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Heavy Metal Characteristics of Soils at the Municipal Solid Wastes Dumpsite at Uyo Metropolis, Akwa Ibom State, South-South, Nigeria

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ABSTRACT

These findings documented the heavy metal contents of soil at dumpsite and soils at 10, 20 and 800m outside the dumpsite, during the wet and dry seasons in the vicinity of the municipal solid wastes dumpsite at Uyo metropolis, Akwa Ibom State, South - South (SS) Nigeria. The soil samples were analyzed for heavy metals Fe, Mn, Cr, Ni, Cd, Pb and Zn. The heavy metal contents recorded for the dumpsite soil and for soils at 10, 20 and 800m outside the dumpsite in both seasons agreed with the World Health Standard (WHO). The heavy metal contents recorded for the dumpsite soil in both seasons; Pb (9.90 and 8.70)mg/kg, Zn (137 and 146) mg/kg, Ni (12.56 and 11.82) mg/kg, Cr (3.60 and 4.05)mg/kg, Cd (9.05 and 12.2) mg/kg, and Mn (94.0 and 91.2) mg/kg were significantly ($P<0.05$) higher than the control values; Pb (3.78 mg/kg), Zn (50.90 mg/kg), Ni (2.19 mg/kg), Cr (1.06mg/kg), Mn (44.27mg/kg) and Cd (1.09 mg/kg). Also, soils sampled from 10 and 20m east of the dumpsite in both seasons showed a significant ($P<0.05$) increase in Pb, Zn, Ni, Cr, Cd and Mn contents compared with the control. These mean values agreed with the mean concentrations measured for the dumpsite soil samples in both seasons. However, soils from 10 and 20m west, south and north of the dumpsite recorded heavy metal contents which agreed with the control results in both seasons. These findings revealed that the dumpsite has a potential effect on the ambient soil characteristics. Particularly soil located east lowland of the dumpsite. Therefore, the government of Akwa Ibom State should set up standard solid wastes recycling and reusing plants within the state to convert the different metal containing wastes generated within the metropolis into useful products. This will minimize heavy metal contamination in the soil in future.

KEY WORDS: Solid wastes, dumpsite area, heavy metals, soil, Uyo, Nigeria.

1.0 Introduction

Pollution occurs when a product added to our natural environment adversely affects nature's ability to dispose it off. A pollutant is something which adversely interfers with health, comfort, property or environment of the people. Generally, most pollutant are introduced into the environment as sewage, solid wastes, and as compounds used to protect plants and animals, (Misra and Alani, 1991). The United States environmental protection Agency (USEPA) (2007), defined solid wastes as "any useless, unwanted or discarded materials with insufficient liquid content to be free flowing. Continuous disposal of solid wastes on soil may influence soil physico-chemical properties. It may increase the heavy metal contents in the soil and even in the groundwater aquifers. Heavy metals may have negative effects on soil, crops and human health. Soil contaminants can have significant deleterious consequences for ecosystem, (Michael, et al, 1973), The presence of solid wastes on soil changes the soil chemistry, and affect soil organisms. The result can be the eradication of some primary food chain, which may in turn have major consequences on consumer species. Eddy et al, (2006) examined the elemental composition of soil in selected dumpsites within Ikot Ekpene. The samples recorded high heavy metals, exchangeable cations and essential non-metals (N and P) contents. Adefemi and Awokunmi (2009) studied the impact of municipal solid wastes on soils around Ado-Ekiti metropolis, Ekiti State, Nigeria. The results revealed high heavy metal contents for soil at the dumpsite and low heavy metal contents for soils examined 20m away from the dumpsite. Similar findings have been reported by Alloway (1971) and Amusen and Olawafe (2005) on the Bodeosi dumpsite and Obafemi Awolowo University central refuse dumpsite respectively. It is observed that municipal solid wastes dumpsites affect the ambient soil properties. The objectives of this study is to assess and compare the heavy metal contents of soil at dumpsite and soils at outside the dumpsite in both seasons with the World Health Organization (WHO) Standards.

1.1 The study area

Uyo municipality is the capital territory of Akwa Ibom State, South South (SS) Nigeria. It is a very busy urban area which links Akwa Ibom State with other neigbouring states like; Rivers, Cross River, Imo and Abia. The location matrix is between latitudes 5^{o} and 5^{o}40^{1}N and longitude 7^{o}54^{1}4^{11} and 7^{o}56^{1}O^{11}E. The area lacks a functional solid wastes management plant. The examined solid wastes dumpsite is located at barrack's road area. The area is located in the sub-equatorial belt characterized by the wet and dry seasons. The wet season begins in April and ends in September, with a peak in July and August while the dry season starts from October and ends in March. Its topography is basically plane except for some areas which end up in ravines. The area locks a functional drainage system, and it becomes flooded each time it rains heavily. However, activities like urbanization, construction and industrialization have combined to deteriorate the natural quality of the ambient environment.

