Journal of Research in Environmental Science and Toxicology (ISSN: 2315-5698) Vol. 2(3) pp.64-70, March 2013
Available online http://www.interesjournals.org/JREST

Full Length Research Paper

A study on the spatial distribution of heavy metal in industrial area of Ikorodu, Lagos State, Nigeria

***Njoku K. L., Akinola M. O. and Zighadina T. M.**

Environmental Biology Laboratory, Department of Cell Biology and Genetics, University of Lagos, Akoka, Lagos, Nigeria

Accepted March 18, 2013

This study examines the spatial distribution of lead (Pb), Cadmium (Cd) and Zinc (Zn) in the industrial areas of Ikorodu, Lagos state Nigeria. Soil samples and samples of the most common plant, *Tridax procumbens* growing in the area were collected around four industries and a control sample from a non-industrial area. The heavy metal concentrations in the soil and plant samples were determined by using the Atomic Absorption Spectrophotometry (AAS) method. The results revealed that the soil of Spintex industry where textile materials are produced was slightly polluted with zinc with a concentration of 84.04±0.02 µg/g when compared with recommended standards of regulatory agencies. Generally, the levels of the heavy metals in the soil were higher in the industrial areas than the non-industrial areas (control) with the level of zinc in soil from Spintex industry being significantly higher than that of non-industrial area (P<0.05). Also, the heavy metals in the soils were generally higher in the dry season than in the wet season As at the time of this study, *T. procumbens* was not polluted with any of the heavy metals but there is no doubt that continuous industrial activities can lead to high level of pollution of the soil and plants growing in the area by heavy metals. Therefore, this may necessitate proper monitoring of industrial activities by regulatory agencies concerned with environmental health.

Keywords: Spatial Distribution, Heavy Metals, Industrial areas

INTRODUCTION

With the turn of the nineteenth century, industrialization has taken centre-stage in the world's affairs, as many countries have become increasingly technologically advanced and numerous industries and factories spring up daily. Nigeria, even as one of the developing countries in the world, is not left behind in the race for industrialization. The 5.3sq ilometre town of Ikorodu in Lagos State, South West, Nigeria has witnessed tremendous growth during the last four decades with the construction of roads, constant supply of electricity and subsequently, the influx of business and industrial activities in the area. The town is situated on a plateau whose top is gently undulating. The town has some major streams such as Apeka, Etunrenren, Erikorodo, Melegoke, Ota Ona, Ribila and Erunwen which sustain the life of the town, as its indigenes use the water for drinking, irrigating their farmlands and for most of their industrial activities. However, most of these streams have been savagely polluted by uncontrolled effluents from its industries, by domestic waste water effluents and by leaking sewage from damaged drainages. With passing years, this advancement brings with it, the problem of environmental pollution and so for decades, the environment has suffered degradation from pollutants emitted from industries, as well as those resulting from natural and anthropogenic causes (Hutton and Symon, 1986). Pollutants are substances in the environment that cause intolerable effects, impairing the welfare of the environment and reducing the quality of life. Sometimes,

*Corresponding Author E-mail: kecynjoku@gmail.com

pollutants may even cause death. Environmental pollution can occur when pollutants are present in the environment (air, land and water) beyond set tolerance limits, or when they exhibit toxic properties and cause harmful effects to living things in the environment (Duruibe et al., 2007). Heavy metals released into the environment are major forms of pollutants that degrade the quality of today's earth (Nriagu, 1996). This is because of their bio-persistent nature; they persist in the environment and bio-accumulate in tissues of living organisms (Peplow, 1999).

With little or no concern for environmental cleanliness in Nigeria and with the myriads of industries located in the last few years in Ikorodu area of Lagos State, it is therefore a thing of interest to investigate the level of heavy metal distribution in the soil and plant growing around these industries. This is to confirm the level of heavy metal pollution that has been constituted by the sudden rapid industrial development experienced in this area. Heavy metals enter the food chain by leaching from surface soil and then they accumulate in surface and underground water sources. Micro-organisms, plants and animals depend on water for life. Along the food chain, larger tertiary and secondary consumer organisms feed on contaminated smaller producer organisms and bio-accumulate heavy metals in their system for long periods (McCluggage, 1991). For instance, plants grown on contaminated soil take up heavy metals and accumulate them in their tissues (Treuby, 2003). Animals that graze on such contaminated plants and drink from polluted water bodies accumulate these heavy metals in their tissues (Gabarino et al., 1995; Peplow, 1999). Humans that consume heavy metal-contaminated animals consequently suffer bio-chemical disorders like anaemia, renal dysfunction hypertension and so on (Ferner, 2001).

