Journal of Environmental Science and Management 20-1: 1- 9(June 2017) ISSN 0119-1144

Spatial Distribution of Some Toxic Metals in Topsoil and Bioaccumulation in Wild Flora Around a Metal Scrap Factory: A Case of Southwestern Nigeria

ABSTRACT

There is increasing metal pollution in soil due to the spate of industrialization in developing countries. It is premised on this scenario that the topsoil around a metal scrap factory was studied to assess the spatial distribution of metal and resultant mobility in native flora. Concentrations of Cd, Zn, Pb and Fe in samples of topsoil and plants were determined by Atomic Absorption Spectrophotometry. Spatial modelling of metals was carried out using the Inverse Distance Weighted (IDW) technique of ArcGIS. Also, metal mobility in native flora was assessed by the transfer factor model. The analysis showed high levels of Cd, Zn, Fe and Pb that were beyond natural concentrations. Spatial mapping of the concentrations indicated that the immediate north and south of the factory were significantly polluted by Cd, Zn and Pb while Fe presence in the area was partially geogenic. The level of Cd, Zn and Pb in the three native species exceeded permissible limits whereas only Cd showed great mobility within the biomass of the three species. The mobility of Cd in the diagnostic species is an indication of possible potential health risk from Cd toxicity through plants ingestion. It is therefore important that measures should be geared towards improving the pollution control system of the factory to stem down the rate of contamination of soil.

Key words: *Heavy metal, spatial distribution, metal mobility, metal accumulation*

Clement O. Ogunkunle[1*]
Mayank Varun[2]
Oluwatosin E. Olushola[1]
Paul O. Fatoba[1]

[1] Environmental Biology Unit, Department of Plant Biology, University of Ilorin, Nigeria
[2] Department of Botany, St. John's College, Agra-282 002, India

*corresponding author:
seyeogunkunle@gmail.com
ogunkunle.co@unilorin.edu.ng

INTRODUCTION

The spatial variability and characterization of metal concentrations in the topsoil may be affected by soil parent materials, anthropogenic sources and the multiple sources of introduction (*Hanesch et al. 2001; Martin et al. 2006*). Different anthropogenic routes of metal introduction into the soil are industrial emissions and wastes generation, agricultural activities, metalliferous mining and smelting, energy and fuel production, and vehicle emissions (*Zeidler 2005; González and González-Chávez 2006*). It is worthy of note that presence of metals in soil is not only toxic to plants and deteriorates soil optimal bio-productivity but also causes severe threat upon exposure to human health especially at elevated level. Some of these metals (Pb, Cd, Hg, As) are known carcinogens and causes a long term damaging effect on the central nervous system. They are non-biodegradable and they have the tendency to bioaccumulate and biomagnify from one trophic level to another (*Khan et al. 2008; Oti et al. 2012*). Plants grown in polluted environment accumulate toxic metals more than others grown outside such an environment and may pose health hazards to biota and humans, which impose harmful impacts upon increased level of exposure (*Ikeda et al. 2000; Khan et al. 2008; Luo et al. 2011).*

Scrap metals is becoming a booming municipal solid wastes (MSW) business in Nigeria; through scavenging activities, scrap metals are recovered from MSW and recycled into products like iron and steel, copper, brass, aluminum (*Olanrewaju and Ilemobide 2009; Onwughara et al. 2010*). The scrap metal recycling process involves remelting of scraps in an electric arc furnace or induction furnace using up to 90-100% scrap and reheating the formed steel bars in a reheating furnace to produce iron rods. The adoption of furnace systems in metal recycling process always results in the generation of dust and metal fumes depending on the operating temperature and raw material contents (*EPA 2001*). Metal particles in the gaseous emissions, if not properly treated through proper/stringent pollution control may be released and deposited into the environment. Depositions may be at different distances away from the factory depending on the wind speed, particle size, atmospheric temperature and residence time of metal particle (*IFS 2007; Luo et al. 2011*). Some of the toxic metals released during metal scrap recycling process are Cd, Pb, Zn, Cr, Co and Cu (*IFS 2007; OSHA 2008; Luo et al. 2011*).

Due to the potential ecological hazards that the presence of these toxic metals at high concentrations in the soil may cause, this study aimed at investigating the spatial distribution in topsoil and bioaccumulation of some of these metals in wild flora around Prism Steel Mills Company, a 7-year old steel recycling factory. The previous study on the assessment of ecological vulnerability to trace metals in topsoil around this recycling factory by *Ogunkunle et al.* (*2016*) has indicated potential ecological hazards from Cd and Pb. This study aims to assess the spatial distribution of Cd, Zn, Pb, and Fe in the topsoil; and to evaluate metal mobility and accumulation in the native flora around the factory.

METHODOLOGY

Study area

The study was carried out around Prism Steel Mills Company, Ikirun in Southwestern Nigeria (**Figure 1**). The location of the factory, climate and geology of the study area have been previously described in a previous study by *Ogunkunle et al.* (*2016*).

Sampling and chemical analysis

Seventy-five samples of topsoil (0-15 cm) were collected within 1-km radius from the perimeter fence of the factory (*Ogunkunle et al. 2016*) with the aid of GPS equipment (Garmin Etrex 20, USA). Samples of plant species (root + shoot) that were encountered within 1 m radius of each sampling point were collected and enumerated to species level. After identification, 35 samples of *Chromolaena odorata*, 20 samples of *Tithonia diversifolia* and 25 samples of *Sida acuta* were used for the study based on the species composition/abundance.

