ASSESSMENT OF HEAVY METALS CONCENTRATIONS IN SOILS OF ACID BATTERY WASTE DUMPSITES IN ABA SOUTHEASTERN NIGERIA

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ABSTRACT

A study of heavy metals concentrations in battery waste dumpsites in Aba Southeastern Nigeria (Latitude 5^0 8′ 59″ and Longitude 7^0 19′ 49″) was conducted. A transect soil survey was used to guide soil sampling. Soil samples (0-20cm) were collected from two dumpsites using a Stainless Steel Auger and the control was collected 100m away from the dumpsites. The samples were air-dried and digested with concentrated HNO_4 and $HClO_4$ acids; Pb, Cu, Mn, Cd, Cr, Fe, Ni and Zn were determined using an Atomic Absorption Spectrophotometer model 211VGP. Data were analyzed statistically using mean, standard deviation and coefficient of variation measured in percentage. The mean concentrations of Pb, Cu, Mn, Cd, Cr, Fe, Ni and Zn in dumpsite 1 (Umuaduru dumpsite) were (1183, 3133, 4550, 416, 3783, 4383, 1216, 886)ppm respectively, while their concentrations in dumpsite 2 (Umuehilegbu dumpsite) were (1666, 3700, 4016, 633, 4333, 4483, 1500, 1234)ppm respectively. The results showed a significant difference between the concentrations of heavy metals studied in the dumpsites and the control (P>0.05). The heavy metals released were found to follow the order; Cd < ZN < Ni < Pb < Cu < Cr < Mn < Zn. The study found that there is an ongoing build up of toxic heavy metals in soil at the dumpsites studied and their concentrations were already higher than the established limits for some metals. The study recommends; prevention of any form of farming on the dumpsites, relocation of the dumpsites out of the city, segregation of wastes at the point of generation, use of geosynthetic clay liners as barriers for the prevention of leachate percolation.

Keywords: Municipal Waste, Dumpsites, Heavy Metals, Soil.

INTRODUCTION

The amount and variety of waste materials have increased with technological advancement, growing human population and industrial processes. Of the known pollutants, heavy metals cause adverse effects on the environment. The disposal of domestic, commercial and industrial garbage in the environment is a problem that continues to grow with human civilization and no method so far is completely safe (Abdus-Salam, 2009). The non free flowing or sticky nature of solid waste gives rise to the accumulation of solid wastes on some habitable parts of the earth surface.

Most commonly, municipal solid wastes are solids, semi-solids or liquid in containers thrown out of houses, commercial and industrial premises. Municipal waste varies in composition which may be influenced by many factors such as culture, affluence and

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location. In Nigeria today, urban centers are experiencing an increased rate of environmental deterioration with refuse dumped along drainage channels. Most cities are faced with waste management problems. This is due to improper solid waste handling and disposal system within the society. It is estimated that between a third and half of waste generated in urban areas goes uncollected (Adefemi *et al*, 2009). Poor management of dumpsites could create a number of adverse environmental impacts including wind blow litter, attraction of mice and pollutants such as leachate which can pollute underground soil bed/aquifer. Leachate from dumpsites is of particular interest when it contains potentially toxic heavy metals. These metals are known to bioaccumulate in soil and have long persistence time through interaction with soil component and subsequently enter food chain through plants and animals. Household and industrial garbage may contain toxic materials such as lead, mercury, cadmium, manganese from batteries, insect sprays, nails, polish cleaners, plastics or polyvinyl chlorides, bottles and other assorted product which have unknown physiological benefits when ingested (Dosumu *et al*, 2003).

Heavy metals are natural components of the earth crust. However, soil contamination with heavy metals is an environmental problem on a global scale and it is becoming increasingly important as industrialization, human population and consumption pattern increases. Most often, pollution by heavy metals stems from industrial discharge in addition to Urban and commercial wastes to soils (Carafa *et al,* 2007). Metals such as Cadmium, Lead, Zinc, Mercury and Copper that possess electron configuration containing 10-12 outer electrons are often toxic to biota at relatively low concentration. Heavy metals that accumulate in soil or plants through leaching or absorption may be toxic to man, livestock or other animals that depend on the water, plant or soil for food, drinking or shelter (Gad *et al*, 2007).