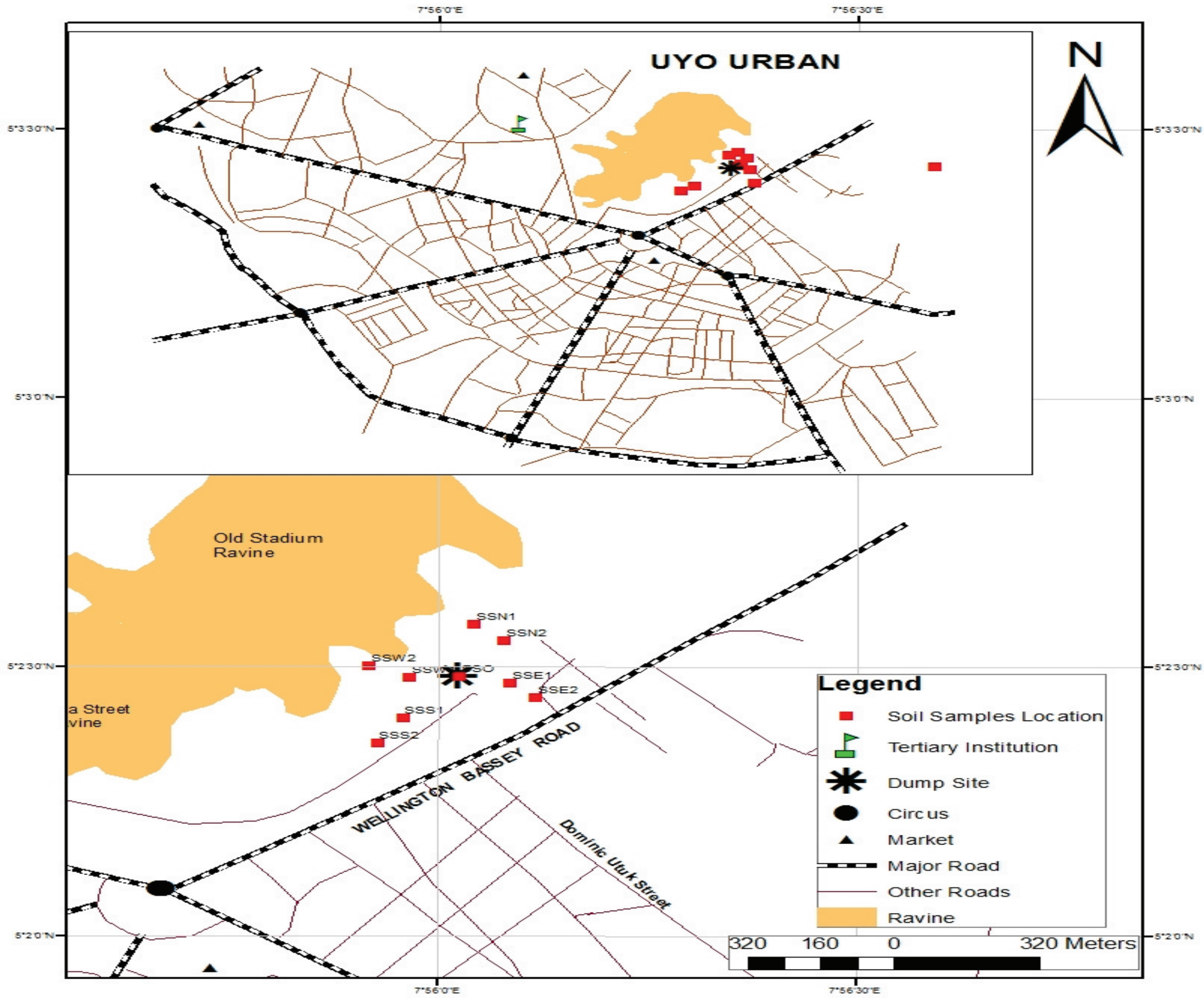

Fig. 1: Map of Uyo urban showing dumpsite and soil sampling points.

2.0 Materials and Methods

The dumpsite and the soil sample sites are shown in figure 1. Ten soil sample sites were selected for the analyses. One from the center of the dumpsite, eight from 10m and 20m west, east, south and north transects of the dumpsite, and one from 800m away from the dumpsite, used as control sample.

2.1 Sample collection and analysis

Soil samples were collected in the months of July and August 2011 during the wet season and in January and February 2012 during the dry season. The soil samples were collected into polyethylene bags and covered with aluminium foil. They were then transported in a cool box to be stored under suitable temperature until analysis. Tables 1.1 and 1.2 shows the locations and characteristic features of the sampling points. Soil samples were digested according to the methods described by Nwajei and Gagophien (2000) and Eddy et al (2006). Heavy metals; Fe, Mn, Pb, Zn, Ni, Cd and Cr were determined using Atomic Absorption spectrophotometer (AAS, Unicon 969) according to the methods of Ekpo and Ibok (1999) and Eddy et al (2006).

3.0 Results and Discussion

The locations and characteristic features of the different soil sample sites in both seasons are shown in tables 1.1 and 1.2.

Table 1.1: Heavy metal contents of soils sampled along wastes and non-waste dumpsites, Uyo, Akwa-Ibom State during wet season. Values are mean ± SEM, n=4.

