Relations between metal levels in plant and soil from waste dumpsite within uyo metropolis

Akanimo N. Ekanem
Department of Chemistry, Akwa Ibom State University, Ikot Akpaden, Mkpat Enin.

ABSTRACT

This study was aimed at determining the uptake of heavy metals (Cd, Pb, Ni, Fe and Zn) by plant (Talinum triangulare) if cultivated at some waste dumpsites in Uyo metropolis. Soil samples were taken within 0-15cm and plant samples were collected in triplicate and analysed using Atomic Absorption Spectrophotometer (AAS). Mean results obtained from the soil and plant samples indicated Fe to have the highest concentration (216.29±29.15mg/kg and 243.339±12.622mg/kg respectively) which is significantly higher than its control (124.00mg/kg and 78.375mg/kg respectively). Concentration of Pb in both dumpsite soil and plant samples were below detectable limit. These results when compared with the acceptable standard revealed that all the metal levels in both soil and plant samples were within the acceptable limits accept Cd in soil sample. Transfer factor for Fe was 1.13, while others were below 1. All the metals showed positive relationship except Cd (-0.60).

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Introduction

Environment etymologically means surroundings. It is the sum total of external factors, substance and conditions, which influence organisms without becoming their intrinsic part. In the search for knowledge and improvement of life, man has influenced his natural environment positively and negatively. Man's activities disturb the atmosphere by deteriorating the environmental conditions suitable to sustain life thereby causing pollution (Gupta, 2001). Waste is generated universally and is a direct consequence of such human activities.

Environmental pollution is any undesirable change in the physical, chemical or biological characteristics of air, water and soil, which may create a hazard or potential hazard to health safety or welfare of any living species. The substance which causes pollution is known as pollutants. Environmental pollution may arise from industrial and commercial activities when substances resulting from these activities enter the environment and attain levels which may cause discomfort and harm to man and his environment (Udosen et al., 1990). Garbage and other forms of wastes (solids and liquids) arising from homes within municipalities, industries and agricultural practices, are the major sources of pollution on our land environment (Ademoroti, 1996). Odewunmi (2001) observed that waste generation is a concomitant aspect of living. It cannot be avoided but can only be managed. Waste management is one of such areas that require special attention to plan and manage in view of the increase in waste generation taking place within the urban milieu. Inappropriately sited open dumps are characteristics of major cities, endangering public health by encouraging the spread of odours and diseases, uncontrolled recycling of contaminated goods and pollution of soil and water sources (Odukoya et al., 2000; IPCC, 2006)

Environments contaminated by heavy metals have given scientists great concern in the last decade because these metals can constitute a hazard to man and other organisms when accumulated within the biological system (IPCC, 2006). Most heavy metals are toxic but the exact toxicity varies considerably.

Most cadmium, mercury and lead compounds are much more toxic than iron II or iron III compounds. Not all the excessive levels of heavy metals we may have in the environment may be due to pollution. They may occur naturally as a result of normal geological phenomena such as formation of dunes, weathering of rocks and leaching. Once metals are available in the environment, they are not rapidly removed by metabolic activities (Ademoroti, 1996; Al-Jassir et al, 2005).

The uptake of toxic heavy metals from contaminated soils by food and forage plant comprises a prominent path for such elements to enter the food chain and will eventually be ingested by human. Heavy metals enter the body system when these plants are directly or indirectly consumed and bioaccumulate over a period of time (Li and Yang, 2008; Fang et al., 2011. This ingestion and the resultant accumulation should therefore be minimized. Of all the natural compartments, soil is perhaps the most important one, because it receives heavy metals coming from very different sources. Metal availability depends on pH, cationic exchange capacity, binding to different soil components (clays oxides, organic matter) and in the plants essentially on the species (Kabata-Pendias and Pendias, 1984; Ideriah et al., 2010).

Uyo metropolis with high population density generates large quantities of waste about 150MT/Week (AKSEPA, 1999). Consequently, the levels of heavy metals in both soil and plants grown on it are expected to be considerable. As such this work was undertaken to evaluate the concentration of heavy metals in soil and plants around the refuse dumpsites and extrapolate the result obtained on the influence of waste dumpsites on the levels of heavy metals in both soil and plants.

Materials And Methods

Site description

All the samples were collected within Uyo metropolis. Uyo, which is the capital city of Akwa Ibom State, is one of the fast growing towns and densely populated. It experiences the tropical wet and dry climate with a lengthy wet season and short dry season. Although not highly industrialized like other cities in Nigeria, it is however, polluted from anthropogenic sources.

Sample collection

Sampling was conducted in May, 2010. All samples (15 soil and 15 plant) were collected randomly from the five (5) different dumpsites in Uyo metropolis. A control sample (3 soil and 3 plant) were also collected from a non-polluted area. The plant species found common in all the waste dumpsites was waterleaf (*Talinum triangulare*).