T. procumbens is indeed an important annual herb, though a weed species, is used to feed rabbits and it is fed upon by other herbivores wherever it is found growing. So in a situation where such primary producer like *T. procumbens* contains a high level of heavy metals, it is obvious that consumers from herbivores to carnivores that feed directly or indirectly can bio-accumulate them in their tissues. There is no doubt that the consequences of this can be very grave to the health of the consumers in such a food chain. Moreover, the results from this study will add to existing information on the level of pollution that industrial development has brought to this area over the last few years. Generally, such data will be useful to regulatory agencies that are interested in environmental cleanliness and human health as it will enhance proper monitoring of the environment and enforcement of environmental laws when and where necessary.

MATERIALS AND METHODS

Study site

This study was carried out in the moderately populated area of Odongunyan in Ikorodu Local Government Area, Lagos State. Ikorodu is located on latitude 3°36' and longitude 6°45'. Odonguyan is a semi-residential as well as a semi-industrial area. It is located along Sagamu road. There are a number of industries spread around Odongunyan. Some of these industries include PZ, a soap and detergent-manufacturing industry; Spintex, a textile industry; Super Engineering, a rubber and plastic company that produces plastic/rubber wares, and Sunflag Steel, an iron and steel company. These industries constitute the sample sites; the soil and plant samples were collected just outside the walls of these industries. The control site, a semi-residential area, was located about twenty kilometres away from the industrial area of the town.

Sampling sites

The sampling sites in this study were located about 1km distance from one another. The sites were around the PZ, Spintex, Super Engineering and Sunflag Steel industries in Odonguyan.

Soil sample collection

Three soil samples were collected at random from three different points (about 30cm apart), from each location (industrial and control sites) using a soil auger. The soil samples were collected from the rooting zone depth (0 to about 20cm) dueing the wet and dry seasons. The three soil samples from each location were placed in properly labelled polythene bags and taken to the laboratory for analysis of heavy metals (Lead, Cadmium and Zinc).

Plant sample collection

Plant samples were collected based on their coverage or dominance at the site at the same seasons as for the samples. The most common plant species at each location was a weedy plant species, *Tridax procumbens*. Three plant samples were collected from each location and so a total of 15 plant samples were collected. The plants were collected carefully from the rooting zone in order to avoid damage or loss of root tissue.

Soil sample digestion

The soil samples were oven-dried at 100℃ to a constant weight and then sieved using a 2mm mesh sieve. Soil sample digestion was carried out by measuring 5g of each sample to be added to 5mls of concentrated nitric acid (HNO3) in a conical flask. Using an electric hot plate, the content was heated to evaporation until the brown fumes cleared leaving white fumes. 100mls of distilled water was then added to the conical flask and heated to a reduced volume of 50mls. The digest was then filtered using a Whatman paper (11cm) and funnel.

Plant sample digestion

Plants samples were divided into roots and shoots, washed gently with distilled water to remove soil particles stuck to the plants. After washing, the plant samples were oven-dried for 2 hours at 100℃ and then ground and seived with a 2-mm mesh sieve for digestion. Sample digestion is carried out to prevent interference of organic matter and to facilitate easy analysis. For digestion, 3g of each of the ground segment was dissolved in 5mls of concentrated nitric acid (HNO_3) in a conical flask. The content of the flask was stirred and using an electric hot plate, it was heated to evaporation (until the brown fumes cleared leaving white fumes). 100mls of distilled water was then added to the conical flask and heated to a reduced volume of 50mls. The concentrate was then filtered using a filter paper and funnel.

ANALYTICAL METHOD

Determination of soil pH

The pH for each soil sample was measured using the elctrometric method. 5g of soil from each sample site was added to a beaker containing 5mls of distilled water. The content of the beaker was stirred with a glass rod and allowed to settle for about 15 minutes. After this time, it was stirred again, the electrodes were placed in the beaker and then the pH was read.