Heavy metals cannot be degraded and there is evidence to show that heavy metals such as Arsenic, Nickel, Cadmium, Lead and Chromium are present in raised levels in mature compost. Leachate from the composting process may also contain heavy metals. Chronic exposure to Cadmium (ingestion or inhalation) results in kidney damage as well as gastrointestinal symptoms, loss of sense of smell, nasal discharge, nose and throat irritation, lack of appetite, weight loss, nausea, tooth discoloration, bone structure defects, liver damage, anemia, pulmonary emphysema, chronic bronchitis, bronchopneumonia and death. Cadmium can contaminate the environment through the application of phosphate fertilizers and sewage sludge to soils and incineration of municipal waste. Cadmium is relatively mobile in soils and can be taken up by plants (Deportes *et al*, 1995).

Chromium can contaminate the environment through waste disposal practices. Once within the soil environment, most metals including chromium become bound to clay and organic matter and typically will be effectively immobilized. Lung cancer is the health effect of concern at environmental exposure levels. Lead is present in solid waste residue. Lead is a cumulative toxin that affects a wide range of biochemical processes in the body. Pregnant women, the foetus, the new born infants and children up to the age of 6 years are more susceptible to lead poisoning.

The major effect of lead may include anaemia, effects on the nervous system, reproductive system, cardiovascular, and hepatic, renal endocrinal and gastrointestinal systems. Lead is toxic even at low concentration and has no function in biochemical process (Sobolv *et al*, 2008). Nickel can contaminate the environment through waste disposal practices. Effects of acute Nickel poisoning include frontal headache, vertigo nausea. Nickel is also carcinogenic and affects reproductive health negatively.

Soil is a vital resource for sustaining basic needs, a quality food supply and a livable environment. It serves as a sink and recycling factory for both liquid and solid wastes. Municipal solid waste has been found to contain appreciable quantity of heavy metals which may eventually end up in the soil and are leached down the profile. This qualifies municipal solid waste as among the principal sources of heavy metals in the environment. The extent of soil pollution by heavy metals and base metal ions some of which are soil micronutrients is very alarming. It has been observed that the larger the Urban area, the lower the quality of the environment. This has been one of the reasons why problems of solid waste disposal have reached critical stage in major Cities of Nigeria (Sutter *et al*, 2004).

However, this research work examines the concentrations of heavy metals in soil at refuse dumps with a view of creating environmental awareness to the government and the public on the present state of the dumpsites.

MATERIALS AND METHODS

Study Area

This study was conducted in two dumpsites in Aba Southeastern Nigeria. The area has a land mass of 198km^2 and lies between Latitude 5^0 8′ 59″ N and Longitude 7^0 19′ 49″E. The area lies within the humid tropics characterized by 9 months of rainfall and 3 months of dryness. Rainfall distribution in the area is bimodal and averages 200cm annually with a relative humidity of 80% and mean temperature of 21^{0}C. The area is principally influenced by two air masses; the tropical maritime air mass (Southwest Trade Wind) and the Tropical continental air mass (Northeast Trade Wind). The topography of the area is basically plain and its hydrology is governed by the Aba River. The commercial and industrial city of Aba is located in close proximity to the area. Dry season vegetable production, arable farming, business activities of different sizes are major socio-economic activities in the area. Metropolitan services such as automobile activities, agro industries, several manufacturing businesses, food vending, packaging activities and others are prominent.

Site Description

Site 1

This burrow pit is located in Umuaduru in Osisioma Ngwa Aba along the Enugu-Port Harcourt expressway. It was excavated to source for materials for road foundation during road building in the area. Waste dumped at this site include; plastic materials, bottles, cartons, textile materials, electrical wires, cans, leather materials, metal objects, used oil cans and commercial and domestic wastes of various compositions.

Site 2

This burrow pit is located in Umuehilegbu in Osisioma Ngwa Aba along Enugu-Port Harcourt expressway close to Ariaria International Market Aba and directly opposite the famous Umuehilegbu Industrial Shoe Market (Bakasi). The ditch was also excavated to source for materials for road building. Wastes deposited on this site are similar to those of site 1.

