there was no significant (P<0.05) difference between the two seasons.The transfer factor levels of Pb (0.58), Cr (0.30) and Cd (0.46) were above the WHO/FAO recommended limits of 0.30, 0.02 and 0.20 respectively.All the heavy metals occurred at toxic levels in both seasons.Therefore, awareness creation of the likely effect of cultivation and consumption of crops grown on such soils should be of utmost priorities by constituted authority.

Keywords: Contamination, Heavy Metals, Transfer Factor

Introduction

Heavy metal pollution of the environment and its resulting long-term cumulative health effects are among the leading health concerns all over the world. The situation is even more worrisome in the developing countries where research efforts towards monitoring the environment have not been given the desired attention by governments and other stakeholders. For instance, bioaccumulation of lead (Pb) in the human body interferes with the functioning of the system, leading to impaired respiration, constipation, swelling of the brain, paralysis and eventual death (Oluyemi *et al.*, 2008).

Heavy metals are released into the environment through man's industrial, domestic and commercial activities, fungicides as well as manure from poultry farms. Leachates from dump sites also constitute a major source of heavy metal pollution in the environment. Due to the rapid increase in urbanization, a high degree of solid waste generation is taking place at a rate faster than they can be evacuated (Ukpong *et al.*, 2013) and this solid waste usually consists of paper, food waste, metal scrap, glass, ceramics, ashes and other materials. The decomposition processes release the heavy metals contained in these wastes into the soils of the dumpsite thereby contaminating the soils, and plants grown around the dumpsite can take up these metals which constitute health hazard to humans on consumption (Ebong *et al.*, 2007). Heavy metals enter the body system through food, air and water and bio-accumulate over a period of time which may result in severe implication on human health. Apart from uptake by plants, they can also be leached into underground water sources (Ukpong *et al.*,2013).

Some heavy metals are required for plant growth in extremely small amounts. They include zinc (Zn), Iron (Fe), Nickel (Ni) and Copper (Cu) and they perform complex roles in plant nutrition (Agbede, 2009). Their roles in plant nutrition vary but they are important in the activation of various enzymatic processes and oxidation reduction reactions that take place in soil-plant systems (Agbede, 2009; Brady and Weil, 2010).

The concentrations of heavy metals vary with dumpsite and the characteristic of waste dispose. The accumulative concentration may reach a toxic level, resulting in increased health risk to humans through exposure pathway especially if plants are cultivated near the dumpsite soils for consumption.

Umoren *et al.* (2019) found higher concentrations of copper, lead and Nickel in cocoyam grown near a waste dumpsite in Uyo,with a higher concentration level above the critical limit of 0.2 $mgkg^{-1}$ by WHO/FAO. The consumption of vegetables irrigated with dye effluent could pose risks to human health, and about 50% effluent resulted in death of *Amaranthus* seedlings (Oguntade *et al*., 2017). The concern about these heavy metals is that, they are not biodegradable and may therefore accumulate in the environment. Slow leaching of these metals during weathering process can lead to underground water contamination since leachates are one of the potential sources of groundwater pollution.

Studies on heavy metals in ecosystems have shown a silent epidemic of environmental poisoning (Umoren *et al.*, 2019).With increasing pressure on agricultural land waste dumpsites are becoming attractive because of their rich deposits of organic matter and plant nutrients.In accordance with the heavy metal pollution on dumpsites, several other works have been carried out. These include the works of Odukoya *et al*. (2000) on heavy metals in the top soils of Abeokuta dumpsites; Oluyemi, Feuyit, Oyekunle and Ogunfowokan (2008) which investigated the levels of Arsenic, Cadmium, Chromium, Nickel and Copper in crop leaves cultivated with waste compost from amended dumpsites and Ubom (2005) which analyzed seasonal variations of some heavy metals in vegetable species grown on refuse dump soils in Uyo metropolis Akwa Ibom State.

