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Studies on the Impact of Municipal Waste Dumps on Surrounding Soil and Air Quality of Two Cities in Northern Nigeria

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Abstract: Atmospheric pollution from municipal refuse dumps and vehicular traffic are matters of growing interest, often leading to temporary restrictions in urban areas. This study aimed at evaluating bioaccumulation and effects caused by airborne pollutants from refuse dumps. Specimens of the moss *Funaria capsularis* collected in five sites in the urban areas of Zaria and Kaduna, Nigeria and trace metals (cadmium, chromium, copper, iron, lead and zinc) were measured. The overall results of this exploratory study suggest the utility of *F. capsularis* as a lower plant for biomonitoring the environmental impact of atmospheric pollution in urban areas. The impact of these dump sites on surrounding soils was also studied.

Key words: Air pollution, muncipal dumps, Vehicular exhausts, bioaccumulation

INTRODUCTION

The amount and variety of waste material have increased with the growing of technology and population. Increased vehicular traffic and emissions from refuse dumps are major contributors to air pollution and a matter of growing importance in many city centres. Of the priority pollutants, heavy metals cause adverse effects on the environment. Normative limits and international guidelines indicate the maximum levels for a number of individual pollutants in air samples. However, no restrictions have yet been given in many Nigerian cities. Municipalities have often suffered from smoke emanating from refuse dumps, which makes air quality sometimes very low.

There are numerous human activities which result in the release of toxic materials to the atmosphere. The identity of these sources has been established in most cases but their quantitative importance is rarely determined. For example, Okuo and Ndiokwere (2005) reported that in Warri (south-south Nigeria), the major sources of elemental pollution were due to re-entrained soil, automobile exhaust, residual oil combustion, petroleum activities, refuse and biomass incineration.

Indiscriminate dumping of refuse can influence soil physicochemical properties, but can still be used for farming provided the risks associated with its usage are continuously assessed and controlled. The introduction of metal contaminants into the environment could result from various sources; a few of which are application of sewage materials and leaching of garbage (Forstner and Wittmann, 1983). The impact on man would be felt if these metals enter into the food chain and accumulate in living organism (Moore and Ramamoorthy, 1984; Altundogan *et al*., 1998).

Waste handling facilities are lacking in many highly populated areas in most developing and under developed countries due to cost and lack of proper planning. This results in the discharge of household sewage and refuse into the environment untreated. Most waterways passing through urban centre are used as dump sites with open gutters leading from household direct to the waterways. A lot of toxic materials are leached by rain into soil and waterways from such dump sites. Waste amended soils have been reported to have high organic matter content (Anikwe, 2000). Soil organic matter influences the degree of aggregation and aggregate stability and it can reduce bulk density and increase total porosity and hydraulic conductivity in heavy clay soils (Anikwe, 2000).

Continuous disposal of municipal wastes in soil may increase heavy metal concentration. Heavy metals may have harmful effect on soils, crops and human health (Smith *et al*., 1996). However, Voutsa *et al*. (1996) maintain that there is generally not strong relationship between the concentration of heavy metals in soils and plants, because it depends on many factors such as soil metal bioavailability, plant growth and metal distribution to plants parts.

In contrast to automatic monitoring techniques, the study of bioindicator organisms can reveal the biologic impact of pollution over a geographical and temporal scale, depending on the selected species and approach.

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In this study mosses and lichens have been recognized as suitable biomonitors or bioaccumulators for air pollution (Bargagli, 1998; Bargagli *et al*., 2002) and terrestrial invertebrates are used for monitoring air and soils (Dallinger, 1994; Bamgbose *et al*., 2005). In this study a moss *F. capsularis* was used to monitor trace metal pollution resulting from burning refuse dumps in the Zaria, Nigeria.