The soil samples were collected at a depth of 5cm with an auger. The samples (3 from each dumpsite) were mixed properly to give a representative sample of each sampling point. The soil samples were stored in black polyethylene bags, properly labelled before being taken to the laboratory.

The plant samples were carefully uprooted from each sampling point where soil samples were taken, and directly transferred into polyethylene bag and labelled properly. A stainless steel knife was used to cut off the root of the plant to reduce the risk of contamination of the samples by heavy metals. All the samples were collected within 3hours in the month of May, 2010.

Sample pretreatment and preservation

The soil samples collected were sun dried for 3 days. Larger stones and sticks were removed by hand picking. After smashing using agate pestle and mortar, the coarse materials were removed and then sieved through 2mm nylon screen to obtain a homogenous particle size of <2mm. The homogenized samples were labelled accordingly in a crucible.

A representative plant samples were collected and placed in a crucible. The samples were oven dried at 50 - 60°C for 8hrs. The plant samples were effectively pulverised using pounder into a powder. Then 1g of the powder was weighed into a crucible. This was ash in a furnace at 500 - 700°C for 4 hours. After ashing it was removed from the furnace and kept for sometime to cool and while still in the crucible, it was properly labelled.

Sample Digestion For Total Metal Analysis

Digestion of soil and plant samples with mixture of acids

The soil samples were digested by wet digestion method while the plant samples were digested using dry ashing method. These methods are used in the treatment of compounds containing silicates, rocks, and other organic complexes. This method is known as the H H H (HNO_3 + $HCLO_4$ + HF) method and it involves treatment of the solid sample by acid digestion producing a clean solution with no loss of the element to be determined.

Digestion of soil by wet digestion

Exactly 1.0g of the crushed, sieved soil sample was weighed into a Teflon flask. Concentrated HNO_3/$HCLO_4$/HF was added in the ratio of 1:1:1 (5ml each). This was repeated for all the soil samples according to their labelling. It was cooled and followed by dissolution of the samples with distilled water before filtration using a Whatman No. 1 filter paper. The residue was leached with 5ml of 20% HNO_3 and the volume made up to 20ml with distilled water. The filtrates were transferred into a small bottle which was properly rinsed with 63ml of HNO_3 in 100ml of distilled water. These bottles were properly labelled and the samples kept until time of analysis.

A blank determination was treated in the same method but omitting the sample.

Digestion of plant sample by dry ashing (dry digestion)

The sample was oven dried at 50 - 60°C. The dry sample was ground into a powdery form using mortar. Exactly 2.0g of the powder was weighed into a crucible. This was ashed in a muffle furnace at 500 - 700°C for 4hrs. It was removed after ashing from the furnace and kept for some time to cool. The

ashed sample was then leached with 5ml of 6M HCl. The volume was made up to 20ml with distilled water in a measuring cylinder. The resulting solution was transferred into pre-washed small bottle and kept until the time for analysis (IITA, 1971).

The blank determination was also carried out in a similar way as described above but without sample.

Instrumental Analysis (IITA, 1971)

Both soil and plant samples were analysed for Lead (Pb), Cadmium (Cd), Nickel (Ni), Zinc (Zn) and Iron (Fe) using Atomic Absorption Spectrophotometer (AAS). Appropriate lamps and resonance wavelength of the metals were used.

Conventional statistical techniques such as mean, standard deviation, correlation coefficient and Transfer Factor (TF) were calculated to measure the strength of the relationship between the soil and plant samples. Transfer Factor (TF) is the ratio of the concentration of heavy metal in a plant to the concentration of heavy metal in soil. The plant transfer factor (TF) was calculated as follows:

$$TF = C_{plant} / C_{soil}$$

where C_{plant} and C_{soil} represents the toxic metal concentration in extracts of plants and soils on dry weight basis respectively.

Results And Discussion

Heavy Metals in Soil

Heavy metal concentration in soil are associated with biological and geochemical cycles and are influenced by anthropogenic activities such as agricultural practises, industrial activities and waste disposal methods (Zauyah *et al*., 2004). In this study, the result obtained shows variation among different dumpsites (5 dumpsites). This could be attributed to the degree of environmental pollution at the different waste dumpsites.. All the metals showed higher concentration over the control sample which was obtained from unpolluted area, the highest concentration was found in Fe for both soil (216.29 ± 29.15) and plant (243.339 ± 12.622) samples as seen in the tables below:

Basically heavy metal concentrations followed the order Fe > Zn > Pb > Ni > Cd in the dumpsite soil samples. High concentrations of heavy metals obtained at the dumpsites showed that concentrations of the metals in dumpsite soil is not dependent on the age of the dumpsites but on the source and composition of the waste disposed in the area (Ideriah *et al*., 2010). Though these heavy metal concentrations fall below the critical permissible concentration level, their persistence in these soil of the dumpsites may lead to increased uptake by plants, though their transfer ratio differ from crop to crop (Okoronkwo *et al*., 2005).