Location	Coordinates	DFD (m)	Fe (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Mn mg/kg)
SSC	05^{o}02’30”N 007^{0}56’48”E	800	1797.56 ±2.000	3.78 ±0.05	50.90 ±3.00	2.19 ±0.03	1.06 ±0.02	1.09 ±0.03	44.27 ±4.50
SS0	05^{o}02’29.1”N 007^{o}56’01”E	0.00	1813.00 ± 3.00	9.90 ±0.70	137.00 ±3.00	12.56 ±1.53	3.60 ±0.20”	9.05 ±0.15	94.00 ±2.00
SSE1	05^{o}02’28.4”N 007^{o}56’05”E	10.0	1837.55 ±4.45	8.47 ±0.34	153.00 ±1.00	10.15 ±0.16	2.90 ±0.10	8.75 ±0.75	82.68 ±1.52
SS E2	05^{o}02’26.6”N 007^{o}56’04”E	20.0	1846.50 ±3.50	8.80 ±0.20	161.40 ±0.60	10.62 ±0.59	3.18 ±0.10	7.50 ±0.10	91.03 ±1.00
SSS1	05^{o}02’24.2”N 007^{o}55’57.6”E	10.0	2000.55 ±1.45	5.65 ±0.55	69.00 ±1.00	3.10 ±0.10	1.13 ±0.02	1.87 ±0.06	49.10 ±0.00
SSS2	05^{o}02’21.5”N 007^{o}55’55.7”E	20.0	1894.90 ±3.50	6.35 ±0.25	70.05 ±1.15	2.90 ±0.10	2.00 ±0.12	2.01 ±0.10	49.45 ±0.65
SSW1	05^{o}02’28.8”N 007^{o}55’58.1”E	10.0	1999.90 ±0.10	5.70 ±0.10	68.05 ±0.25	3.20 ±0.20	1.51 ±0.05	1.81 ±0.05	59.20 ±1.00
SSW2	05^{o}02’30.1”N 007^{o}55’55.1”E	20.0	2505.00 ±5.00	6.60 ±0.50	60.32 ±0.08	3.10 ±0.11	1.74 ±0.14	1.80 ±0.09	55.50 ±0.50
SSN1	05^{o}02’34.8”N 007^{o}56’02.83”E	10.0	2007.50 ±7.50	4.50 ±0.30	56.65 ±1.55	4.55 ±0.55	1.64 ±0.36	1.75 ±0..05	70.40 ±0.40
SSN2	05^{o}02’33.2”N 007^{o}56’04.97”E	20.0	1999.52 ±0.52	4.00 ±0.00	64.65 ±0.55	4.00 ±0.20	1.60 ±0.10	1.77 ±0.05	62.80 ±0.50

DFD = Distance from dumpsite
SSC = Soil sampled from control site
SSO = Soil sampled from dumpsite
SSE = Soil sampled east of the dumpsite
SSS = Soil sampled south of the dumpsite
SSW = Soil sampled west of the dumpsite
SSN = Soil sampled north of the dumpsite

Table1.2: Heavy metal contents of soils sampled along wastes and non-waste dumpsites, Uyo, Akwa Ibom State during dry season. Values are mean ± SEM, n=2.

Location	Fe (mg/kg)	Pb (mg/kg)	Zn (mg/kg)	Ni (mg/kg)	Cr (mg/kg)	Cd (mg/kg)	Mn (mg/kg)
SSC	1797.56	3.78	50.90	2.19	1.06	1.09	44.27
	±2.000	±0.05	±3.00	±0.03	±0.02	±0.03	±4.50
SS0	1804.00	8.70	146.00	11.82	4.05	12.21	91.20
	± 4.00	±0.50	±2.00	±1.00	±0.05	±0.19	±0.80
SSE1	1845.50	8.65	149.00	10.40	3.18	6.72	89.12
	±2.50	±0.25	±1.00	±0.20	±0.06	±0.52	±1.08
SS E2	1866.00	8.93	159.60	10.85	3.15	6.90	92.03
	±4.00	±0.27	±0.40	±0.65	±0.14	±0.10	±1.97
SSS1	1994.00	5.45	71.10	2.90	1.95	2.09	46.65
	±4.00	±0.55	±0.90	±0.10	±0.25	±0.21	±0.65
SSS2	1899.60	6.20	72.35	2.40	1.92	1.90	46.50
	±0.40	±0.20	±1.05	±0.30	±0.12	±0.10	±0.50
SW1	2002.00	5.15	61.25	3.05	1.65	1.81	51.65
	±2.00	±0.15	±1.05	±0.04	±0.15	±0.01	±1.45
SSW2	2430.00	5.53	60.57	2.95	1.63	1.82	54.50
	±30.00	±0.33	±0.27	±0.05	±0.03	±0.02	±0.50
SSN1	2001.00	4.50	56.65	4.55	1.64	1.75	70.40
	±7.50	±0.30	±1.55	±0.55	±0.36	±0..05	±0.40
SSN2	1999.50	4.00	64.55	3.85	1.55	1.73	62.75
	±0.50	±0.00	±0.45	±0.05	±0.05	±0.01	±0.45

Table 2.0: P values independent t-test for heavy metals in dumpsite soil and soils outside the dumpsite compared with the control.

	SSO	SSE_1	SSE_2	SSS_1	SSS_2	SSN_1	SSN_2	SSW_1	SSW_2
Iron	0.342	0.262	0.142	0.275	0.435	0.368	0.521	0.633	0.045
Manganese	0.009	0.008	0.078	0.822	0.789	0.641	0.610	0.545	0.623
Lead	0.01	0.03	0.02	0.169	0.109	0.205	0.326	0.119	0.908
Zinc	0.034	0.030	0.002	0.452	0.460	0.541	0.510	0.520	0.530
Nickel	0.001	0.006	0.004	0.781	0.750	0.541	0.520	0.621	0.610
Chromium	0.003	0.009	0.006	0.895	0.870	0.683	0.851	0.731	0.744
Cadmium	0.005	0.079	0.01	0.03	0.841	0.759	0.762	0.920	0.846

Number of samples = 4

Iron recorded highest concentrations while chromium recorded the least concentrations for all the soil samples analyzed in both seasons. Tables (1.1 and 1.2) show the means and standard deviations of heavy metals in soil during the wet and dry seasons. The highest concentration of iron was recorded for soil sampled 20m west of the dumpsite (SSW_2) (2505mg/kg) during the wet season, while the lowest concentration was recorded for the control sample (1797.56mg/kg). The mean concentrations of iron in soil sampled from the dumpsite range between 1804 to 1813mg/kg in both seasons. At 10 and 20m north, south, west and east outside the dumpsite, the mean iron concentrations in the soil range from 1837.55 to 2007.50mg/kg and from 1846.50 to 2505.00mg/kg during the wet season, while during the dry season, the mean iron concentrations range from 1845.50 to 2002.00mg/kg and 1886.0 to 2430.mg/kg. (Tables1.1 and 1.2).