Determination of the heavy metal concentrations in samples

The soil and plant sample digests were analyzed for Lead, Cadmium and Zinc in three replicates, using the Atomic Absorption Spectrophotometry (AAS) equipment (Buck scientific model 200A). Flame type for all analysis was air-acetylene (acetylene and natural oxygen) and suitable working blanks were prepared from solutions used to digest the samples. Necessary dilution was also made using distilled water to maintain concentrations of the metals at suitable concentration range and then results from the equipment were recorded. The values obtained from the analysis were converted into actual concentrations of metals in the samples using the following equation:

$$\text{Concentration } (\mu g/g) = \text{Calibration reading} \times \frac{\text{Extraction Volume}}{\text{Sample Weight}}$$

Extract volume represents the final volume of digest used for the AAS analysis.

Sample weight represents the weight of sample used (3g of plant and 5g of soil samples).

In this study, extraction volume was 50ml for both soil and plant analysis.

Calculation of the bioconcentration (BCF) and translocation factors (TF) for samples

Bioconcentration factor (BCF) and the translocation factor (TF) were calculated as defined by Joonki *et al.* (2006) as follows:

$$BCF = \frac{\text{Concentration of heavy metal in roots}}{\text{Concentration of heavy metal in soil}}$$

$$TF = \frac{\text{Concentration of heavy metal in shoots}}{\text{Concentration of heavy metal in roots}}$$

RESULTS

The concentrations of heavy metals lead (Pb), cadmium (Cd) and zinc (Zn), along with the pH value of the soil at each sampled point are presented in Table 1. The soil pH of both industrial area and non-industrial area was slightly acidic to near neutral. Generally, the heavy metal concentrations in the soil samples collected from the indutsrial areas were higher than those of the non-industrial area. Also, the heavy metals in the soils were generally higher in the dry season than in the wet season.

In both seasons, Zn was accumulated more in the soils than Pb and Cd had the least accumulation. The levels of the heavy metals in the different soils from the different sites also vary; the heavy metals levels were lowest in the soil from the control site. The Pb level in the soils was significantly higher than Cd level and was significantly lower than the Zn level ($p<0.001$). The Cd level in the soil was also significantly lower than the Zn level in the soils ($p<0.001$). For the soils from the industrial sites, Pb occurred more in the PZ soil than in the other sites, Zn was highest in the soil from the Spintex industry and Cd level was more in the Sunflag and super plastic soils than in the Spintex and PZ soils.

Table 2 shows the levels of Pb, Cd and Zn in the roots, leaves and stems of *T. procumbens* in the wet and the dry seasons. The results reveal that in all the plant samples analyzed for heavy metals, the highest concent-

Table 1. The pH and the heavy metal contents (µg/g) of the soils.

	pH dry	pH wet	Pb dry	Pb wet	Cd dry	Cd wet	Zn dry	Zn wet
Control	5.43±0.01	5.32±0.01	1.09±0.02	1.01±0.01	0.12±0.01	0.07±0.02	7.25±0.01	7.11±0.01*
Sunflag	4.93±0.11	4.69±0.03	2.09±0.02	2.04±0.01	0.24±0.08	0.16±0.02	61.74±0.03	60.52±0.04***
Spintex	5.70±0.05	5.63±0.02	4.43±0.03	4.33±0.02	0.15±0.01	0.03±0.02*	84.04±0.02	83.05±0.04***
PZ	6.43±0.02	6.54±0.03	5.80±0.04	5.69±0.03*	0.08±0.03	0.02±0.01	14.30±0.02	13.20±0.01***
Super plastic	6.66±0.04	6.78±0.04	5.51±0.03	5.39±0.04	0.25±0.02	0.13±0.01	51.79±0.02	50.66±0.04***

*shows the level of significance between the metal in the wet season and the dry season

Table 2. The Levels of Pb, Cd and Zn (µg/g) in the root, stem and leaf tissues of *Tridax procumbens* from the different sites.