MATERIALS AND METHODS

Collection and treatment of samples: This study was carried out in the city of Zaria and Kaduna in northern Nigeria, where five locations were chosen in each case. Four dump sites were sampled in Zaria and another four dump sites from Kaduna. In each of these sites composite samples of soils were collected seven meters within the vicinity of the dump sites (K_1, K_2, K_3 and K_4; Z_1, Z_2, Z_3, Z_4). Soil samples were also collected from uncontaminated areas in Zaria and Kaduna. The samples were air-dried, ground and sieved using 300 μm sieve. The moss plants identified as *Funaria capsularis* at the Biological Sciences Department, Ahmadu Bello University, Zaria, Nigeria, were collected from building walls near four major roads Zaria. Control samples were also collected from uncontaminated sites, which are essentially residential. They were scooped with plastic spoon and transferred into polythene bags. The samples were rinsed first with tap water and then with distilled water to remove any attached soil particles. They were then air-dried, ground and stored for analysis.

Chemical analysis: The soil and moss samples were digested by standard methods described in Awofolu (2005). The digested samples were analyzed for metals (cadmium, copper, iron, lead and zinc) using Atomic Absorption Spectrophotometer (SOLAR 32) at the chemistry laboratory of National Research Institute for Chemical Technology, Zaria, Nigeria and expressed as micrograms per gram dry weight. The Cation Exchange Capacity (CEC) was determined and calculated using method described by Agbeni (1995).

RESULTS AND DISCUSSION

The values obtained for the different dumpsite samples in Kaduna were varied. In all the cases the pH of the dump sites were found to be higher than pH of the control site. Of the dump sites analyzed, K_2 had the highest pH (Table 1). The pH of soil samples collected in the vicinity of the dump sites were also found to be higher than that obtained for the control site. The pH of soil affects all soil its properties i.e., chemical, physical and biological (Brady and Weil, 1999). Even though the pH of soil may be dependent on several factors such as chemical activities taking place in it, it appears that leaching or runoffs from these dump sites could have contributed to the relatively higher pH observed in these soil samples (Table 1). This means that dump sites could impact on the characteristics of soil in close proximity to them, which in turn affect plant growth because pH has been widely accepted as exerting a controlling influence on the availability of micro-nutrients to plant (Sanders, 1982). The increase in pH of the dump sites may be because of high organic matter which tend to buffer the soil by preventing excessive pH changes due to release of exchangeable cations during mineralization of organic matter (Woomer *et al*., 1994).

Organic matter is the reservoir of essential and non-essential elements for plant growth and development; hence increased organic matter may lead to increased soil productivity (Anikwe and Nwobodo, 2002). The control site had the lowest organic matter content of 1.96%, while the site K_2 had the highest organic matter content of 7.10% of all the dump sites investigated (Table 1). The organic matter content of the soils in the vicinity of these dump sites was found to be higher than that of the control sites. The high organic matter content of the dump sites may be attributed to the decaying municipal wastes. The relatively higher organic matter content in soils around the dump sites also gives an indication that the source of organic matter is the dumpsite. K_2 samples with the highest organic matter content also showed highest concentration for cadmium, copper, lead and iron, with the exception of zinc-these metals are capable of being

Table 1: pH, OM, CEC and metal ion concentration in soil samples from dump sites in Zaria and Kaduna, Nigeria

				Cd	Cu	Pb	Zn	Fe
Sample site	Soil pH	Organic matter (%)	Cation exchange	($\mu g\ g^{-1}$)				
ZC	6.50	3.44	10.20	0.0010	0.0100	0.0026	0.0100	0.0031
Z_1	8.20	6.24	22.20	0.0998	0.9846	0.0578	1.4138	0.9998
Z_2	8.50	5.23	15.00	0.0836	2.0852	0.0745	1.5538	0.7263
Z_3	9.00	7.40	28.00	0.0057	2.5431	0.0800	2.9592	1.5248
Z_4	7.40	6.90	23.60	0.0478	2.2583	0.0421	2.0198	1.1681
KC	6.30	1.96	8.60	0.0000	0.0010	0.0019	0.0019	0.0009
K_1	8.00	7.09	17.40	0.0591	1.5684	0.0643	2.3824	1.3984
K_2	8.80	7.10	18.80	0.1018	2.2432	0.1703	1.9529	1.0019
K_3	8.70	5.53	17.60	0.1000	1.3462	0.1450	0.9987	0.5432
K_4	8.20	5.50	15.80	0.0898	1.9756	0.1531	1.8254	1.0008