The highest lead concentration was recorded for the dumpsite soil sample during the wet season (9.90mg/kg) while the lowest concentration of lead was recorded for the control sample (3.78mg/kg). The mean lead concentrations in the dumpsite soil range from 8.70 to 9.90mg/kg in both seasons. At 10 and 20m north, west, south and east of the dumpsite, the mean lead concentrations in the soil range from 4.50 to 8.47mg/kg and from 4.00 to 8.80mg/kg during the wet season while during the dry season, the mean lead contents range from 4.0 to 8.65mg/kg and from 4.0 to 8.93mg/kg. Soil sampled from the dumpsite and from 10 and 20m east of the dumpsite recorded significance increase ($p<0.05$) in lead contents in both seasons compared with the control result (fig. 3).

The highest concentration of zinc was recorded for soil sampled 20m east of the dumpsite (161.4mg/kg) during the wet season while the lowest content was recorded for the control (50.90mg/kg). The mean zinc contents in the dumpsite soil range from 137.0 to 140.0mg/kg in both seasons. At 10 and 20m north south, west and east of the dumpsite, the mean zinc contents in the soil range from 56.65 to 153mg/kg and from 60.32 to 161.40mg/kg during the wet season while during the dry season, the zinc contents in the soil range from 63.60 to 149.0mg/kg and from 60.57 to 159.60mg/kg. (Tables 1.1 and 1.2). Soil sampled from the dumpsite and from the east transect, recorded significant increase ($p<0.05$) in zinc contents in both seasons compared with the control result.

The highest concentration of nickel was recorded for soil sampled from the dumpsite (12.56mg/kg) during the wet season while the lowest concentration was recorded for the control sample (2.19mg/kg). The mean Nickel contents recorded for the dumpsite soil in both seasons range from 11.82 to 12.56mg/kg. At 10 and 20m north, south, west and east of the dumpsite, the nickel contents range from 3.10 to 10.5mg/kg and from 3.10 and 10.62 during the wet season while during the dry season the nickel contents range from 2.90 to 10.4mg/kg and from 2.4 to 10.85mg/kg (Tables 1.1 and 1.2). Soil sampled from the dumpsite and from the east transect recorded significant increase ($p<0.05$) in nickel contents in both seasons compared with to the control result.

The highest content of chromium was recorded for the dumpsite soil (4.05mg/kg) during the wet season while the lowest content was recorded for the control sampled (1.06mg/kg). The mean chromium contents recorded for soil from the dumpsite range from 3.6 to 4.05mg/kg in both seasons. At 10 and 20m north, south, west and east of the dumpsite, the mean contents of chromium range from 1.13 to 2.90mg/kg and from1.60 to 3.18mg/kg during the wet season while during the dry season, the mean chromium contents range from 1.65 to 3.18 and from 1.55 to 3.15mg/kg. Soil sampled from the dumpsite and from the east transect recorded an increase in chromium contents in both seasons compared with samples from the control site. This increase was not significant at $p<0.05$. Soil sampled from the west, north and south of the dumpsite recorded chromium contents which agreed with the control result.

The highest cadmium content was recorded for soil sampled from the dumpsite (12.21 mg/kg) during the wet season while the lowest content was recorded for the control sample (1.09 mg/kg). The mean cadmium contents recorded for the dumpsite soil range from 9.05 to 12.21mg/kg in both seasons. At 10 and 20m east, west, south and north of the dumpsite, the cadmium contents range from 1.75 to 8.75mg/kg and from 1.77 to 7.50mg/kg during the wet season while during the dry season, the cadmium contents in the soil samples range from 1.75 to 6.72mg/kg and from 1.73 to 6.90mg/kg. Soil sampled from the dumpsite (SS_0) and from the east transect in both seasons recorded significant increase ($p<0.05$) in cadmium content compared with the control result. The cadmium contents in soil sampled from 10 and 20m west, south and north of the dumpsite agreed with the control result in both seasons.

The highest manganese concentration was recorded for the dumpsite soil (94.0 mg/kg) during the wet season, while the lowest manganese concentration was recorded for the control sample (44.27mg/kg). The mean manganese contents recorded for the dumpsite soil range from 91.20 to 94.0 mg/kg in both seasons. At 10 and 20m north, south, west and east of the dumpsite the manganese contents range from 49.01 to 82.68 mg/kg and from 49.45 to 91.03 mg/kg during the wet season while during the dry season, the manganese values range from 46.68 to 89.12 mg/kg and from 46.50 to 92.03 mg/kg. Soil sampled from the dumpsite and from 10 and 20m east of the dumpsite recorded significant increase ($p<0.05$) in manganese contents compared with samples from the control site.

The results in Tables 1.1 and 1.2 shows that soil sampled from the dumpsite and from 10 and 20m east of the dumpsite recorded high heavy metal concentrations. The soil parameters determined at dumpsite correlated positively with soil at the east transect of the dumpsite. The trends of the heavy metal contents in soil sampled from the dumpsite during the wet season is as follows: Fe>Zn>Mn>Ni>Pb>Cd>Cr. During the dry season, the trend recorded is as follows: Fe>Zn>Mn>Cd>Ni>Pb>Cr. The heavy metal trends for the control sample was similar to that recorded for the dumpsite soil during the wet season. Fe>Zn>Mn>Ni>Pb>Cd>Cr.