Site	Plant Part	Pb Dry	Pb Wet	Cd Dry	Cd Wet	Zn Dry	Zn Wet
Control	Root	3.59 ± 0.05	3.38 ± 0.02	0.25 ±0.03	0.21 ±0.03	103.08±0.02	101.03± 0.03
	Stem	1.44 ±0.02	1.36±0.02	0.18±0.02	0.13±0.02	99.71±0.02	96.71±0.04
	Leaf	1.03 ±0.018	0.96±0.03	0.09±0.04	0.06±0.02	88.61± 0.02	86.43±0.13
Sunflag	Root	10.88±0.06	9.40±0.08	0.71± 0.02	0.53±0.02	176.85± .04	174.87± 0.05
	Stem	8.30±0.05	8.07±0.04	0.66±0.02	0.46±0.00	187.40±0.19	185.16±0.05
	Leaf	1.12 ±0.06	0.97±0.05	0.57±0.02	0.42±0.04	160.13±0.06	158.38±0.28
Spintex	Root	18.34±0.33	17.40±0.25	0.96±0.02	0.60±0.02	193.82±0.31	191.05±0.07
	Stem	3.78 ±0.03	3.40±0.03	0.38±0.23	0.23±0.01	164.46±0.02	161.58±0.31
	Leaf	1.64 ±0.03	1.34±0.03	0.39±0.02	0.22±0.01	127.13±0.04	125.33±0.18
PZ	Root	5.65 ±0.03	5.25±0.02	0.56±0.02	0.36±0.02	184.26±0.03	182.24±0.02
	Stem	2.88 ±0.04	2.45±0.03	0.36±0.01	0.24±0.02	172.01±0.04	170.01±0.04
	Leaf	1.78 ±0.07	1.45±0.03	0.31±0.02	0.20±0.02	136.42±0.03	134.43±0.87
Super	Root	3.59 ±0.05	3.30±0.03	0.40±0.01	0.25±0.03	115.51±0.04	113.32±0.02
	Stem	1.440±0.02	1.28±0.01	0.18±0.03	0.13±0.02	110.04±0.02	108.08±0.04
	Leaf	1.027 ±0.01	0.85±0.02	0.16±0.02	0.13±0.02	82.74±0.02	81.26 ±0.67

rations of Pb, Cd and Zn were recorded in the root tissues, with the leaves and stems containing lower levels of the heavy metals. However the stem and the leaf tissues from the Sunflag industry have levels of the heavy metals than the stems and the leaves from the other sites. Also, the leaves of the plants at both industrial and non-industrial areas recorded higher concentrations of the three heavy metals than the stems. The plants from the non-industrial area (control) recorded significantly lower concentrations of all three heavy metals (Pb, Cd and Zn) in their roots when compared with the roots of plants from industrial areas ($p<0.001$). Significant differences exist between the metals in the different plant parts or different sites ($p<0.001$).

Table 3 indicates the concentrations of Pb, Cd and Zn levels in root tissues, soil samples, and their respective pH, BCF and TF values. In this study, the plant samples accumulated higher concentrations of the three heavy metals in their root tissues than in the soil on which they grow. Higher heavy metal concentrations in plant roots than in the soil, accounts for the correspondingly high BCF values, far greater than 1 for the both industrial and non-industrial areas. Sunflag Steel industry had the highest BCF value of 5.22 for Pb. PZ recorded the highest BCF of 6.88 for Cd while the control site had the highest BCF value of 14.24 for Zn (Table 3). The TF values for Pb ranged from 0.30 at Spintex to 1.53 at Super Engineering site which was the only site with TF greater than 1 for Pb. The TF values for Cd ranged from a low 0.80 at Spintex to 1.70 at Sunflag steel. TF values for Zn was greater than 1, with the values ranging from the lowest of 1.50 at Spintex to 1.96 at Sunflag steel (Table 3). The BCF and TF varied significantly ($p<0.001$) for the different heavy metals in the different sites. Seasonal effects on the accumulation of heavy metals in the biconcentration and the translocation of the heavy metals were not significant ($p>0.05$).

The bioconcentration and translocation factors of the heavy metals in the soils from the different sites are show in Table 3. Table 3 also compares the heavy metals contents in the soils, root tissues and shoot tissues from the different sites. Pb accumulation was more in the root tissues of plant from the control, sunflag industry and spintex industry than in the soil and shoot tissues from same sites. The accumulation of Zn is more in the shoot of the plant in the sites than in the soil and the root. The

Table 3. The levels of the heavy metals in the soil and plant samples showing the biocncentration and translocation factors.