Soil pH was determined in a soil suspension (1:2.5 w/v) using a glass electrode pH meter (PHC-3C model) and the total organic matter (OM) content was determined by loss on ignition (*Reddy et al. 2009*). Digestion of soil and plant samples were done using aqua regia method (*Chen and Ma 2001*). Briefly as described in *Ogunkunle et al.* (*2016*), 1 g of each sample (soil or plant) was weighed into a 250-mL Pyrex glass beaker, and a mixture of 2 mL concentrated HNO_3 and 6 mL HCl were added and heated on a hot plate for 2 h at a temperature of 110°C until the solution becomes clear. The solution was allowed to cool, filtered using Whatman No. 42 filter paper into a 50-mL volumetric flask and made up to mark with deionized water. Cd, Zn, Pb and Fe in the digest were determined by Atomic Absorption Spectrophotometry using Peckin Elmer A Analyst 200. Quality Assurance/Quality Control (QA/QC) was ensured by replicate digestion, use of blanks and percentage recovery of elements using certified reference materials for soil and plant (IAEA-SL-1 and IAEA 359, respectively) were between 84-95% and 92-110%, respectively.

Statistical analysis and data analysis

Kolmogorov–Smirnov tests was used to evaluate if data were normally distributed since normal distribution of data has been proven to theoretically favour geo-statistical modeling (*Cressie 1993*). Kruskal-Wallis test was used to determine significant differences (P<0.05) among the mean

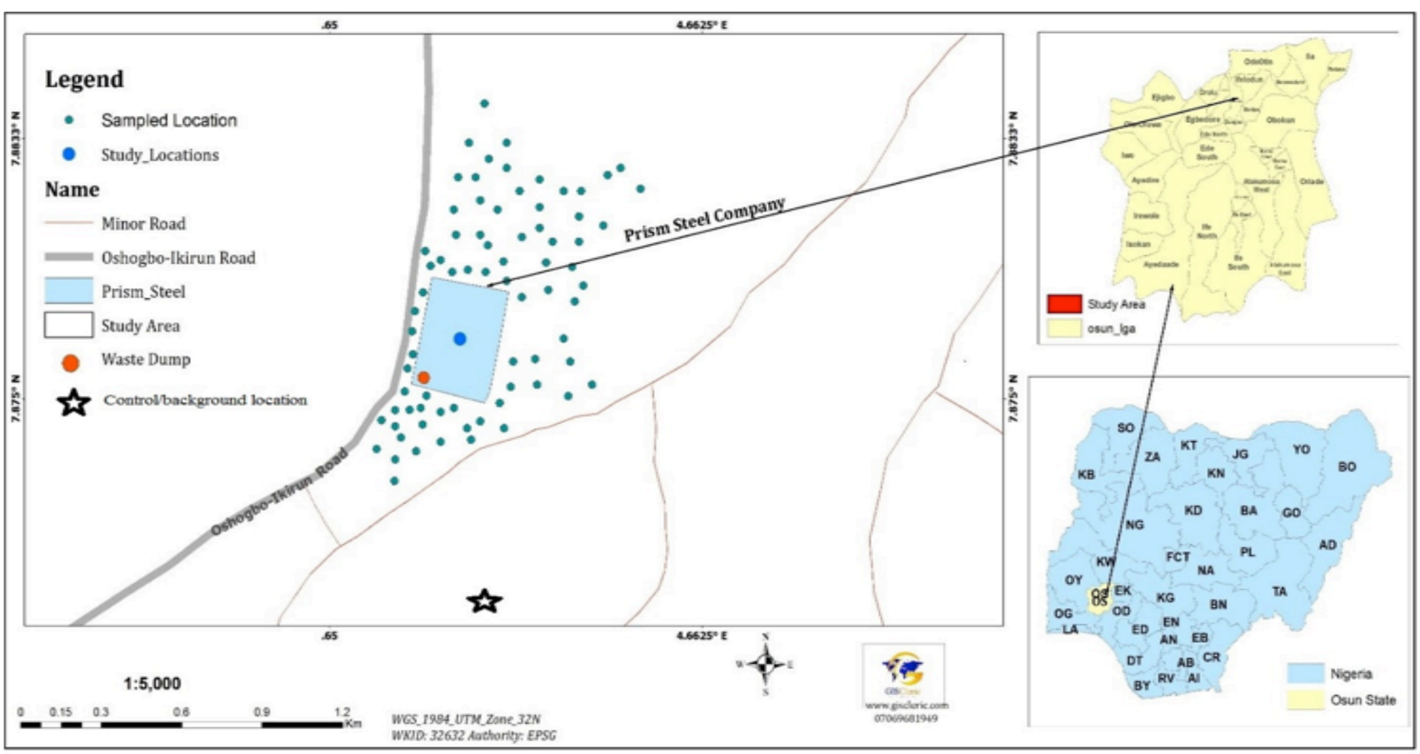


Figure 1. Map of study area showing Prism Steel Mills Company, Southwestern Nigeria (*Ogunkunle et al. 2016*).

concentrations of metals in plant biomass as the distribution of plant data failed the Normality test. Statistical Software for Social Sciences (SPSS) for Windows version 16.0 was used for the analysis.

Spatial distribution of total concentration of Cd, Zn, Pb and Fe in the soil was carried out by Inverse Distance Weighted (IDW) technique of ArcGIS 10 [Environmental System Research Institute (ESRI), Redlands, Canada]. It relies mainly on the inverse of the distance raised to a mathematical power which controls the significance of known points on the interpolated values based on their distance from the output point (*Watson and Philip 1985*).

Assessment of ecological vulnerability through metal transfer in the flora was studied by assessing the mobility of metal (Transfer factor) into plants (*Intawongse and Dean 2006*).