Discussion

The heavy metal characteristics of soils at the biodegradable waste dumpsite and along non-wastes dumpsites agreed with the WHO standards. There was evidence of relative increase in the mean concentrations of heavy metals in soil at the dumpsite and soils at 10 and 20m the east of the dumpsite compared with soils sampled from the control site, and from 10 and 20m south, north and west transects of the dumpsite. The existing soil characteristics at the dumpsite, coupled with biological and chemical reactions taking place within the waste matrix may have influenced the ambient soil characteristics. Therefore, the properties of soil that require evaluation depend upon the waste composition and the type of land fill disposal method practiced, as well as the topography of the site.

The iron contents in soils sampled from the dumpsite and outside the dumpsite in both seasons agreed with the WHO standards. (3000 to 250,000mg/kg). The low iron contents in the dumpsite soil in both seasons may be due to the high permeability of the dumpsite soil, which supports leachate migration, and also the incline nature of the dumpsite which favours the washing away of wastes components from the dumpsite to the low land communities. Ademority (1996); Aluko et al., (2003); reported that natural soils contain significant concentration of iron. Eddy et al., (2006) suggested that pollution of the environment by iron cannot be conclusively linked to waste materials alone but other natural sources of iron must be taken into consideration. Besides, iron had earlier been reported to be the most abundant element in Nigeria soil (Amusen and Olawafe 2005). The results of iron recorded by Eddy et al (2006) and Akaeze (2001) for dumpsite soils in Abak and Ikot-Ekpene, Akwa Ibom state Nigeria were considerably higher than the iron concentrations recorded for soil at dumpsite in this study.

The lead contents recorded for soil sampled from the dumpsite and outside the dumpsite agreed with the WHO standard (15 to 25 mg/kg). The significant increase in lead contents in soil sampled from the dumpsite and from

10 and 20m east of the dumpsite in both seasons compared with the control (fig.3) indicates the presence of significant proportion of lead containing wastes at the dumpsite. There has been increased concern about lead in the environment, especially in the use of lead as anti-knock additive to petrol or in the use of lead in battery accumulators, ceramics, solders, lead pipes, paint, glasses and plastics. Lead is toxic even at low concentrations and has no known function in the biochemical process (Haggins and Burns 1995). The mean concentrations of lead in the dumpsite soil in both seasons in this study were lower than the lead values recorded by Eddy et al., (2006). Aluko et al (2003) reported mean lead concentration in soil at Ibadan dumpsite to range from 1.34 to 1.69 mg/kg. These values were considerably lower than the lead values obtained for the dumpsite soil in this study.

The zinc contents recorded for the dumpsite soil and outside the dumpsite in both seasons agreed with the WHO standard (20 to 300 mg/kg). The significant increase in zinc contents for the dumpsite soil and for soil sampled 10 and 20m east of the dumpsite compared with the control (fig. 4) indicates significant proportion of zinc wastes at the dumpsite, which affect the ambient soil properties negatively. Aluko et al (2003) reported lower zinc concentrations ranging from 1.42 to 2.42mg/kg for soils at Ibadan dumpsites. The incorporation of zinc in the manufacture of tyres is a good source of zinc from tyre abraision Nriagu (1988). Also, discarded builders rubbles and some dysfunctional electrical equipments, can also increase the zinc contents in the environment.

The nickle contents recorded for the dumpsite soil and for soils outside the dumpsite in both seasons, agreed with the WHO standard (0 to 100 mg/kg). The significant increase in nickle contents for soil sampled from the dumpsite and from 10 and 20m east of the dumpsite in both seasons compared with the control sample (fig. 5) suggests the presence of significant proportion of nickle containing wastes at the dumpsite. Nickle can be added into the soil through different solid wastes materials like dysfunctional electrical equipments, ceramics, storage batteries, coloured glasses, textiles, leather, stainless steel, as well as wearing of mechanical parts. The concentrations of nickle recorded for the dumpsite soil in this study in both seasons were higher than the values obtained by Eddy et al., (2006).

The manganese contents records for the dumpsite soil samples, control and soil sampled from 10 and 20m north, south, west and east of the dumpsite in both seasons were lower than the WHO international standards (200 to 9000 mg/kg). The significant increase in manganese contents in soil sampled from the dumpsite and from 10 and 20m east of the dumpsite in both seasons compared with the control (fig. 6) may reflect significant proportion of manganese containing waste at the dumpsite which may affect the soil properties negatively. From the findings at Elelewo dumpsite reported by Akaeze (2001), the concentration of manganese was relatively lower than the values recorded in this study.

The mean chromium contents recorded for the dumpsite soil, and for soils outside the dumpsite in both seasons, agreed with the WHO standard (0 to 35 mg/kg). The significant increase in Chromium content for soil sampled from the dumpsite and from 10 and 20m east of the dumpsite in both seasons compared with the control sample (fig. 7), indicates the presence of significant proportion of chromium containing wastes at the dumpsite, which may affect the surrounding soil properties. The source of chromium in soil may be attributed to waste like chrome pigment containers as well as dysfunctional boilers in which chromium is used as anticorrosive agent.

The mean cadmium contents recorded for the dumpsite soil, and soils outside the dumpsite in both seasons, agreed with the WHO standard (0 -30 mg/kg). The significant increase in cadmium contents in soil sampled from the dumpsite and from 10 and 20m east dumpsite in both seasons compared with the control sample (fig. 8) suggests significant proportion of cadmium containing waste at the dumpsite. Heavy metals such as chromium and cadmium can be added into the soil through discarded rechargeable batteries, stainless steel, tanned leather, fabrics, dysfunctional electrical equipment such as alloys, and in waste materials in which chromium and cadmium are used as anti-corrosive agents. Chronic exposure to chromium, cadmium, lead and other heavy metals may lead to congenital disorder, or can cause other chronic health conditions.

