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IMPACT OF MUNICIPAL SOLID WASTE ON TRACE METAL CONCENTRATIONS IN HERBAGE AND SOIL SAMPLES OF THE ABUJA MUNICIPALITY.

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ABSTRACT

The impact of municipal solid waste on the levels of cadmium, copper, nickel, lead and zinc in herbage and soil samples within Abuja municipality was studied. The flame atomic absorption spectrophotometry was used in the determination of the metals. The average concentration of Cd, Cu, Ni, Pb and Zn in the herbage samples were 0.3 ± 0.1, 3.8 ± 1.2, 2.9 ± 0.8, 50.7 ± 14.3 and 34.7 ± 6.1 µg g^{-1} weight respectively. The concentrations of metal in the soil were higher than in the herbage samples and were in the order of Pb> Zn >> Cu > Ni> Cd. The concentrations of metal in the soil samples were higher than levels in normal farmlands. The levels of Cd and Pb in the soil samples were higher than levels in soil criteria of many countries suggesting that municipal wastes are contributing significantly to the metal concentrations in the herbage and soil samples.

KEY WORDS: Solid waste, trace metals, environmental samples.

INTRODUCTION

Soil surface and vegetation are the major sinks for airborne metals. Consequently the measurement of metals in these media can be useful to establish trends in abundance and their consequences as a result of natural changes caused by man (Hamilton, 1995 and Frink, 1996). Marked increases in global population and in the gross national products of developed countries since the beginning of the last century have been accompanied by a rapid increase in metal production (Nriagu, 1992). Modern societies have developed a range of increasingly sophisticated metallic products with specific physical and chemical properties. Each new process or compound used in scientific research and development can generate a different type of metallic waste and such wastes are usually discharged into the environment, where it can disrupt natural processes and endanger human health (Nriagu 1992 and FMWHE, 1982). Large quantities of metal enriched wastes likewise arise from the ever increasing production and manufacture of goods and services for human comfort and from huge quantities of fossil fuels that are burned to generate the energy needed to sustain industrial and domestic activities (Haertling 1989 and Nriagu 1990).

Although the amounts of solid wastes produced in many communities are large, lack of adequate disposal facilities, manpower and funds force disposal of wastes on open sites from where they are gradually burned off. Most municipalities in developing nations do not have an organized method of disposing solid wastes hence they are dumped indiscriminately at different sites thus creating environmental hazards. Leachates from these uncontrolled land filled sites are high in biochemical oxygen demand as well as dissolved toxic metals which pose series deleterious health problems on both the surrounding animal and human population using either the surface soil or ground water or eating vegetables grown on such land (Ademoroti 1996). In 1982, the Nigerian Federal Ministry of Works, Housing and Environment reported 0.5kg $capita^{-1}$ day^{-1} as the domestic waste generation in the country (FMWHE, 1982). These wastes contain large quantities of metal-containing materials such as agricultural and animal wastes, solid wastes from metal fabrication and discarded manufactured goods. While magazines and papers are notable sources of Pb, Zn, Fe and Mo, Cd is found in some plastics at relatively high levels (Campbell 1976). Incineration of these wastes represents a significant source of heavy metals released into environment (Nriagu, 1990 and Meneses et al, 1999). For instance, incineration of discarded batteries can be a source of Cd, Hg, Pb, and Zn (Bergstrom, 1986; while volatile chlorides of Cd, Fe, Pb and Zn may be also found during municipal solid waste incineration (Jarvis et al, 1995). Cadmium, chromium and beryllium are among the elements released by solid waste incineration that are carcinogenic while Pb, Hg and vanadium are associated with a wide range of toxic effects including tetragenicity (Christensen, 1995 and Domingo, 1994). Soils can be contaminated by metals which bioaccumulate in plants and animals, eventually making their way to humans by way of the food chain or contamination of drinking water, (Schubmacher et al, 1999).

At the moment, virtually all the major Nigerian cities and towns are faced with the problems of solid

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waste management. The main aim of this study was to determine the impact of municipal solid waste dump sites on the metal levels in the soil and vegetation of the Abuja municipality.

MATERIALS AND METHODS

Soil and vegetation samples were collected from the vicinity of nine different dumpsites within the Abuja municipality and one site in Gwagwalada Area Council - Table 1. The sites AD, D3 and GP II are permanent dumpsites and had existed for nearly ten years whilst the rest are temporary dumpsites that are evacuated from time to time. Triplicate soil samples were taken from the upper 5cm of the soil with aid of a stainless steel hand trowel at each dumpsite. These were stored in polythene bags and taken to the laboratory where they were dried at about 80^{0}C in an oven for about 6 hours followed by grinding in a porcelain mortar. The samples were then sieved with 2mm-nylon sieve with the portions passing through the sieve being stored in glass bottles till analysis. Triplicate samples of the leaves of the members of the Graminae family commonly used as fodder for animals were collected within the vicinity of the dumpsites. They were stored in polythene bags which had been cleaned with HNO_3 (1:3) and rinsed with distilled water. The vegetation samples were oven dried at 60^{0}C for four hours after which they were ground in porcelain mortar and stored in polythene bags till analysis.