Field Studies

A transect soil survey technique was used to guide soil sampling. A traverse was cut from center (origin) of the dumpsites outwards. Four outstanding land units were identified for the study. They include dumpsite (Heavily dumped) 10M away from dumpsite (moderately dumped), 20m away from dumpsite (slightly dumped) and 100m away from dumpsite (control). The dumpsites were sampled after the fresh wastes were cleared to reach topsoil. Surface (0-20cm) samples of the dumpsites were taken with stainless steel auger. Control soil sample was taken 100m away from where the wastes have not extended. Ten auger bores were thoroughly mixed together to get a composite sample for each of the sampling point. The composite was sub sampled for Laboratory analysis.

Laboratory Analysis

The soil samples were air-dried at room temperature and sieved through a 2mm sieve and the products were used for routine Laboratory analysis. The soil pH was measured in a 2:1 soil to distilled water suspension with a P^H meter model 407A. The heavy metals; Pb, Cu, Cr, Mn, Cd, Fe, Ni and Zn were determined using the perchloric acid digestion method and reading the concentration from the absorbance in Atomic Absorption Spectrophotometer model 211VGP. The mean values of the parameters generated were subjected to statistical analysis using the standard deviation and coefficient of variation to show the variation of the mean values of the dumpsites from the control.

RESULTS AND DISCUSSION

The results of the concentrations of Pb, Cu, Mn, Cd, Cr, Fe, Ni and Zn in soil at the dumpsites and control are shown in Tables 1 and 2 below.

Table1: Concentrations of Heavy Metals in Dumpsite 1

Parameters (ppm)	PT1	PT2	PT3	Mean	Control
Pb	1950	900	700	1183.33	102
Cu	3400	2800	3200	3133.33	177
Mn	3300	5250	5100	4550	1725
Cd	550	300	400	416.67	175
Cr	5150	2900	3300	3783.33	265
Fe	4800	4400	3950	4383.33	2525
Ni	1750	850	1050	1216.67	97
Zn	1122	835	701	886.00	58

PT1= Heavily dumped, PT2= Moderately dumped, PT3= Slightly dumped

Table 2: Concentrations of Heavy Metals in Dumpsite 2 (Umuehilegbu Dumpsite)

Parameters (ppm)	PT1	PT2	PT3	Mean	Control
Pb	2200	1750	1050	1666.67	102
Cu	4250	3900	2950	3700.00	177
Mn	5450	3650	2950	4016.67	1725
Cd	800	650	450	633.33	175
Cr	5450	4800	2750	4333.33	265
Fe	5150	4600	3700	4483.33	2525
Ni	2300	1600	750	1500	97
Zn	1423	1300	980	1234.33	58

PT1 = Heavily dumped, PT2 = Moderately dumped, PT3 = Slightly dumped

DISCUSSION

The concentration of Pb in soil at the dumpsites ranged from 700 to 2200ppm. Higher concentration of Pb was recorded in dumpsite 2 with a mean of 1666.67ppm, while lower concentration was recorded in dumpsite 1 with a mean of 1183.33ppm. The control sample recorded 102ppm. There was a significant difference / variation between the concentration of Pb in soil at the dumpsites and the control with a positive correlation. (Awokunmi *et al*, 2010) reported concentration of Pb in soil at Ikere and Ado Ekiti dumpsites that was higher than the one obtained in this study, but (Adelekan *et al*, 2011) reported the mean concentration of Pb in 5 dumpsites in Ibadan that was lower than the one obtained in this study, while (Aluko *et al*, 2003) in presenting the results of a study on Ibadan dumpsites reported the concentration of Pb that was comparable to the one obtained in this work. These variations could be attributed to the nature, composition and amount of Pb containing wastes disposed off in these dumpsites which may not be the same.

At the dumpsites, the concentration of Cu ranged from 2800 to 4250ppm. Higher concentrations were recorded in dumpsite 2 with a mean of 3700ppm and lower concentrations were recorded in dumpsite 1 with a mean of 3133.33ppm against 177ppm of the control sample. Dumpsite 2 contained more Cu than dumpsite 1. There was a significant difference between the concentration of Cu in soil at dumpsites and the control. (Eddy *et al*, 2006) reported a similar result in 10 dumpsites in Ikot Ekpene. Biodegradable waste introduces metallic Cu into soil at levels above the natural level for soil as reported by (Dara, 1993). (Ademoroti, 1996) listed categories of Cu containing wastes to include Industrial wastes, agricultural wastes and some domestic wastes. This might be responsible for the high concentration of Cu in soil at dumpsites.