The positive correlation of the toxic heavy metals in soils at the dumpsite compared with soil at the east transect may be due to leaching of leachate and washing away of wastes contaminants from the dumpsite to the east transect located low land of the dumpsite. This reflects evidence of impact of the dumpsite on the ambient environment. Lead can be added into the soil through discarded paint materials and plastics in which lead is used as a component. The low heavy metal contents in the dumpsite soil in this study, contradicts the findings of Alloway (1971), Amusen et al., (2005) Eddy et al., (2006) and Adefemi et al., (2009).

However, these low values for the dumpsite soil in both seasons may be as a result of the high permeability of the dumpsite soil which is conducive for leachate transport, and the inclined nature of the dumpsite which may have influenced the washing away of wastes contaminants from the dumpsite down to the low land communities. The significant increase in the heavy metal contents for soils sampled at 10 and 20m east, low land of the dumpsite in both seasons compared with the results for soils sampled 10 and 20m west, north, and south of the dumpsite, shows evidence of migration of leachate and wastes contaminants from the dumpsite to the low land areas. This therefore reduces the heavy metal contents in the dumpsite soil. The variations in the heavy metal contents for the dumpsite soil in this study compared with others may be as a result of the following factors: topography of the sites, soil texture, waste composition at the site, as well as the suitability of the sites for solid wastes disposal. The heavy metal contents of soils at the barrack road solid wastes dumpsite and outside the dumpsite during the wet and dry seasons are shown in figures 2-8 below.

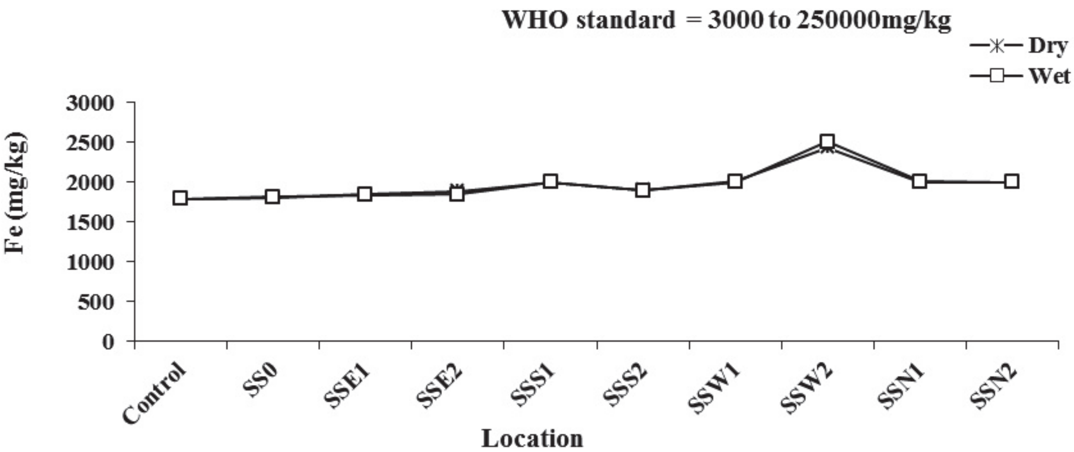

Fig. 2: Iron (Fe) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4.
*** = significance (P<0.05) compared with control sample**

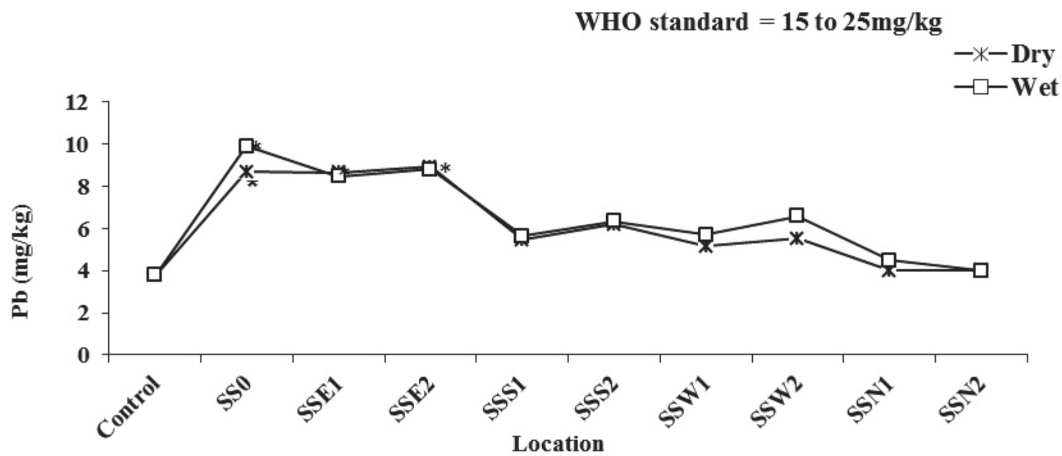

Fig. 3: Lead (Pb) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4.
*** = significance (P<0.05) compared with control sample**