The nitric acid-perchloric acid (4:1) mixture was used in the digestion of the vegetation samples (Zasoski et al, 1987). The acid mixture (10cm^3) was added to the vegetation sample (5g) in a 100cm^3 beaker and left to predigest overnight. This was followed by refluxing on a hot plate for 6 hours. The digests were quantitatively transferred into a 50cm^3 volumetric flask and diluted to volume with distilled water.

The digestion procedure for the determination of metal in the vegetation samples was ascertained by the analysis of seven replicates followed by runs of recovery which involved the spiking of samples with standard

Table 1: Descriptions of the sampling points for soil and vegetation samples

Site	Area Description
AD	Maitama - near Minister's Hill
D_3	Durumi Three - near a Feeder Road linking Durumi to Kabusa Village
GP 11	Gwarimpa Phase Two - Close to the Kubwa Express Way
D2	Durumi Tsho
DT	CBN/Dantata Junction
A_7	Area Seven
GS	Garki Police Station
MM	Monday Market
G 11	Garki II
GW	Gwagwalada - Unity Shopping Centre Junction
GWP	Gwagwalada Farmlands (Control)

Table 2: Mean Metal Concentration in the Herbage from the various dumpsites. Concentrations in μg g^{-1} dry weight.

Site	Cd	Cu	Ni	Pb	Zn
AD	0.3 ± 0.1	2.9 ± 0.8	1.7 ± 1.0	65.3 ± 9.4	41.3 ± 6.7
A7	<0.1	5.7 ± 1.2	3.6 ± 1.4	51.6 ± 7.4	30.1 ± 5.2
DT	0.4	3.7 ± 0.7	2.9 ± 0.8	58.0 ± 10.3	45.3 ± 8.1
D2	0.2	2.6 ± 1.0	2.7 ± 0.6	45.9 ± 5.1	37.6 ± 3.9
D3	0.3	2.1 ± 0.8	1.9 ± 0.8	34.3 ± 4.6	31.3 ± 3.0
G II	0.2	4.1 ± 1.4	3.8 ± 1.2	78.1 ± 7.3	40.9 ± 6.8
GS	<0.1	5.0 ± 2.0	4.2 ± 1.3	58.3 ± 3.8	27.4 ± 4.7
GW	0.3	5.2 ± 1.7	2.5 ± 0.8	41.0 ± 9.0	29.0 ± 5.0
GP II	0.2	3.1 ± 1.1	2.2 ± 1.0	36.4 ± 8.1	31.9 ± 4.5
MM	0.4	3.8 ± 1.7	3.4 ± 1.3	37.7 ± 6.5	32.0 ± 5.0
GWF	0.2	2.9 ± 1.3	2.4 ± 0.9	19.6 ± 3.4	21.4 ± 3.6

Table 3: The Mean pH, % Organic C, and metal levels in soil samples within the vicinity of the dumpsite. Concentrations of metals in $\mu g\ g^{-1}$ dry weight

Site	pH	%org C	Cd	Cu	Ni	Pb	Zn
AD	6.6	1.95±0.28	5.9±0.8	4.6±1.5	5.1±1.6	205.3±20.5	37.9±3.6
A7	8.1	2.18±0.67	2.5±0.4	15.9±2.6	4.7±1.8	204.4±36.2	32.2±9.2
DT	8.5	1.42±0.48	2.7±1.1	7.2±1.4	4.6±2.3	158.0±11.9	20.4±6.0
D2	8.9	2.25±0.93	3.8±0.4	19.9±4.0	4.2±1.0	204.9±21.7	87.0±4.4
D3	4.8	1.17±0.75	2.4±0.8	3.8±0.9	4.9±1.6	170.0±20.1	6.7±1.73
G II	8.8	2.01±0.41	2.6±0.6	7.3±0.7	4.6±0.9	301.6±36.2	39.9±5.6
GS	9.2	1.87±0.38	3.5±1.1	5.3±1.4	3.3±0.9	73.0±16.5	29.0±4.0
GW	10.2	2.89±0.76	2.9±1.1	5.7±1.2	4.4±0.4	154.1±19.8	13.4±1.2
GP II	5.7	1.41±0.51	3.6±1.9	6.1±2.3	3.9±1.1	207.8±41.0	27.7±3.3
MM	8.5	2.03±0.38	2.7±1.5	8.4±1.1	4.5±0.9	184.1±19.5	27.4±1.7
GWF	6.8	0.65±0.20	1.2±0.5	7.8±1.2	5.0±1.6	25.8±7.2	26.4±4.0

Table 4: Mean metal levels in the herbage and soil samples from all sites Concentrations in $\mu g\ g^{-1}$ dry weight.