	Pb Dry	Pb Wet	Cd Dry	Cd Wet	Zn Dry	Zn Wet
control soil	1.09±0.02	1.01±0.01	0.12±0.01	0.07±0.02	7.250±0.012	7.113±0.01
control root	3.59±0.05	3.38±0.02	0.25±0.03	0.21±0.03	103.08±0.02	101.03±0.03
control shoot	2.46±0.03	2.47±0.01	0.27±0.05	0.20±0.050	188.31±0.02	186.19±0.05
BCF	3.31±0.03	3.16±0.06	0.26±0.03	0.23±0.02	14.24±0.05	14.16±0.06
TF	0.67±0.04	0.56±0.03	1.08±0.04	1.04±0.03	1.740±0.031	1.70±0.033
sunflag soil	2.10±0.03	2.04±0.01	0.24±0.03	0.16±0.02	61.74±0.03	60.52±0.04
sunflag shoot	9.50±0.03	8.40±0.08	1.46±0.24	1.37±0.20	347.97±0.66	346.30±0.02
sunflag root	10.88±0.06	10.38±0.04	0.71±0.02	0.53±0.02	176.85±0.04	174.870±0.05
BCF	5.20±0.05	5.21±0.05	2.33±0.09	2.05±0.03	2.85±0.06	2.69±0.02
TF	0.86±0.03	0.87±0.06	1.737±0.05	1.537±0.05	1.94±0.03	1.907±0.05
Spintex soil	4.43±0.03	4.33±0.02	0.15±0.01	0.03±0.02	84.04±0.02	83.05±0.04
spintex root	18.34±0.33	17.40±0.25	0.96±0.02	0.60±0.02	193.82±0.31	191.05±0.07
spintex shoot	5.45±0.03	4.64±0.02	0.75±0.03	0.63±0.021	291.62±0.02	290.57±0.02
BCF	4.05±0.03	4.08±0.02	6.48±0.02	6.35±0.03	2.27±0.02	2.24±0.04
TF	0.31±0.03	0.29±0.03	0.77±0.02	0.63±0.02	1.52±0.03	1.42±0.023
PZ soil	5.80±0.04	5.69±0.04	0.08±0.03	0.02±0.01	14.30±0.02	13.20±0.006
PZ root	5.65±0.03	5.25±0.02	0.56±0.02	0.36±0.02	184.26±0.04	182.24±0.02
PZ shoot	4.65±0.04	3.91±0.05	0.64±0.027	0.52±0.03	308.45±0.04	306.34±0.04
BCF	0.98±0.02	0.96±0.02	6.85±0.037	6.62±0.03	15.19±2.36	12.78±0.04
TF	0.85±0.03	0.81±0.03	1.13±0.04	1.04±0.06	1.64±0.03	1.61±0.035
super soil	5.51±0.04	5.39±0.04	0.25±0.02	0.13±0.01	51.79±0.02	50.66±0.04
super root	3.59±0.05	3.30±0.03	0.40±0.01	0.25±0.03	115.52±0.04	113.32±0.02
super shoot	6.67±0.02	6.39±0.04	0.32±0.02	0.21±0.03	192.72±0.02	190.29±0.05
BCF	0.79±0.02	0.69±0.01	1.38±0.05	1.22±0.03	2.25±0.02	2.16±0.04
TF	1.47±0.02	1.25±0.02	0.97±0.03	0.73±0.02	1.63±0.04	1.59±0.04

accumulation of Cd in the different sites did not follow any particular pattern; in some sites, it occurred more in the shoot, more in the root in some sites and more in the soil in some sites.