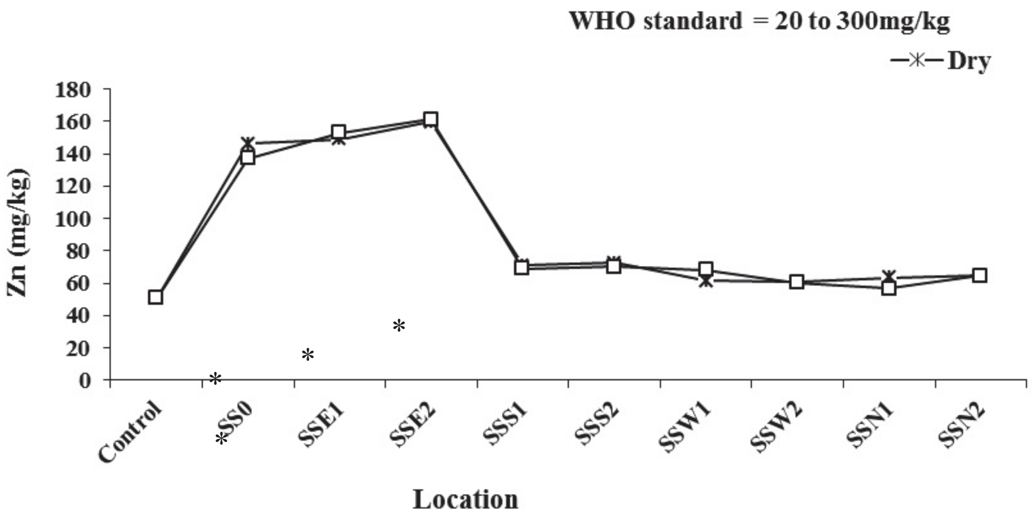

Fig. 4: Zinc (Zn) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4. * = significance ($P<0.05$) compared with control sample

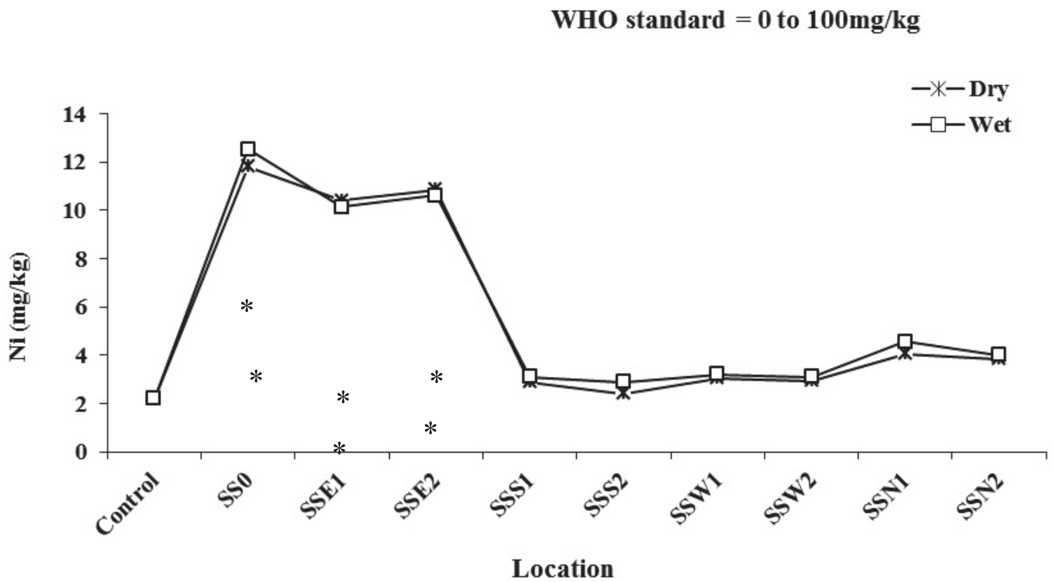

Fig. 5: Nickel (Ni) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4. * = significance ($P<0.05$) compared with control sample

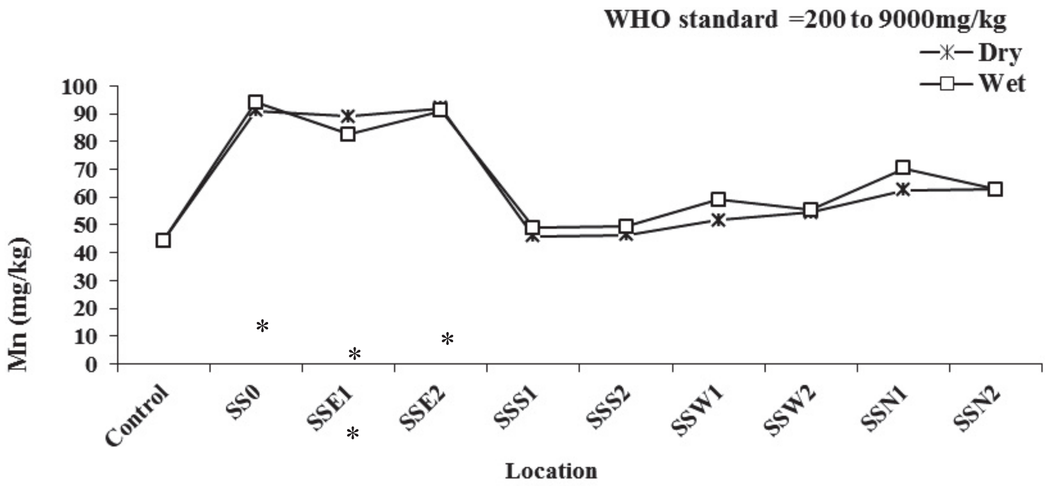

Fig. 6: Manganese (Mn) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4.
*** = significance (P<0.05) compared with control sample**