Metal	Vegetation	Soil
Cd	0.3 ± 0.1	3.3 ± 0.8
Cu	3.8 ± 1.2	8.4 ± 1.7
Ni	2.9 ± 0.8	4.4 ± 1.1
Pb	50.7 ± 14.3	186. ± 57.5
Zn	34.7 ± 6.1	32.2 ± 21.8

Table 5: Metal Correlation in Herbage Samples (r at $p < 0.01$)

	Cd	Cu	Ni	Zn
Pb	0.401	0.106	-0.023	0.583
Zn	0.106	-0.028	0.206	
Ni	0.006	0.214		
Cu	-0.314			

metal solutions. The precision and average% recovery were Cd 13.7%; 88 ± 11%; Cu 6.4%, 96± 7%; Ni 10.3%, 90 ± 8%; Pb 10.6%, 90 ± 12% and Zn 5.8%, 95 ± 5% respectively

The soil pH levels were determined electrometrically using a glass electrode. The soil samples were extracted with distilled water in a ratio of 4:1 of water to the soil sample. The mixture was shaken for two hours and left to settle over night. This was filtered and the pH of the filtrate was determined with the glass electrode. The potassium dichromate method was used in the determination of the percent organic carbon in the soil samples (Gross 1971).

The HNO_3 - HCl - HF mixture was used in the preparation of the soil samples prior to the heavy metal determination. The soil samples (1.0g) was digested with a mixture of $10cm^3$ of HNO_3 - HCl (3:1) and $1cm^3$ HF in a $50cm^3$ teflon beakers. These were heated in a microwave oven at 200W for 10 minutes. After cooling, the digests were filtered, transferred into a $50cm^3$ volumetric flask and diluted to volume with distilled water.

In all the determinations, blanks were prepared in order to know the reagents' contribution to metal levels. The standard metal solutions were prepared from either the nitrate or chloride of the metal of analytical grade, manufactured by BDH, England. The metal concentrations of the vegetation and soil samples were determined with a Pye unicam atomic absorption spectrophotometer model SP 9 in the flame mode, using the conditions listed in the operations manual.

RESULTS AND DISCUSSION

The summary of the results of metal concentrations in the vegetation samples is listed in Table 2. Generally

TABLE 6: Soil Quality Criteria for some Countries Compared with levels (ppm) in this study

Country	Cd	Cu	Ni	Pb	Zn	Reference
Canada (residential	10	63	50	140	200	CCME, 1999
Canada (agricultural)	1.4	63	50	70	200	CCME, 1999
Canada (Commercial)	22	91	50	260	360	CCME, 1999
Canada (Industrial)	22	91	50	600	360	CCME, 1999
Norway	1.0	100	30	50	150	Reiman et al 1997
Switzerland Guide Values	0.8	50	-	50	200	FOEFL 1987
This Study (Range)	24-5.9	3.8-19.9	3.3-5.1	73-301.6	6.7 - 87.0	
(Mean)	3.3±0.8	8.4±0.8	4.4±1.7	186.3±57.5	32.2 ± 21.8	

the concentrations of metal in the vegetation samples from all the dumpsites were low. The mean concentration of Pb in the vegetation samples is 50.7 ± 14.3 μg g^{-1} dry weight with a range of 34.3 - 78.1 μg g^{-1} dry weight. The highest concentration of Pb was found in the sample obtained from the vicinity of the Garki Two (G 11) site with a mean of 78.1 ± 16.7 g g^{-1} dry weight. This site is a temporary dumpsite within an area of heavy traffic density. This tends to suggest that the high Pb content in this sample might be attributed to the high automobile emissions in the area as a result of the use of leaded gasoline in the country. The Durumi Sabo site (D_3) recorded the lowest concentration of Pb in the vegetation samples with a mean and range of 34.3 ± 10.6 μg g^{-1} and 20.3 - 437 μg g^{-1} dry weight respectively. Though this site had existed for over ten years, it is in the rural area of the municipality that the solid wastes are mainly agricultural and animal wastes that do not significantly contribute to the Pb levels in the environment. The concentrations of Zn, Cu, Ni and Cd were lower than those of Pb. The mean and ranges for these metals in the vegetation samples are respectively: Cd 0.26 ± 0.09, 0.10 - 0.40; Cu 3.8 ± 1.2, 2.1 - 6.7; Ni 2.9 ± 0.8, 1.7 - 4.2 and Zn 34.7 ± 6.1; 27.4 - 45.3 μg g^{-1} dry weight respectively (Tables 2 and 4). The highest concentration of zinc 45.3 μg g^{-1} dry weight was recorded in the herbage of the DT samples obtained from the dumpsite of the Central Bank Dantata junction on the Nnamdi Azikwe Way of Garki District. Although it is a temporary dumpsite, yet most of the contents of this site are mainly of automotive type - such as lubricant containers, hence the high level of zinc in the herbage samples in the site.