In Nigeria, especially Akwa Ibom State, limited information exists on the distribution of heavy metals in soils and vegetables grown near dump sites. The main aims of this study were to characterize solid wasteat different dumpsites and determine the concentrations of Cr, Cd, Ni, Cu and Pb in soils and *Telfairia occidentalis* in wet and dry seasons

Materials and methods

Description of study area

The study was conducted in Uyo Metropolis, the capital city of Akwa Ibom State, Nigeria, which has a population of 305,961 people (TWG, 2007). It is situated between latitudes 7° 50' E and 8° 00' E, and Longitudes 4° 59' N and 5° 05'N (Fig. 1) at an altitude of 60 m above sea level with a mean annual rainfall of 3000mm and temperature range between 27 to 34°C. The relative humidity varies through the year from 70 to 80% (AKSEPA, 1999). The city has two distinct seasons, namely dry and wet seasons. The dry season usually starts in November and ends in March while the wet season usually starts in April and ends in October. Uyo is within the modified rainforest zone now called oil palm bush. The secondary forest type of vegetation is however disappearing due to urban development. The topography of the area is generally undulating, except in some parts that are occupied by valleys. Parts of the valleys are so steep that they are described as ravines. This topography poses a major limitation to physical development of the city. The waste dumpsites and control sites under study wereMbakItam, Old Stadium Road, EkomIman and Uyo Village Road. Farmlands (200 m) far away from each dumpsite served as control sites.

Study Design

A Randomized Complete Block Design (RCBD) with three replications was used for this study. Four waste dumpsites were randomly selected to represent the North, East, South and West of Uyo Metropolis as follows: Uyo Village Road, MbakItam III, Ekom Iman, and Old Stadium Road. A farm land of about 200 m away from each dumpsite was used as the control site. At each site, soil samples were collected at the depth of 0-30 cm and bulked together to represent each dumpsite. Soil and plant sampling were done twice to represent the dry and wet seasons, respectively.

Sample collection and preparation

Five sampling points were randomly made within each dumpsite to cover the total dumpsites area. The collection and sorting of the refuse/waste materials were performed with the help of refuse collectors at each dumpsite. The materials were sundried to eliminate moisture before the dry weight was determined. The wastes were sorted into food and foliage, bottles, plastics, glass, paper wastes and metals categories among others. The weighing was performed using a top load weighing balance capacity scale. Data obtained were extrapolated to cover the size (area) of each dumpsite.

Composite soil samples (0-30 cm depth) were collected near the dumpsites using Dutch auger, sample were air- dried, crushed, passed through a 2 mm size sieve and subjected to laboratory analysis. Also, the edible parts of *Telfairia occidentalis* plant were collected near the dumpsites using a knife. Prior to analysis, Plant samples were dried in an oven at 80°C for 24 hours and ground with a blender to powder to obtain particles less than 2 mm in diameter size.

Laboratory Analysis

One gram of each sample of soil and plant was weighed into a digestion flask, followed by the addition of analytical grade [analar (R)] concentrated nitric and perchloric acids (HNO_3 and $HClO_4$) in the ratio of 2:1 (10 ml and 5 ml), respectively. The HNO_3 acid was added to the sample before $HClO_4$ acid to avoid any explosive reaction of $HClO_4$ with untreated organic materials. This was achieved by covering the digestion flask with a watch glass. The flasks and the contents were placed in a standing position on an electric hot plate in a fume cupboard and gently heated to evaporate until 1-2 ml of the acid was left (near dryness) and the colour changed to white. This was allowed to cool before leaching the residue with 5ml of 20% HNO_3. The filtration was done using Whatman No 1 filter paperand the filtrate was finally made up to 50 cm with de-ionized water. A blank determination that served as the control was also carried out with all the reagents used for digestion except that it contained no sample of interest. The aliquots were used to determine cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr) and copper (Cu) using a Unicam atomic absorption spectrophotometer (AAS) MODEL 939 (Udo *et al.*, 2009).

Statistical analysis

Data generated from the laboratory were subjected to analysis of variance and means compared using least significant difference at $P<0.05$. In order to qualify the relative differences in bioavailability of metals to plant or identify the efficiency of a plant species to accumulate a given heavy metal, the Transfer Factor (TF) and Pearson's Correlation Coefficient were also analyzed (Gomez and Gomez, 1984).

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Results and discussion

Characterization of solid waste materials

The components of waste at the four dumpsites (Mbak Itam (MI), Old Stadium Road (OSR), Ekom Iman Junction (EIJ) and Uyo Village Road (UVR) are presented in Table 1. The waste components and their weights were as follows – food and garden waste (45 kg), plastic (40 kg), bottle (35 kg), metal (30 kg), paper waste (20 kg) and Glass (10 kg). Table.2 shows the percentage of the refuse released by dwellers in the study area. Metal (10 – 43%) and plastics (10 – 33%) wastes has the highest percentage followed by organic food and garden wastes (12 – 26%). Each waste component was significantly higher at the Uyo Village Road (UVR) dumpsite and significantly lower in Ekom Iman Junction (EIJ), following the order: 198 kg (UVR) > 96 kg (OSR) > 32 kg (MI) > 77 kg (EIJ). The following mean percentages waste were identified in at the dumpsites as plastics (21%) > metal (20%) > food and garden waste 19% > bottle (13.3%) > glass (8.5%) > paper (8.2%).