Heavy Metals in Plant

Accumulation of metals in edible vegetables poses a great threat to human health especially to local communities that collect vegetables such as waterleaf freely growing on dumpsites. For these reason, the international and national regulations on food quality have lowered the maximum permissible levels of toxic metals in food items due to an increased awareness of the risk these metals pose to food chain contamination (Radwan *et al*., 2006). Metal accumulation in the plant samples taken from different dumpsites in Uyo metropolis varies significantly from one element to the other as is seen in the above table. Generally, heavy metal concentrations followed the order Fe > Zn > Pb > Cd > Ni in the plant samples. The uptake and bioaccumulation of heavy metals in vegetables is influenced by many factors such as atmospheric depositions, climate, the concentration of heavy metals in the soils, the nature of soil and the degree of maturity of the plants at the time of the harvest (Ademoroti, 1995; Suruchi and Panka, 2001).

Table 1: Concentration of Metals in Soil Samples (mg/kg) DM

Sample Name	Cd	Pb	Ni	Fe	Zn
DS1- S	8.650	50.600	2.150	237.200	11.350
DS2- S	3.050	42.050	15.900	193.150	41.950
DS3- S	1.850	47.300	11.050	183.300	119.300
DS4- S	5.150	60.850	20.550	261.900	50.250
DS5- S	2.900	45.850	14.450	205.900	96.350
DSC – S	0.150	BDL	0.100	124.000	24.200
Mean ± S.D	4.32 ± 2.42	49.33 ± 6.38	12.82 ± 6.15	216.29 ± 29.15	63.84 ± 38.86

Where DS 1-5 indicates the different dumpsites sampled, DSC- control sample and S- soil sample

Table 2: Concentration of Metals in Plant Samples (mg/kg) DM

Sample Name	Cd	Pb	Ni	Fe	Zn
DS1 - P	0.100	1.550	0.050	241.025	24.425
DS2- P	0.225	1.075	0.050	253.250	2.200
DS3- P	0.150	0.325	0.100	238.995	29.950
DS4- P	0.175	1.350	0.450	260.000	23.625
DS5- P	0.300	0.550	0.150	223.425	10.550
DSC – P	0.025	BDL	0.025	78.375	0.625
Mean ± S.D	0.163 ±2.42	0.808 ± 0.558	0.160±0.150	243.339±12.622	17.750 ± 9.765

Where DS 1-5 indicates the different dumpsites sampled, DSC- Control sample and P- Plant sample

Table 3: Transfer factor for the metal concentration in soil to the plant at Uyo dumpsites

Cd	Pb	Ni	Fe	Zn
0.04	0.02	0.01	1.13	0.28

Transfer Factor

Soil to plant transfer of heavy metals is the major path way of human exposure to metal contamination.

Transfer factors for heavy metals from soils to vegetables in this study are presented in the table below

Highest TF value was obtained in Fe (1.13) which indicates that the accumulation of Fe is more in plant while those of Cd, Pb, Ni, and Zn were low.

Relationship between metal levels in the soil and plant samples

The relationship between metal levels in the soil and plant samples were determined from the above data using Pearson's correlation coefficient as seen in the tables below:

Table 4: Pearson's Correlation Coefficient of the different metals in soil and plant

Metals	Pearson's Correlation Coefficient
Cd	-0.60
Pb	0.48
Ni	0.68
Fe	0.49
Zn	0.13

From the table above, it reveals that only Cadmium had a negative relationship between the soil heavy metal concentrations in the plant sample (r = -0.60). This negative relationship shows that, as the heavy metal concentration of Cadmium in soil increases, the concentration in plant decreases and vice versa. All other metals showed positive relationship. The positive relationship shows that as the heavy metal concentration in soil increases, the concentration in plant also increases and vice versa. None of the sample showed no relationship (r = 0). This means that the uptake of metals by plant corresponds to the soil metal concentration.

Conclusion

In conclusion, the risk of pollution of soils and plants in Uyo Metropolis is rather low, but there was a high risk of pollution by specific metals such as Zinc (Zn) and Iron (Fe). All the heavy metals investigated in different dumpsites were found in concentration higher than the control site. Metal accumulation in vegetables taken from dumpsites in Uyo metropolis varies significantly from one element to the other. The transfer factor (TF) of the metals showed significant accumulation of Fe and Zn in the vegetable. This suggests that consumption of vegetables grown on such sites could be dangerous to human health. Also from Pearson's Correlation Coefficient, it was realized that only Cadmium (Cd) showed a negative relationship between the soil and plant among all the metals.

Our environment is where we live and for intergenerational equity must be protected especially with the current climate change. Every activity carried out in it should be performed in a way that it does not deviate so much from its natural carrying capacity. Activities carried out on the environment should be done with high level of sustainability. As such, our waste should be properly managed to avoid the risk of feeding on heavy metals instead of nutrients. Also, waste dumpsite should be properly sited so as to reduce the rate of cultivating plant near them. To deal with heavy metal contamination and decrease their dietary toxicity, micro-organism-based remediation techniques should be adopted.

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