Transfer factor (TF) is defined as the ratio of metal concentration in plant biomass to concentration of total metal in soil (*Cui et al. 2004; Chojnacka et al. 2005*) and expressed in equation 1.

$$TF = \frac{Cp}{Cts} \quad \text{Equation 1}$$

Where:
C_p = the concentration of a particular metal in plant biomass
C_{ts} = the concentration of a particular metal in soil

RESULTS AND DISCUSSION

Level and spatial distribution of Cd, Zn, Pb and Fe in the topsoil around the factory

The chemical characteristics of the topsoil has been previously reported in *Ogunkunle et al.* (*2016*). Soil pH was slightly acidic to neutral and the average soil OM showed a relative fertility of the soil (**Table 1**). These two attributes render metal ions readily bound to soil and reduce bioavailability. Solubility, bioavailability and adsorption of metals to solid phases in soil are influenced by soil properties like the pH and OM (*Alloway 1995; Vega et al. 2004; Stehower et al. 2006*). Despite the vegetation within the site, the OM content in the soil was considerably lower than the soil found within the same region of the state (*Awotoye et al. 2011; Salami and Sangoyomi 2013*), but yet higher than some other soils (*Salami and Sangoyomi 2013*) in other areas.

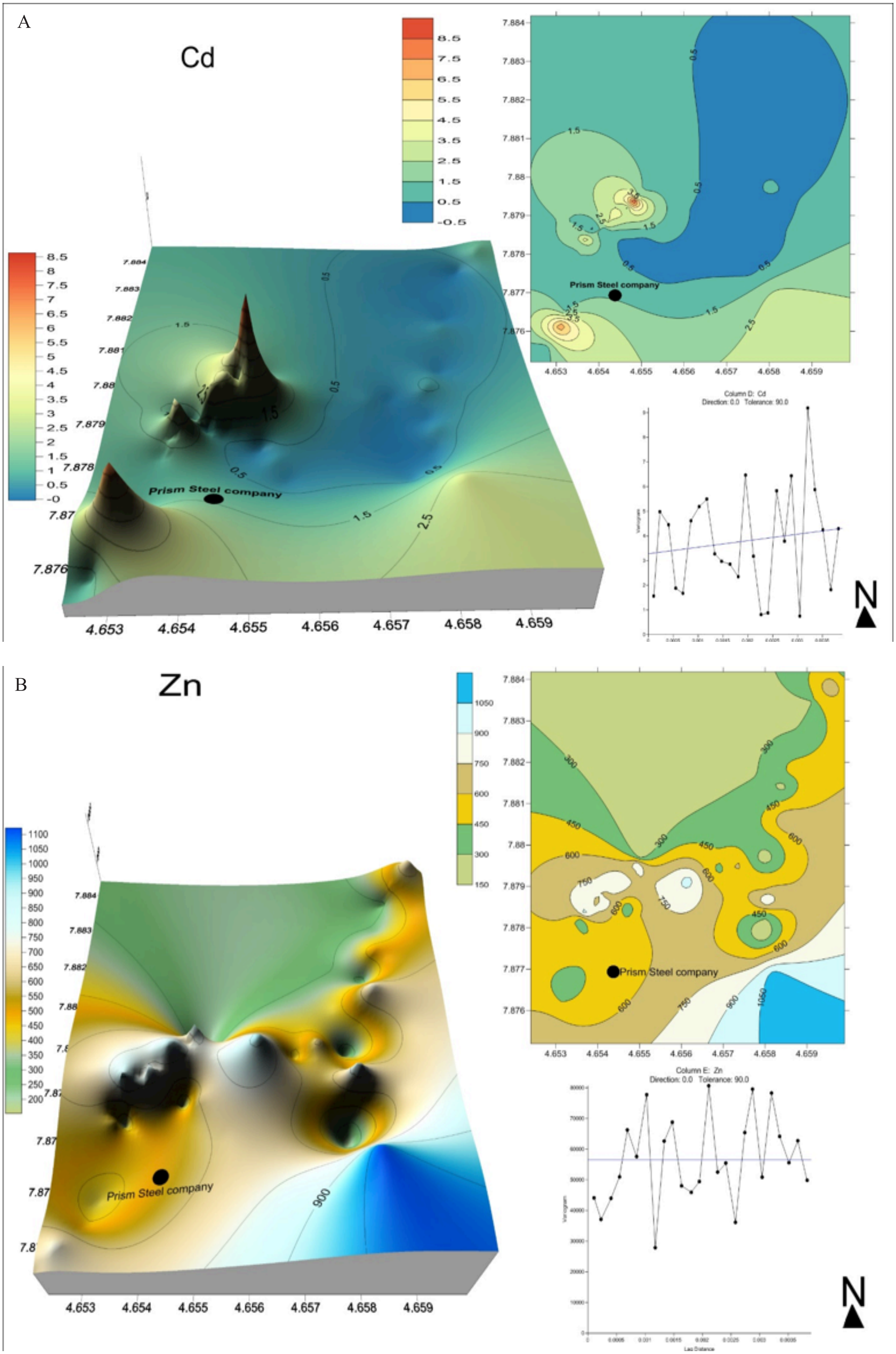
Concentrations of trace metals in the soil varied with some hotspots but the average concentration of the metals followed the order Fe > Zn > Pb > Cd. The results indicated that most of the metal concentrations were above the Environmental Quality Standards for Soils as previously reported by *Ogunkunle et al.* (*2016*). These concentrations were also found to exceed the environmental soil quality guidelines set by the National Environmental Standards Regulations and Enforcement Agency of Nigeria. The levels of Cd, Zn and Pb in the soil surrounding the recycling factory exceeded the crustal value by 4.3, 7.6 and 2.9 folds, respectively; this is an indication of increasing contamination of the topsoil around the factory. Though, the concentrations of metals in the soil may be influenced by the geology of the parent materials, but elevated concentrations above tolerable level is a strong indication of anthropogenic influence on the environment (*Al-Khashman and Shawabkeh 2006; Awotoye et al. 2011*). Furthermore, the mean concentrations of Pb and Zn in the study exceeded concentrations reported in similar studies on metal recycling factories in Spain (*Acosta et al. 2011*), Algeria (*Maas et al. 2010*) and Greece (*Voutsa et al. 1996*). In addition, the level of Cd in this study was higher than the concentrations found in studies on metal recycling factories in Algeria (*Maas et al. 2010*) and Spain (*Acosta et al. 2011*) but lower than Cd concentration (289 mg kg^{-1} and 11.9 mg kg^{-1}) reported for Fe and Zn smelters in Bulgaria and China, respectively (*Li and Huang 2007; Schulin et al. 2007*).