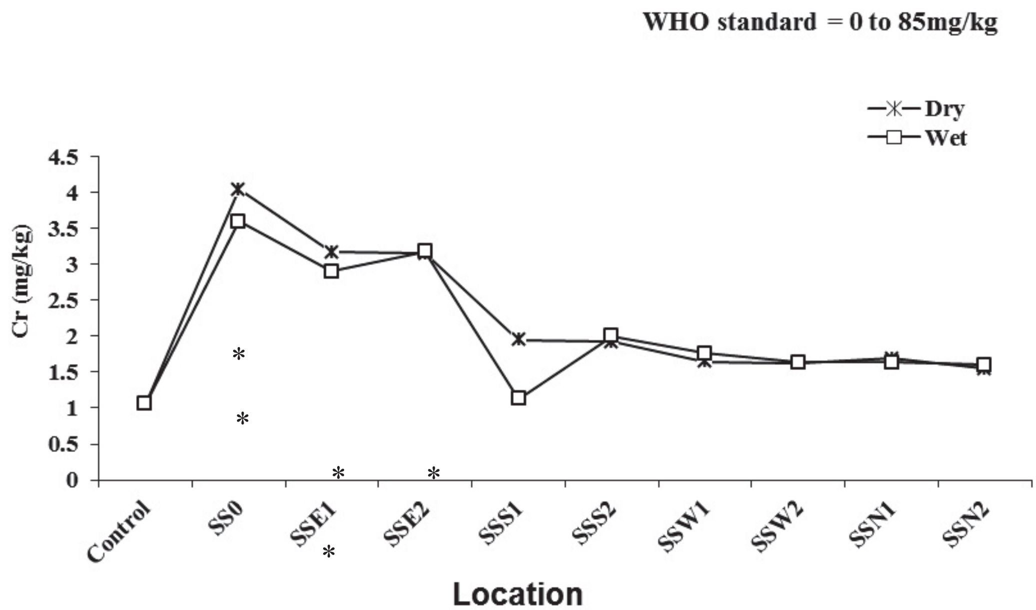

Fig. 7: Chromium (Cr) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4.
*** = significance (P<0.05) compared with control sample**

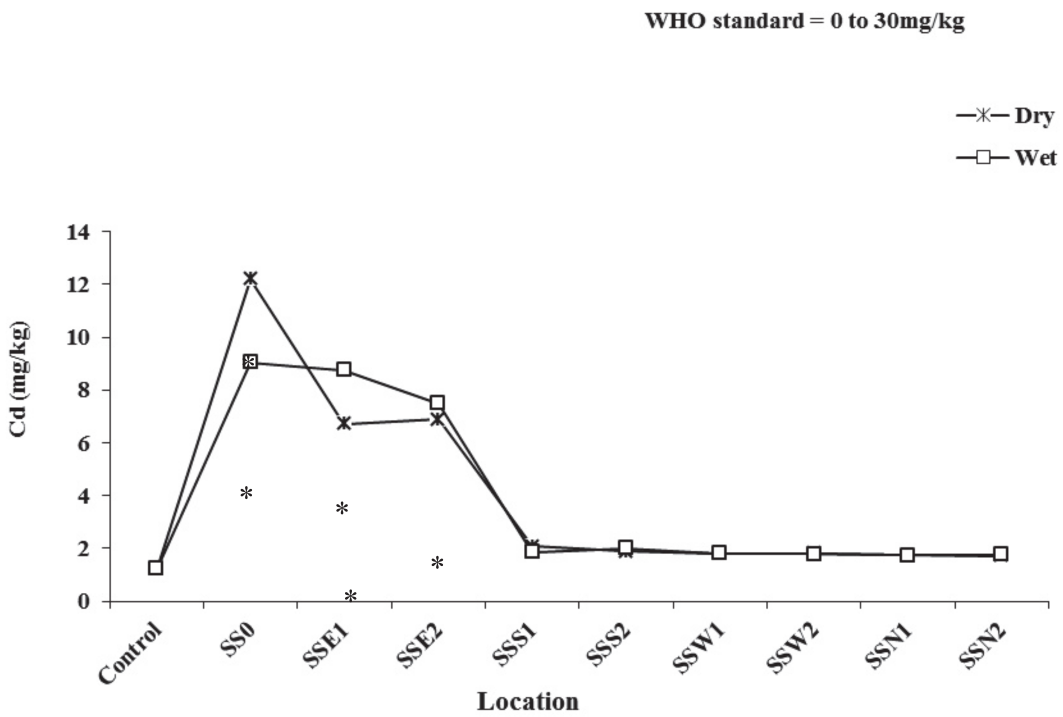

Fig. 8: Cadmium (Cd) contents of soils sampled along wastes and non-waste dumpsite, Uyo, Akwa Ibom State during dry and wet seasons. Values are mean ± SEM, n = 4.
*** = significance (P<0.05) compared with control sample**

Conclusion

The heavy metal contents for soil at dumpsite and outside the dumpsite in both seasons agreed with the WHO standards. However, the heavy metal contents for soil at dumpsite and at 10 and 20m east of the dumpsite were significantly (P<0.05) higher than that of soils from the control, and from the south, west and north transects of the dumpsite in both seasons. Soil sampled at 10 and 20m east, low land of the dumpsite did not show any significant (P>0.05) difference in heavy metal contents compared with the dumpsite soil in both seasons. This inferred that the dumpsite has a significant effect on the ambient soil characteristics particularly, soil located lowland of the dumpsite. Thus, curtailing the volume of heavy metal bearing wastes at the dumpsite means reducing the concentrations of heavy metals in the ambient environment. This can only be achieved by setting up local recycling and reusing plants within the state, to help recycle the non biodegradable solid wastes materials into useful products, as this would create more job opportunities for the indigenes, boost the State economy and in turn make the environment friendly to our health. Also, site selection should be taken into consideration, the topography and the existing soil texture as well.

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