DISCUSSION

The higher concentrations of the three heavy metals recorded in the industrial area than the non-industrial area and significant difference in the level of Zn in the soils from the industrial and non-industrial areas is an indication that the concentration of heavy metals decreased with increasing distance away from industrial area in conformity with the findings of Agrawal et al. (1988), Akinola et al. (2008). The concentration of Pb, Cd and Zn in the soil was higher in soil samples from the industrial site compared with the non-industrial site. Heavy metals are present in soil naturally and non-degradable, and can be accumulated in the plant tissues (Lasat, 2002; Nriagu, 1990) as shown by the concentrations of heavy metals obtained in soils from non-industrial area, but their concentrations can be increased by industrial activities (Singh, 2001). In this case, chemicals such as dyes and other finishes used on the fabrics can lead to an increase in the concentration of heavy metals in the soils. This is similar to the observation of Abdulkaaheem and Singh (1999), Akinola et al. (2008) in which heavy metals like Cd, Cr, Cu, Pb and Zn in soil and plants samples around tannery and textile industries decreased as the distance from point of effluent discharge increased. Fakayode and Onianwa (2001) made similar observation noting that plant and soil samples from industrial sites contain more heavy metals than those from non-industrial sites. In this study, the control site is 20 kilometres away from the industrial area and there were no industries located in the control area or around its vicinity. For instance, all the industries use diesel for one thing or the other during production and diesel may contain some amount of Cd and Pb. But more specifically, high concentration of Cd of 0.25±0.007µg/g was recorded in soil at Super Engineering where the use of cadmium as stabilizer during plastic production or as plastic coatings and paint pigments, may have contributed to such Cd levels. PZ industry recorded the highest Pb level because it is located along the road and so, vehicular emmissions from exhausts of automobiles may have contributed to elevated Pb levels in the area. Furthermore, industrial effluents, domestic wastes and waste water can increase the concentrations of heavy metals because they are regularly discharged into the environment. Accumulation of heavy metals in soil and vegetation has been reported by Fatoki (2003). The soil of the industrial area was slightly polluted with zinc. Zinc pollution may arise as a result of illicit release of effluents from smelters, electroplating and metallurgical industries and mining, paint/dye industries (Asamit, 1994; Ademoroti, 1996; Odiete, 1999). In this study, the Sunflag Steel industry produces iron and steel and Spintex is a textile company which usually produces large amount of textile effluents which contain heavy metals. The heavy metal concentration in the tissues of *T.procumbens* is in the series of stem < leaves < roots. The roots of plants having higher concentration of heavy metals have been reported by Yang et al., (2003). Lead (Pb) has also been found at lower concentration in foliage of *Talinum triangulare* (Akinola and Ekiyoyo, 2006). This is mainly because the root is the primary site of absorption or uptake of materials from the soil. For instance, plant roots have an ability to take up significant quantities of lead (Pb) whilst simultaneously greatly restricting its translocation to above ground parts (Lane and Martin, 1977). This result is in line with the findings of Chandra and Kulshreshtha (2004); Gosh and Singh (2005). Furthermore, lead (Pb) is classified as a weak Lewis acid, which implies a strong covalent character to many of the ionic bonds it forms in soil and plants. Lead (Pb) present in soil is nearly always tightly bound to organic or colloidal material or in a precipitated form, all of this serve to reduce the uptake of lead (Pb) by plant roots Sharma and Dubey, (2005). Moreover, the pH of low to near neutral recorded for soil could be the cause of high uptake of the heavy metals by the roots since absorption of lead (Pb) has been reported to increase with increasing pH between 3-8.5 (Lee et al., 1998).The high BCF and generally low TF values recorded in this study further confirms the high concentration of the heavy metals in the roots than the shoots of the plant and low translocation to the shoot. This is coupled with the low to near neutral pH of the soil.

The ability of a plant to tolerate and accumulate heavy metals may provide useful information for phytoremediation purposes. The bioconcentration factor (BCF) and translocation factor (TF) can be used to assess a plant's potential for phytoremediation purposes. The BCF also called Multiplication coeffient (MC), estimates a plant's ability to take up heavy metals from the soil to its roots. Translocation factor, TF as defined by Joonki *et al.* (2006) is the ratio of metal concentration in the shoots to the roots. The TF measures a plant's ability to translocate metals from the roots to the shoots.

Tolerant plants usually limit transfer of heavy metals from soil to root and root to shoot, and thus, accumulate less heavy metals in their tissues. Hyperaccumulators on the other hand, actively take up and translocate heavy metals into their shoots. According to Fitz and Wenzel (2002) plants having TF and BCF values less than one have limited ability of heavy metal accumulation and translocation, and are therefore unsuitable for phytoextraction.

REFERENCES

Abdulkaheem MD, Singh BR (1999). Heavy metal concentration of soil and vegetation in the vicinity of industries in Bangladesh. Water, Air, and Soil pollution. 115 (1-4):347-361.

Ademoroti CMA. (1996). Environmental Chemistry and Toxicology. Ibadan Foulex Press Ltd. 215.

Agrawal KM, Sharma HC, Aggarwal. AL (1988). Heavy metal pollution of air, soil and plants around a zinc smelter: A case study. Indian J. Environ. Health. 30(3):234-241.