It was realized that all trace metals (Cd, Zn and Pb) except Fe were heterogeneously distributed around the factory with peculiar hotspots indicating potential anthropogenic source. These localized hotspots were mainly located at the north and north-eastern part of the factory. For instance, the mapping of Cd showed low concentration of Cd in the North of the factory while the South of the factory showed an even spread of high concentrations of Cd. Localized 'hotspots' (areas with isolated extreme

Table 1. Descriptive statistics of metal concentrations in the topsoil surrounding the factory (*Ogunkunle et al. 2016*).

	Metal Concentration (mg kg^{-1})					
	pH (H_2O)	OM	Cd	Zn	Pb	Fe
Mean	6.9±0.1	1.5±0.05	1.3±0.9	573.2±141.1	40.5±30.7	20 246.0±5 792.1
Minimum	6.7	1.4	0.5	137.5	3.3	10 875
Maximum	7.2	1.5	9.6	1 125.0	118.7	37 825
CCME[a]	NA	NA	1.4	200	70	NA
Mean crust[b]	NA	NA	0.3	75	14	47200[c]

[a]*Canadian Council of Ministers of the Environment* (*2007*); [b]*Bowen* (*1979*); [c]*Turekian and Wedepohl* (*1961*)


A
Cd
Prism Steel company
Column D: Cd
Direction: 0.0 Tolerance: 90.0
N
B
Zn
Prism Steel company
Column E: Zn
Direction: 0.0 Tolerance: 90.0
Lag Distance
N

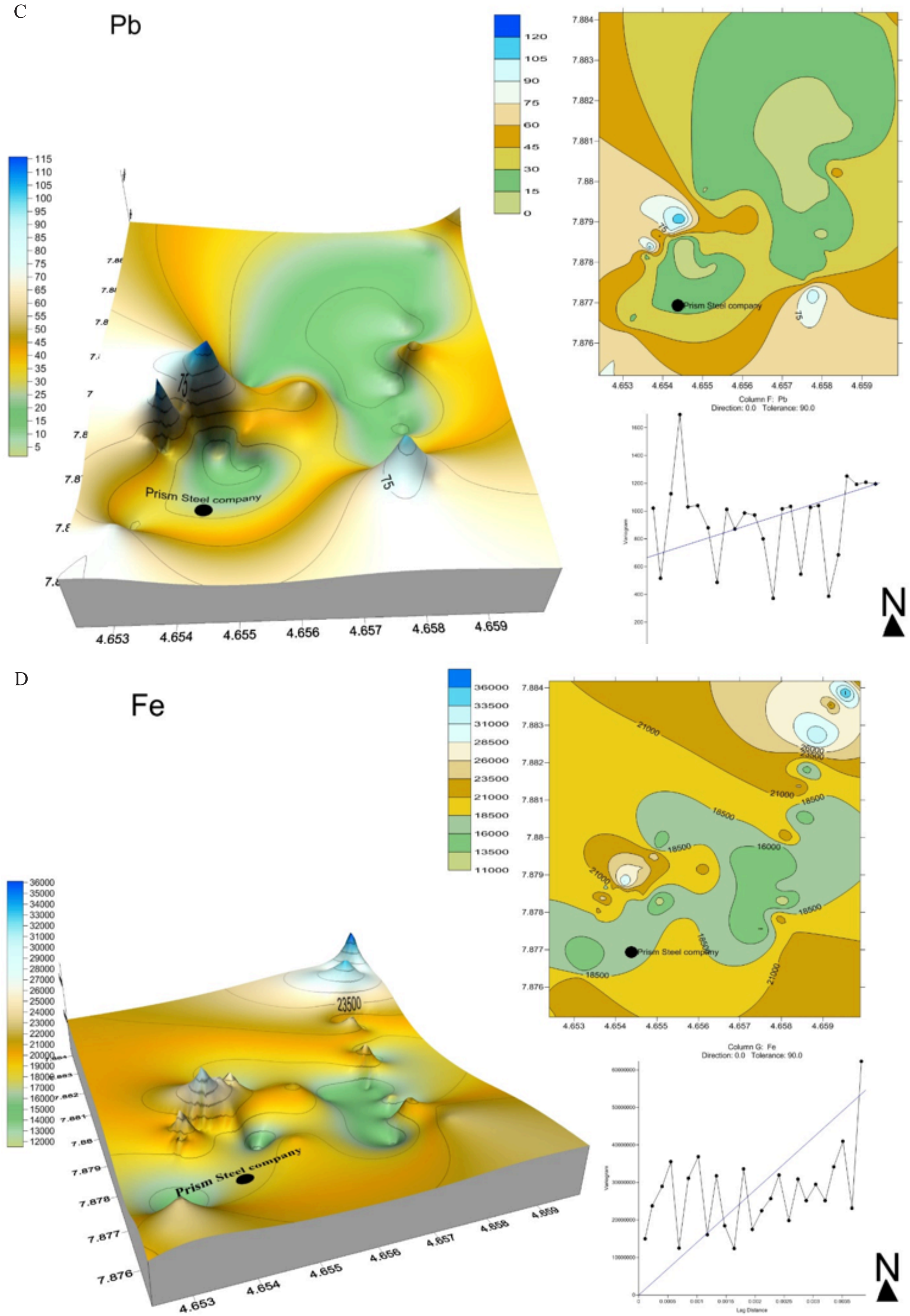


Figure 2. Spatial distribution of (a) Cd, (b) Zn, (c) Pb and (d) Fe in the topsoil using Inverse Distance Weighted technique (ArcGIS 10).