The result of pH, % organic carbon and the trace metal concentrations in the soils of the dumpsites are listed in Table 3. The mean pH of the soils is 7.9 ± 1.7. With the exception of the Durumi Three (D_3) and Gwagwalada (GW) dumpsite which are acidic pH 4.8 and alkaline pH 10.2 respectively, most other sites were slightly neutral. Generally the organic carbon content of the soils ranged from 1.17 - 2.29% with a mean of 1.95 ± 0.52%. These high organic carbon contents of the soils could be due to the content of the wastes in most of the sites, which consists mainly of paper and many organic materials such as agricultural and animal wastes.

The concentrations of Pb and Zn in the soils of the dumpsite were general higher than those of other metals (Tables 3 and 4). For instance, the Pb content of the soils ranged from 73.0 - 301.6 μg g^{-1} dry weight with a mean of 186.3 ± 57.5 μg g-1 dry weight. The highest Zn concentration of 87.0 μg g^{-1} dry weight was recorded at the Durumi Two (D_2) site whilst the lowest with a concentration of 6.7 μg g^{-1} dry weight was recorded at Durumi Three (D_3) site. The concentrations of Cd, Cu and Ni in the soils were quite low and their mean values are 3.3 ± 0.8, 8.4 ± 1.7 and 4.4 ± 1.1 μg g^{-1} dry weight for Cd, Cu and Ni respectively. The presence of these trace metals in the soils of the dumpsites could be attributed to the presence of agricultural wastes, discarded manufactured products, urban refuse as well as atmospheric fall out which are known to have high inputs of trace elements into soils (Nriagu 1990). The high levels of Pb in the samples could be due to the presence of large quantities of storage battery in the wastes as well as the emissions from automobile exhausts within the vicinity of these dumpsites.

A correlation studies between the metals in the herbage and the soil samples was carried out. In the herbage samples (Table 5) only Zn and Pb correlated ($r = 0.58$, $p < 0.01$). Pb and Cd showed a slight correlation ($r = 0.401$, $p < 0.01$). In the soil samples, pH correlated with percent organic carbon content ($r = 0.79$, $p < 0.01$). There was no correlation between metals in the herbage and in the soil samples. The concentration of metal in the soils of the dumpsites were generally higher than the levels in farm lands in Gwagwalada District used as control for the studies. For instance, the Cd, Pb and Zn content in the control were 1.2, 45.8 and 26.4 μg g^{-1} dry weight respectively compared to mean levels of 3.3 ± 0.8, 186.3 ± 57.5 and 32.2 ± 21.8 μg g^{-1} dry weight for Cd, Pb and Zn in the soils of the dumpsite.

The metal levels in the study area was compared with soil quality criteria from other countries, as Nigeria does not have a quality standard (Table 6). Most of the levels of cadmium in the study area were higher than Canadian agricultural, Norwegian and Swiss standards. Cu, Ni and Zn levels in the soils of the study area were much lower than soil quality criteria for other countries. This could be due to the levels in the wastes.

Sixty-five percent of the soil lead in the vicinity of these dumpsites were higher than the 50ppm for Norwegian soil standards (Table 6). This could be accounted for as a result of atmospheric fallout or automobile emissions, for this is a major source of Pb in the Nigerian environment as the Pb levels in Nigeria gasoline is 0.66g/1 of gasoline (World Resource Institute 2000).

Secondly the mean metal contents in world soils and crustal abundances are: Pb 10.0, 12.0; Zn 50.0, 70.0; Cu 20.0, 55.0 and Cd 0.30, and 0.20 ppm respectively (Bini et al 1988) compared to a level of 73 - 302; 6.7 - 87, 3.4 - 20, and 2.4 - 6.0ppm for Pb, Zn, Cu, and Cd respectively in the soils of the dumpsite. The high levels of Cd and Pb in these soils as well as higher levels of metal in the soils of the municipality compared to the control sites are indicative that these wastes have had a major impact on the levels of metals in the soil of the study area.

CONCLUSION

Although soils are used mainly to described the long term exposure to environmental pollutants, the average concentration of trace metals in the herbage and soils of solid waste dumpsites in Abuja municipality are much higher than concentrations in normal farm land soils from the study area suggesting that municipal solid wastes are a major factor to these levels. With increase in urbanization in the area there is the need to build modern incinerations rather than the present practice of burning wastes in open spaces.

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