Effect of Season on the Levels of Heavy Metals in Soils and Telfairia occidentalisgrown around the dumpsites

Table 3 shows the effect of seasons on the levels of the heavy metals in the dumpsite soils of Uyo Metropolis while Table 4 shows the effect of seasons on the levels of the heavy metals in *Telfairia occidentalis* grown near the dumpsites. At all the sites studied, the concentrations of heavy metals in the soil samples were higher in the wet season than in the dry season except for Cd (2.23) and Ni (1.24) (Table 3). The same trend was also observed in plant samples. The concentrations of the heavy metals were higher in the wet season than in the dry season except for Pb (0.76) (Table 4). This might be due to rapid decomposition of waste and rainfall effect which may facilitate the dissolution of metal making them readily available at the exchange site during the wet season. The high values recorded during the dry season, may be due to more intense dumping and burning of wastes which makes soil solution more concentrated when ashes dissolves in water solution.

The sequence of metal concentrations in the dumpsites were Cu >Pb> Cr > Cd > Ni for soil and Cu >Pb> Cd > Cr > Ni for plant in both seasons, respectively. The heavy metals concentrations in soils and plants in the study area (dumpsites) were higher than the control site. Generally higher heavy metal concentration was recorded in soils than in plant samples during the wet season. Nickel had the least concentrations of 1.24 $mgkg^{-1}$ and 1.30 $mgkg^{-1}$in the soil, and 0.31 $mgkg^{-1}$ and 0.27 $mgkg^{-1}$ in *Telfairia occidentalis*, respectively, while Cu had the highest concentrations of 14.42 and 12.31 $mgkg^{-1}$ in soil and 8.73 and 6.19 $mgkg^{-1}$ in *Telfairia occidentalis* during the wet and dry seasons respectively. The heavy metals levels recorded in the dumpsite soil and *Telfairia occidentalis* were higher than the maximum recommended rates proposed by WHO/FAO (1996), except for Ni where the *Telfairia occidentalis* sample concentration was within the recommended levels (WHO/FAO 1996).

Although the concentrations of the other metals were within the recommended WHO/FAO standards in the control samples, the concentrations of copper were higher than the WHO/FAO recommended limits in soil and plant samples. A similar finding was observed by Salihu (2019) and Umoren *et al.*(2019).The relatively high values of Cu in the control samples might be as a result of copper being known to occur naturally in soils as increased plant micro-nutrients uptake, because they are essential elements for plants and animals but when present in high quantity, may become toxic to plant and animals (Madejon *et al.*, 2003). In addition, copper salts though poisonous, are essential for human metabolism, having a powerful emetic action (Udosen *et al.*, 1990): Agbede, 2009). However, when ingested in large doses by humans could result in severe diarrhea, intestinal cramps, hepatic and renal damage (Goyer, 1991).

In comparing with similar research work, the concentration values are in conformity with the work of Ubom (2005) on seasonal variation of the levels of some heavy metals in the vegetable species grown on refuse dump soils in Uyo, and Oluyemi *et al.* (2008) which investigated the seasonal variations of the levels of arsenic, cadmium, chromium, nickel and copper in soil and selected crops at a landfill in Nigeria.

Effect of season on transfer factor (TF) of metal concentration

The transfer factor (TF), which is the ratio of the concentration of metal in the aerial portion of the plant to the total concentration in soil, is shown in Table 5. The transfer factors (TFs) for all the metals in the study area significantly differed in seasons. Lead and Cr had the highest and the least TFs of 0.58 and 0.30 in dry season respectively, while Cu and Pb had the highest and the least TF values of 0.64 and 0.13 in the wet season respectively. The transfer factors of Pb, Cd and Cr are above the normal range in plant species as recommended by WHO/FAO (1996) and it is of importance since Pb, Cd and Cr with high TF values are non-essential toxic elements for plants, animals and humans. The high TF value for Cu in the dumpsite soilmay be due to its strong adsorption into the organic matter and solid waste component (Table 1) which render it less bioavailable to plants (Alloway and Ayres, 1997).