concentrations) of Cd were also noticed in the north and south-east parts of the factory. Kriging graph of Cd distribution indicated relative variability in the concentrations of Cd around the factory (**Figure 2a**). Similarly, low concentrations of Zn were noticed in the far-north of the factory while high concentrations were observed at the immediate north, north-eastern and south-western part of the factory (**Figure 2b**), whilst extremely high concentrations of Zn were also observed at the far south-eastern part of the factory. Variability in the spatial distribution of Pb was noticed in the immediate north and north-eastern part of the factory with some isolated hotspots. Low distribution of Pb was observed at the far north-east of the factory while the far south-eastern was largely distributed with relatively high Pb loads (**Figure 2c**). Mapping of Fe concentrations in the topsoil surrounding the factory indicated extremely low variability (as shown by the Kriging graph) with limited number of hotspots around the northern area of the factory (**Figure 2d**). The low variability indicated by the Kriging graph indicates that Fe was homogenously distributed in the topsoil and that Fe contents in the soil were geogenic in nature, since control soils within Ikirun were <50% of the values in this study as per *Abidemi* (*2013*) and *Abiala et al.* (*2013*).

The heterogeneous distributions of Cd, Zn and Pb in the maps showed that most of the metal contents in the topsoil were from artificial sources, and the main source is likely the factory. Steel and iron manufacturing has long been demonstrated as a major source of trace metals (e.g. Cd and Pb) but depends largely on the type of technology used for processing (*Pacyna 1987*). Cadmium is used in the plating of iron, steel, and other metals, whilst lead is used to increase durability of steel, Zn is used as an alloying and coating element and Fe is also part of the scrap materials used in steel production (*Pacyna 1987; Janke et al. 2000; Arruti et al. 2010*). These metals are often released as particulate matter ($PM_{2.5}$, PM_{10}) associated with dust or as off-gas during pre-treatment and melting stages of steel production. In addition, metal-containing dust particulates are generated from unprotected storage of metal scrap within site for pre-treatment (*Janke et al. 2000; Jiang et al. 2002*). The emitted dust and off-gas would eventually settle on nearby soils by rain or wind and would account for the hotspots of metal concentrations around the immediate vicinity of the factory. The heterogeneous distrbution of Cd, Zn and Pb could be attributed to the wind action as the wind directions in the region are south-westerly and north-easterly in the rainy and dry seasons, respectively. Wind transport of dust has previously been pointed as animportant factor that influences the spread of pollutants from industrial foci (*Al-Khashman and Shawabkeh 2006; Tembo et al. 2006; Owoade et al. 2014*).

Accumulation and transfer of Cd, Zn, Pb and Fe in flora around the factory

Metal accumulation in native flora around the factory resulted to the following pattern: Cd: *C. odorata*=*T. diversifolia*=*S. acuta*; Zn: *T. diversifolia*> *Chromolaena odorata*= *Sida acuta*; Pb: *C. odorata*=*T. diversifolia*=S. *acuta;* and Fe: *T. diversifolia*> *C. odorata*=*S. acuta* at $P<0.05$ **(Table 2**). Level of Cd and Pb in the three native flora exceeded the permissible limit in plant (0.2 mg kg^{-1} and 2.0 mg kg^{-1}, respectively). Concentrations of Zn in *C. odorata* and *T. diversifolia* exceeded the permissible threshold by the Canadian Council of Ministers of the Environment (CCME) while Zn accumulation in *S. acuta* was below the threshold (200 mg kg^{-1}). In comparison with another study, the levels of metals in plants in this study were significantly higher than the reported concentrations in plants by the study of *Owoade et al.* (*2014*) around a similar facility in southwest Nigeria. The possible reason for this variation is pinned on the factory's duration of production. In this study, the factory is operating for seven years as against the less than 4 years of production in the report of *Owoade et al.* (*2014*). The near neutral pH (6.91) and OM content (1.4%) are responsible for reducing potential mobility and bioavailability of some of the trace metals despite the high concentrations found in soil. However, within the soil matrix, fractions of individual metal are bioavailable to biota, whilst residual fractions are non-bioavailable (restricted by pH and OM) at particular time, however if the concentration of such trace metals increases, the fraction of individual metals bioavailable or mobilized increases owing to carrying capacity of the soils (*Papadopoulos et al. 2007*; *Zeng et al. 2011*; *Adamo et al. 2014*). Although not investigated, metals often exist in four major forms in soils: dissolved, mineral, organic and sorbed (bound to soil). Most of the metals remain bound in soil mineral and organic matter, and is non-bioavailable to biota such as plants (*Jones and Jacobsen 2009; Zeng et al. 2011*).