Akinola MO, Ekiyoyo TO (2006). Accumualtion of lead cadmium and chromium in some plants cultivated along the bank of River Ribila at Odo-nla Area of Ikorodu, Lagos State, Nigeria. J. Environ. Biol.; 27 (3): 597-599.

Akinola MO, Njoku KL, Ekeifo BE (2008). Determination of Lead, Cadmium and Chromium in the tissue of an economically important plant grown around a textile industry at Ibeshe, Ikorodu area of Lagos State, Nigeria. Advances in Environmental Biology. 2 (1):25–30.

Asamit B (1994). Environmental pollution by cadmium and zinc discharged from a Braun tube factory, Ibaraki *Daigaku Nogakubu Gakujutsu Hokakn* 22:19-23.

Chandra P, Kulshreshtha K (2004). Chromium accumulation and toxicity in aquatic vascular plants. *The Bot. Rev.* 70 (3):313-327.

Duruibe JO, Oguegbu, MOC, Egwurugwu, JN (2007). Heavy metal pollution and human biotoxic effects. Int. J. Physi Sci.; 2 (5):112-118.

Fakayode S, Onianwa P (2002). Heavy metal contamination of soil and bioaccumulation in guinea grass *(Panicum maximum*) around Ikeja industrial estate, Lagos, Nigeria. J. Environ. Geo. 43 (1-2):145-150.

Fatoki, OS (2003). Lead, Cadmium and Zinc accumulation on soil and vegetation along some selected roads of Eastern Cape. Int. J. Environ. Studies.60: 199-204.

Ferner DJ (2001). Toxicity, heavy metals. eMed. J. 2 (5):1.

Fitz WJ, Wenze WW (2002). Arsenic transformation in the soil–rhizosphere– plant system, fundamentals and potential application of phytoremediation. J. Biotechnol. 99: 259-78.

Garbarino JR, Hayes H Roth D, Antweider R, Brinton TI, Taylor H (1995). Contaminants in the Mississippi River. U. S. Geological Survey Circular 1133, Virginia, U.S.A.

Gosh M, Singh, SP (2005). Comparative uptake and phytoextraction study of soil induced chromium by accumulator and high biomass weed species. Appl. Ecol. Environ. Res., 3(2):67-79.

Hutton M, Symon C (1986). The Quantities of Cadmium, Lead, Mercury and Arsenic Entering the U.K. Environment from Human Activities. *Sci. Total Environ.* 57: 129-150.

Joonki Y, Xinde C, Qixing Z, Lena Q (2006). Accumulation of Pb, Cu, and Zn in native plants growing on a contaminated Florida site. Science of the Total Environment. 368: 456–464.

Lane SD, Martin ES (1977). A histochemical investigation of lead uptake in Raphanus sativus. New Phytol. 79: 281-286.

Lasat MM (2002). Phytoextraction of toxic metals: A Review of Biological mechanisms. J. Environ. Qual.. 31: 109 -120.

Lee SZ, Yang HH, Chen CM, Liu MC (1998). Absorption characteristics of lead onto soil. J. Haz. Mat.; 63:37-49.

McCluggage D (1991). Heavy Metal Poisoning, NCS Magazine, Published by The Bird Hospital, CO, U.S.A.

Nriagu JO (1990). Global metal pollution: Poisoning the biosphere. *Environment ENVTAR.* 32 (9):7-11, 28-33.
Nriagu JO (1996). History of global metal pollution. *Science.* 272:223–244.
Peplow D (1999). Environmental Impacts of Mining in Eastern Washington, Center for Water and Watershed Studies Fact Sheet, University of Washington, Seattle.
Sharma P, Dubey RS (2005). Lead toxicity in plants. Braz. J. Plant Physiol. 17(1): 35-52.
Singh B (2001). *Heavy metals in soils: Sources, Chemical Reactions and Forms in Geoenvironment.* Proceedings of the 2nd Australia and New Zealand conference on environment geotechniques. New Castle, New South Wales.
Trueby P (2003). Impact of Heavy Metals On Forest Trees From Mining Areas. In: *International Conference On Mining And The Environment III*, *Sudbury, Ontario, Canada.*
Yang B, Shu W, Ye Z, Lan C, Wong M (2003). Growth and metal accumulation in Vetiver and two Sesbania species on lead/Zinc mine tailings. *Chemosphere.* 52:1593-1600.