Relationship between the heavy metals in soils and plant (Telfairia occidentalis)

The Pearson's correlation coefficients revealed strong positive correlations ($P < 0.05$) between the heavy metals concentrations in the dumpsite soils and their concentrations in *Telfairia occidentalis*. The high positive correlations indicate that all the heavy metals were being influenced by similar anthropogenic sources (Table 6). The Pearson's correlation coefficients also revealed weak correlations between the heavy metals concentrations the transfer factor (TF). Therefore, negative and low positive correlation were observed in all metals (Cr, Cd, Ni, Cu and Pb) signifying that they were weak and no linear correlation between these metal (Table 6).

Conclusion

The study revealed that the dumpsite soils and *Telfairia occidentalis* plants had higher accumulation of (Cr, Cd, Ni, Cu and Pb) metals than the control soils during the wet and dry seasons. This study showed that the use of the dumpsite soils for agricultural purposes is unsafe and the consumption of vegetables from the dumpsite soil could be hazardous for animal and human health since plants are known to take up and accumulate heavy metals from contaminated soils. However, high concentration of heavy metals was recorded in wet season than dry season. Therefore, the consumption of *Telfairia occidentalis* from the study area could be dangerous due to the high TF values recorded for Pb, Cr and Cd which were above the WHO/FAO recommended maximum limits and the accumulated metals may end up in human food chain with adverse health risk effects.

Recommendation

It was noticed that the concentrations of the heavy metals were higher during the wet season than the dry season, therefore dry season planting is recommended but should be incorporated with the planting of phytoremediation plants to reduce the toxic effect of metals, and proper management processes and improved remediation techniques such as bioremediation that have shown potentials for their ability to degrade and detoxify certain contaminants must be practiced.

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Table1: Fraction of the solid waste material in different dumpsites in Uyo metropolis

Refuses type	Weight (kg)				Mean	Percentage by weight (%)				Percentage (%) mean
	1*	**2****	**3*****	**4******		**1***	**2****	**3*****	**4******	
Food and garden wastes	10	14	20	45	22.3	12	15	26	23	19.0
Bottles	6	20	5	35	16.5	7	21	7	18	13.3
Plastics	8	20	25	40	23.3	10	21	33	20	21.0
Glass	10	5	10	10	8.8	12	5	12	5	8.5
Paper waste	5	10	5	20	10.0	6	10	7	10	8.2
Metals	35	12	8	30	21.3	43	12	10	15	20
Others	8	15	4	18	11.3	10	16	5	9	10
Total	**82**	**96**	**77**	**198**						

Dumpsites location:1* MbakItam III (MI), 2** Old Stadium Road (OSR), 3*** EkomIman Junction (EIJ), 4**** Uyo Village Road (UVR)

Table 2: Percentage range of solid waste material identified in the study area

Refuse type	Percentage Range (%)
Food and garden waste	12 – 26%
Bottles	7 – 21%
Plastics	10 – 33%
Glass	5 – 12%
Paper waste	6 – 10%
Metals	10 – 43%
Others	5 – 16%

Table 3: Effect of season on the levels of the heavy metals in the dumpsite soils

Season	Cr	Cd	Ni	Cu	Pb
	→	mg kg^{-1}	←		
Wet	3.26	2.23	1.24	14.42	6.92
Dry	2.39	2.25	1.30	12.31	5.61
Control	0.41	0.49	0.33	1.68	0.73
$LSD_{(0.05)}$	0.42*	0.28*	0.20*	1.27*	0.71*
Fcal	28.01	30.32	17.33	60.09	50.07
Ftab	2.53	2.53	2.53	2.53	2.53

Table 4: Effect of season on the levels of some the heavy metals in *Telfairia occidentalis* plants at the dumpsites

Season	Cr	Cd	Ni	Cu	Pb
	→	mg kg^{-1}	←		
Wet	0.85	0.99	0.31	8.73	0.76
Dry	0.63	0.79	0.27	6.19	1.03
Control	0.12	0.21	0.03	1.27	0.25
$LSD_{(0.05)}$	0.20*	0.26*	0.18*	0.94*	0.26*
Fcal	10.00	7.76	3.72	30.51	7.54
Ftab	2.53	2.53	2.53	2.53	2.53

Table 5: Effect of season on the transfer factor of the heavy metals in the dumpsite soils

Season	Cr	Cd	Ni	Cu	Pb
	→		mgkg^{-1}	←	
Wet	0.29	0.46	0.23	0.64	0.13
Dry	0.30	0.38	0.21	0.56	0.58
Control	0.42	0.64	0.20	0.81	1.43
$LSD_{(0.05)}$	0.08 ^{ns}	0.13 ^{ns}	0.12 ^{ns}	0.15 ^{ns}	0.83 ^{ns}
Fcal	1.62	2.42	1.21	1.45	1.17
Ftab	2.53	2.53	2.53	2.53	2.53