The metal transfer to the native flora in terms of transfer factors (TFs) were analyzed (**Figure 3**). Transfer of Cd in *C. odorata* was greater than 1.0 (TF_{Cd}>4.0) and 54% of sampled plant species recorded TF>1.0 while TF_{Zn}, TF_{Pb} and TF_{Fe} were below 1.0. *T. diversifolia* also recorded TF_{Cd} greater than 1.0 (TF_{Cd} >6.0) and 56% of the plant species that were sampled gave TF>1.0 while TFs for Zn, Pb and Fe were below 1.0. The same pattern of TF recorded in *T. diversifolia* was the same in *S. acuta*. TF_{Cd} was greater than 1.0 (TF_{Cd} >8.0) and 74% of sampled plants recorded TF>1.0 while TF_{Zn}, TF_{Pb} and TF_{Fe} were below 1.0. Since greater than 50% of total number of sampled plants had TF_{Cd}>1.0 in all the plant species, these species can be referred to as potential accumulator of Cd. Several studies

Table 2. Metal accumulation in plant species growing around Prism Steel Mills factory.

	Metal Accumulation in Plant Biomass (mg kg^{-1})				
Plant Species	**N**	**Cd**	**Zn**	**Pb**	**Fe**
Chromolaena odorata[1]	35	0.9±0.5[a*]	225.6±80.7[b]	9.3±3.91[a]	746.1±100.6[b]
Tithonia diversifolia[1]	20	0.8±0.6[a]	323.5±134.6[a]	12.4±6.8[a]	1 213.1±266.1[a]
Sida acuta[1]	25	0.8±0.5[a]	184.4±53.9[b]	10.8±6.9[a]	453.1±140.6[b]
Permissible limit in plant[2]		0.2	200	2.0	NA

*Values with the same letter are not significantly different at $P<0.05$ by Kruskal Wallis test.
[1]Refers to perennial herb; [2]*FAO/WHO* (*1996*); NA- Not applicable

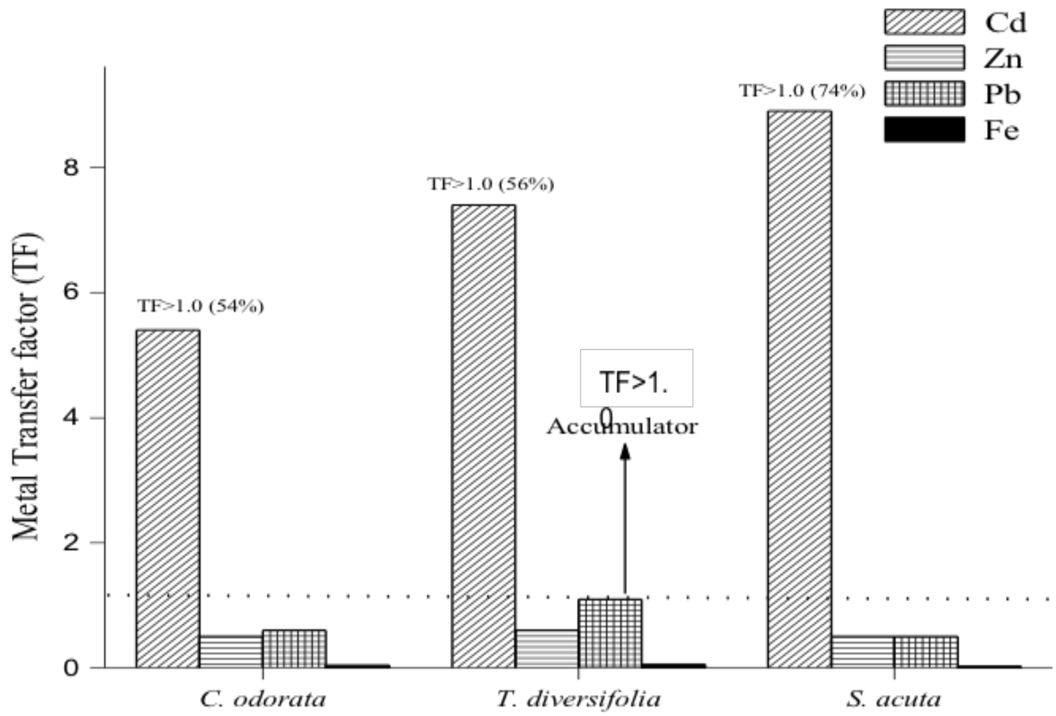


Figure 3. Transfer factor (TF) of metals in biomass of plant species around Prism Steel Mills factory.

have also reported the potential of *S. acuta* to accumulate and phytoextract Cd from polluted soil (*Gupta and Sinha 2007; Ogunkunle et al. 2014*) and the possible reason for greater accumulation of Cd by the three species could be linked to the nature of Cd, it is less retained by the soil than other toxic metals (*Lokeshwari and Chandrappa 2006*). It has also been reported that plants could accumulate Cd more efficiently than other trace metals in the ecosystem (*Amoo et al. 2005; Fagbote and Olanipekun 2010*). Ecological implications of the high mobility of Cd in the flora around the factory could be felt primarily on herbivores that browse on these plants through biomagnification of Cd and therelative transfer to humans through the food chain.

CONCLUSION

The study has evaluated the metal status of the surrounding topsoil of metal scrap factory after seven years of production. It was found that Cd, Zn and Pb have been greatly enriched in the soil and the level of pollution was high but still manageable if consideration to pollution control is given by the factory. Spatial mapping of metal concentrations showed that the immediate environment of the factory is at risk of progressive contamination which may portend potential ecological hazards. Plant species found at the surrounding showed reduced accumulation of Zn, Pb and Fe while Cd showed significant mobility in the studied species; which is suggestive of being potential Cd accumulator. The high mobility of Cd in the soil seems to indicate serious ecological problem because of the potential transfer of Cd along the food chain. It is recommended that increased efforts should be put into the pollution control system of the factory so that metal levels in the soil especially Cd and Pb would not exceed tolerable threshold.

REFERENCES

Abiala, M.A., Odebode, A. C., Adeoye, G. O., Hsu, S., Blackood, C. B. 2013. "Soil Chemical Dynamics in Maize Field of Southwestern Nigeria". *American-Eurasian Journal of. Agriculture and Environmental Science* 13: 234-243.