The permissible range for the concentration of Mn in soil is 200 to 9000ppm (Eddy *et al*, 2004). At the dumpsites, the concentration of Mn ranged from 2900 – 5450ppm with mean concentrations of 4550 and 4016.67ppm in dumpsite 1 and dumpsite 2 respectively. The control recorded 1725ppm. There was a significant difference between the mean concentrations of Mn in dumpsite and the control. (Akaeze, 2001) in Akwa Ibom presented results that were relatively lower compared to the one obtained in this study. These variations may be attributed to the nature and compositions of wastes.

There was a significant difference between the mean concentration of Cd in soil at dumpsites and the control. The concentration of Cd in the dumpsites ranged from 300 to 800ppm with means of 416.67 and 633.33ppm in dumpsites 1 and 2 respectively. The control sample recorded 175ppm. (Amusan *et al,* 2005) reported results of Cd in soil of Obafemi Awolowo University Central refuse dumpsite that was comparable to the one obtained in this study. This means that dumpsites contributed significant amount of Cd to the environment.

The concentration of Cr in soil at dumpsites was found to range from 2750-5450ppm. Higher values were recorded in dumpsite 2 with a mean of 4333.33ppm and dumpsite 1 had a mean of 3783.33ppm. The control recorded 265ppm which was significantly lower than the one recorded at the dumpsites. (Awokunmi *et al,* 2010) reported concentration of Cr in Ikere and Ado Ekiti dumpsites that was lower than the one obtained in this study.

The natural range for Fe in soil is between 3000-500,000ppm (Eddy *et al,* 2006). At the dumpsites, the concentration of Fe ranged from 3700-5150ppm. High concentration was recorded in dumpsite 2 with a mean of 4483.33ppm, and dumpsite 1 had a mean of 4383.33ppm. The control recorded 2525ppm. These results although within the natural limit were significantly higher than the control. There was a significant difference between the mean concentration of Ni in soil at dumpsites and the control. The control recorded 97ppm while the mean concentration of Ni in dumpsites was 1216.67ppm and 1500ppm in dumpsites 1 and 2 respectively. Similar findings have been reported by (Eddy, 2004a). This might be due to similarities in the nature, compositions and amount of Ni containing wastes deposited in the dumpsites.

The concentration of Zn in dumpsites ranged from 701-1423ppm. Dumpsite 2 recorded high concentration with a mean of 1234.33ppm and dumpsite 1had a mean of 886ppm. The concentration of Zn in the control was 58ppm. There was a significant difference between the concentration of Zn in dumpsites and the control. The natural range for concentration of Zn in soil is 10-300ppm as reported by (Eddy *et al,* 2004). The results obtained in this study were significantly higher than the natural range. This showed that waste releases significant amount of Zn to the environment.

CONCLUSION

Heavy metals could be toxic to humans and plants; and Municipal solid waste has been found to significantly increase the concentrations of the heavy metals studied in the environment. The study revealed significant differences in the concentration of heavy metals such as Pb, Mn, Cu, Cr, Cd, Fe, Ni and Zn in soil units at the dumpsites and the control. This could lead to negative changes in some soil properties. Elevated values of heavy metals studied were found in soil at the dumpsites when compared to the control. The concentration of heavy metals released were found to follow the order; Cd < Zn < Ni < Pb < Cu < Cr < Mn < Fe. Dumpsite 2 (Umuehilegbu dumpsite) was observed to have more concentration of heavy metals than dumpsite 1 (Umuaduru dumpsite). This could be attributed to the age of the dumpsite.

To safeguard human health and preserve the soil, groundwater and the environment, wastes should be segregated at the point of generation and effectively collected; any form of farming on the dumpsites should be discouraged. The plastic and metal components should be recycled, the use of geosynthetic clay liners as barriers for the prevention of leachate percolation on the open dumpsites should be adopted. There should be provision of a basement treatment for the dumpsites before use to provide sorption surfaces for pollutants and prevent groundwater contamination. The dumpsites should be relocated outside the city and phytoremediation of soil should be initiated as a matter of urgency especially in dumpsite 2.

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