Table 6: Correlation matrix of heavy metals concentrations in dumpsite soils and *Telfairia occidentalis* plant

	Cr (Soil)	Cd (Soil)	Ni (Soil)	Cu (Soil)	Pd (Soil)	Cr (Plant)	Cd (Plant)	Ni (Plant)	Cu (Plant)	Pb (Plant)	TF (Cr)	TF (Cd)	TF (Ni)	TF (Cu)	TF (Pb
Cr (Soil)	1.000														
Cd (Soi)	0.890**	1.000													
Ni (Soil)	0.803**	0.781**	1.000												
Cu (Soil)	0.888**	0.886**	0.807**	1.000											
Pd (Soil)	0.902**	0.887**	0.773**	0.952**	1.000										
Cr (Plant)	0.834**	0.691**	0.655**	0.670**	0.729**	1.000									
Cd (Plant)	0.767**	0.705**	0.570**	0.597**	0.659**	0.913**	1.000								
Ni (Plant)	0.540**	0.418**	0.467**	0.485**	0.496**	0.714**	.645**	1.000							
Cu (Plant)	0.814**	0.741**	0.626**	0.882**	0.850**	0.715**	.658**	.574**	1.000						
Pb (Plant)	0.517**	0.573**	0.554**	0.583**	0.653**	0.505**	.444**	.499**	.468**	1.000					
TF(Cr)	0.182	0.184	0.134	0.209	0.157	-0.237	-0.199	-0.227	0.049	0.068	1.000				
TF(Cd)	-0.074	0.016	-0.062	0.038	-0.040	-0.333*	-.456**	-0.275	-0.092	-0.176	.349*	1.000			
TF(Ni)	0.042	0.126	0.281	0.071	0.108	-0.094	-0.111	-.301*	-0.169	.347*	0.204	0.113	1.000		
TF(Cu)	-0.099	-0.006	-0.068	-0.114	-0.115	-0.139	-0.139	-0.111	-0.276	-0.036	-0.043	.539**	0.125	1.000	
TF(Pb	-0.161	-0.181	-0.016	-0.184	-0.232	-0.109	-0.111	-0.190	-0.144	-.529**	-0.197	-0.131	-0.042	-0.188	1.000

TF = transfer factor

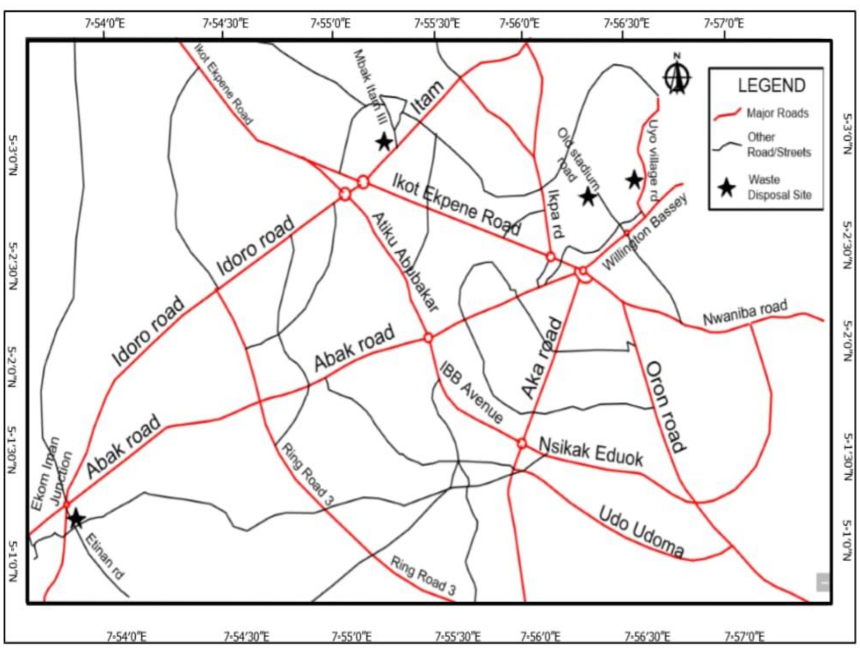

Figure 1: Locations of the waste dumpsites on the map of Uyo metropolis