Abidemi, O.O. 2013. "Accumulation and contamination of heavy metals in soil and vegetation from industrial area of Ikirun, Osun State, Nigeria". *Global Journal of Pure and Applied Chemistry Research* 1: 25-34.

Acosta, J. A., Faz, A., Martinez-Martinez, S., Arocena, J. M. 2011. "Enrichment of metals in soils subjected to different land uses in a typical Mediterranean environment (Murcia City, southeast Spain)". *Applied Geochemistry* 26: 405-414

Al-Khashman, O.A. and Shawabkeh, R. A. 2006. "Metal distribution in soils around the cement factory in southern Jordan". *Environmental Pollution* 140: 387–394.

Alloway, B.J. 1995. "Soil processes and the behaviour of metals. In: B. J. Alloway (Ed.), Heavy Metals in Soils (pp. 38–57). London, Blackie Academic & Professional.

Amoo, I. A., Adebayo, O. T., Lateef, A. J. 2005. "Evaluation of heavy metals in fishes, water and sediments of Lake Kanji". *Nigeria Journal of Food, Agricultural Environment* 3(1): 209-212.

Arruti, A., Fernandez-Olmo, I., Irabien, A. 2010. "Evaluation of the contribution of local sources to trace metals levels in urban PM2.5 and PM10 in the Cantabria region (Northern Spain)". *Journal of Environmental Monitoring* 12: 1451–1458.

Awotoye, O. O., Dada, A. C., Arawomo, G. A. O. 2011. "Impact of palm oil processing effluent discharge on the quality of receiving soil and river in South Western Nigeria". J*ournal of Applied Sciences Research* 7(2): 111-118.

Bowen, H.J.M. 1979. Environmental chemistry of the elements. Academic Press, London. 333pp

Canadian Council of Ministers of the Environment 2007. Canadian soil quality guidelines for the protection of environmental and human health: Summary tables. Updated September, 2007, Winnipeg, Canada.

Chen, M. and Ma, L.Q. 2001. "Comparison of three aqua regia digestion methods for twenty Florida soils". *Soil Sci. Soc. Am. J.* 65: 491-499

Chojnacka, K., Chojnacki A., Gorecka H., Gorecki H. 2005. "Bioavailability of heavy metals from polluted soils to plants". *Science of the Total Environment* 337: 175-182.

Cressie, N. 1993. Statistics for Spatial Data, Revised edition. John Wiley & Sons Inc., New York.

Cui, Y.J., Zhu, Y. G., Zhai, R. H., Chen, D. Y., Huang, Y. Z., Qiu, Y., Liang, J. Z. 2004. "Transfer of metals from soil tovegetables in an area near a smelter in Nanning, China". *Environment International* 30: 785-791.

EPA 2001. Emission Inventory Improvement Program. U.S. Environmental Protection Program. 2001. http://www.epa.gov/ttn/chief/eiip/

Fagbote, E. O. and Olanipekun, E. O. 2010. "Evaluation of the status of heavy metal pollution of soil and plant (Chromolaena odorata) of Agbabu Bitumen Deposit Area, Nigeria". *American-Eurasian Journal of Scientific Research* 5(4): 241-248.

González, R. C. and González-Chávez, M. C. A. 2006. "Metal accumulation in wild plants surrounding mining wastes". *Environmental Pollution* 144: 84-92. doi:10.1016/j.envpol.2006.01.006

Gupta, A.K. and Sinha, S. 2007. "Phytoextraction capacity of the plants growing on tannery sludge dumping sites". *Bioresource Technology* 98(9): 1788-1794

Hanesch, M., Scholger, R., Dekkers, M. J. 2001. "The application of Fuzzy C-Means cluster analysis and non-linear mapping to a soil data set for detection of polluted sites". *Physical Chemical Earth Science*s 26: 885-891

Ikeda, M., Zhang, Z. W., Shimbo, S., Watanabe, T., Nakatsuka, H., Moon, C. S., Matsuda, I. N., Higashikawa, K. 2000. "Urban population exposure to lead and cadmium in east and south-east Asia". *Science of the Total Environment* 249: 373-384.

Intawongse, M. and Dean, J. R. 2006. "Uptake of heavy metals by vegetable plants grown on contaminated soil and their bioavailability in the human gastrointestinal tract". *Food Additives and Contaminants* 23(1): 36-48.

International Finance Corporation (IFS), (2007) Environmental, health, and safety guidelines for integrated steel mills. World Bank Group Report

Janke, D., Savov, L., Weddige, Shulze, E. 2000. "Scrap-based steel production and recycling of steel". *Materiali in Tehnologije* 34: 387-399.

Jiang, L., Yang, X., Ye, H., Shi, W., Jiang, Y. 2002. "Effect of copper refining on spatial distribution of heavy metal in surrounding soils and crops". *Journal of Zhejiang University (Agriculture & Life Science)* 28: 689-693.

Jones, C. and Jacobsen, J. 2009. Micronutrients: Cycling, Testing and Fertilizer Recommendations. Nutrient management modules 7, 4449-7. Montana State University Extension Service, Bozeman, Montana. pp. 1-16.

Li, X. and Huang, C. 2007. "Environment impact of heavy metals on urban soil in the vicinity of industrial area of Baoji city, P.R. China". *Environmental Geology* 52: 1631-1637.

Lokeshwari, H. and Chandrappa, G. T. 2006. "Impact of heavy metal contamination of Bellandur lake on soil and cultivated vegetation". *Current Science* 91(5): 622-627

Luo, C., Liu, C., Wang, Y., Liu, X., Li, F., Zhang, G., Li, X.

2011. "Heavy metal contamination in soils and vegetables near an e-waste processing site, south China". *Journal of Hazardous Materials*, 186: 481-490

Maas, S., Scheifler, R., Benslama, M., Crini, N., Lucot, E., Brahmia, Z., Benyacoub, S., Giraudoux, P. 2010. "Spatial distribution of heavy metal concentrations in urban, suburban and agricultural soils in a Mediterranean city of Algeria". *Environmental Pollution* 158: 2294-2301.

Occupational Safety and Health Administration (2008) Guidance for the identification and control of safety and health hazards in metal scrap recycling. Occupational Safety and Health Administration, U.S. Department of Labor, Washington, DC, USA.

Ogunkunle, C. O., Fatoba, P. O., Oyedeji, A. O., Awotoye, O. O. 2014. "Assessing the heavy metal transfer and translocation by Sida acuta and Pennisetum purpureum for phytoremediation purposes". *Albanian Journal of Agricultural Sciences* 13(1): 71-80

Ogunkunle, C. O., Varun, M., Dawodu, O. F., Awotoye, O.O., Fatoba, P. O. 2016. "Ecological vulnerability assessment of trace metals in topsoil around a newly established metal scrap factory in southwestern Nigeria: geochemical, geospatial and exposure risk analyses". *Rendiconti Lincei* 27(3): 573-588.

Olanrewaju, O.O. and Ilemobade, A. A. 2009. "Waste to wealth: A case study of the Ondo State Integrated Wastes recycling and treatment projects, Nigeria". *European Journal of Social Science* 8(1): 7-16.

Onwughara, N.I., Kanno, O. C., Chukwuma, R. C., Nnorom, I. C. 2010. "Disposal methods and heavy metals released from certain electrical and electronic equipment wastes in Nigeria: Adoption of environmental sound Recycling system". *International Journal of Environmental Science and Development* 1(4): 290-297.

Oti-Wilberforce, J. O. Nwabue F. I., Afiukwa J. N. 2012. "Analysis of heavy metals in soils of Enyigba and Abakaliki using Proton Induced X-ray Emission (Pixe) spectroscopy". *Environment and Pollution* 1(2): 183-193

Owoade, O. K., Awotoye, O. O., Salami, O. O. 2014. "Ecological vulnerability: seasonal and spatial assessment of trace metals in soils and plants in the vicinity of a scrap metal recycling factory in Southwestern Nigeria". *Environmental Monitoring and assessment.* DOI 10.1007/s10661-014-3896-1

Pacyna, J. M. 1987. "Atmospheric Emissions of Arsenic, Cadmium, Lead and Mercury fromHigh Temperature Processes in PowerGeneration and Industry". In: Lead, Mercury, Cadmium and Arsenic in the Environment (eds. T. C. Hutchinson and K. M. Meema). John Wiley & Sons Ltd, USA. pp 69-87.

Papadopoulos, A., Prochaska, C., Papadopoulos, F., Gantidis, N., Metaxa, E. 2007. "Determination and evaluation of cadmium, copper, nickel, and zinc in agricultural soils of western Macedonia, Greece". *Environmental Management* 40: 719-726.

Reddy, K.R., Hettiarachchi, H., Gangathulasi, J., Bogner, J. E., Lagier, T. 2009. "Geotechnical properties of synthetic municipal solid waste". *International Journal of Geotechnical Engineering* 3: 429-438.

Rodrıguez-Martin, J. A., Arias, M. L., Grau-Corbi, J. M. 2006 "Heavy metals contents in agricultural topsoils in the Ebro basin (Spain). Application of the multivariate geoestatistical methods to study spatial variations". *Environmental Pollution* 144: 1001-1012

Salami, B. T. and Sangoyomi, T. E. (2013). Soil fertility status of cassava fields in south western Nigeria. A*merican Journal of Experimental Agriculture,* 3(1): 152-164

Schulin, R., Curchod, F., Mondeshka, M., Daskalova, A., Keller, A. 2007. "Heavy metal contamination along a soil transect in the vicinity of the iron smelter of Kremikovtzi (Bulgaria)". *Geoderma* 140: 52-61.

Stehouwer, R., Day, R. L., Macneal, K. E. 2006. "Nutrient and trace element leaching following mine reclamation with biosolids". *Journal of Environmental Quality* 35(4): 1118-1126.

Tembo, B.D., Sichilongo, K., Cernak, J. 2006. "Distribution of copper, lead, cadmium and zinc concentrations in soils around Kabwe town in Zambia". *Chemosphere* 63: 497-501.

Turekian. K.K. and Wedepohl, K. H. 1961. "Distribution of elements in some major units of the Earth's crust". *Geological Society of America Bulletin* 72: 175-192.

Vega, F.A., Covelo, E. F., Andrade, M. L., Marcet, P. 2004. "Relationships between heavy metals content and soil properties in minesoils". *Analytica Chimica Acta* 524: 141–150

Voutsa, D., Grimanis, A., Samara, C. 1996. "Trace elements in vegetables grown in an industrial area in relation to soil and air particulate matter". *Environmental Pollution* 94: 325-335.

Watson, D.F. and Philip, G. M. 1985. "A refinement of inverse distance weighted interpolation". *Geo-Processing* 2: 315-327.

Zeidler, M. 2005. "Heavy metals in two herb species (river Morava, Czech Republic)". *Polish Journal of Ecology* 53: 185-195.

Zeng, F., Ali, S., Zhang, H., Ouyang, Y., Qiu, B., Wu, F., Zhang, G. 2011. "The influence of pH and organic matter content in paddy soil on heavy metal availability and their uptake by rice plants". *Environmental Pollution* 159: 84-91.