Table 2: Pearson correlation coefficient metals and other parameters analyzed in soils (Kaduna)

Metals	Soil pH	Soil organic matter	Cation exchange capacity
Cadmium	0.98	0.78	0.91
Copper	0.89	0.90	0.90
Lead	0.91	0.68	0.81
Zinc	0.68	0.93	0.82
Iron	0.64	0.91	0.78

Table 3: Pearson correlation coefficient metals and other parameters analyzed in soils (Zaria)

Metals	Soil pH	Soil organic matter	Cation exchange capacity
Cadmium	0.33	0.17	0.05
Copper	0.73	0.82	0.72
Lead	0.98	0.72	0.65
Zinc	0.81	0.94	0.91
Iron	0.77	0.99	0.97

Table 4: Heavy metal concentration in *Funaria capsularis* ($\mu g\ g^{-1}$)

Sites	Cd	Cu	Pb	Zn	Fe
M_1	0.0487	1.3781	0.1151	1.0498	0.9153
M_2	0.0246	1.3856	0.9560	0.9826	0.8451
M_3	0.0362	1.4092	0.1092	1.2361	0.5682
M_4	0.0101	1.0267	0.0986	1.5782	0.0005
Control	0.0000	0.0726	0.0026	0.0098	0.0005

retained in the organic phase of the soil. The Pearson correlation coefficient showed that there is a positive correlation between organic matter and metal concentrations (Table 2).

Cation Exchange Capacity (CEC) which is a measure of the sum total of the exchangeable cations that a soil can absorb was relatively higher in the dumpsite samples. Again the K_2 sample had a value more than two times the value obtained from the control samples i.e., 8.60 and 18.80 cmol kg^{-1}, respectively (Table 1). The higher value of CEC obtained for the soils around dump sites compared to the control sites again showed that the dump sites could affect the properties of the soils in close proximity to them. The highest value of CEC obtained in K_2 was expected because soils with high pH and high humus content normally have high cation exchange capacity (Brady and Weil, 1999). K_2 with the highest CEC also had the highest concentration of Cd, Cu, Pb and Fe with the exception of Zn in the dump sites soil. The high cation exchange capacity of the dump sites may also be attributed to decomposition of municipal wastes, which yield more of the exchangeable bases thereby raising the fertility status of the dump sites.

Zaria control samples showed relatively low pH values of 6.50, while Z_3 showed the highest value of 9.00 (Table 1). The values here were higher than the values obtained from sites in Kaduna. The dump sites had higher pH values when compared with soil samples collected in the vicinity of the dump sites and control sites. This suggests that the dump sites in Zaria may also affect plant growth like the samples collected from Kaduna. The values for the soil samples collected from around the dump sites were found to be higher than the control site. This again suggests that the relatively high pH observed in these areas is as a result of leaching from the dump sites into the surrounding soils. Soil pH showed similar correlation with all analyzed metals with exception of Cd in soil (Table 3).

The organic matter content of the control site was the lowest (3.44%) while that of Z_3 was the highest (7.40%) (Table 1). The highest and lowest values here were also higher than the values obtained for sites in Kaduna. The organic matter content of the dump sites was higher than control sites. The higher level obtained for soils around dump sites compared with that of the control sites, showed that the dump sites had effects on the soil. The high organic matter content of the dump sites may be attributed to the use of the sites for dumping of municipal wastes. Site Z_3 with the highest organic matter content also showed highest concentration of Cu, Pb, Zn and Fe with the exception of Cd. This contrasts site K_2 with highest organic mater showing highest concentration of all metals analyzed with the exception of Zn. Organic matter showed high positive correlation with all metal analyzed in the soils with exception of Cd, which showed low correlation (Table 3).

The results of the study showed that Cation Exchange Capacity (CEC) had highest value in site Z_3 (28.00 cmol kg^{-1}) while control site had the lowest value with 10.20 cmol kg^{-1} (Table 1). The higher value obtained in the soil collected in the vicinity of the dumpsite compared to the control sites may be as a result of the effect of dump sites has on it. The highest value of CEC obtained in Z_3 was not unexpected because soils with high pH and high humus content also have high CEC (Brady and Weil, 1999). This is result is similar to that obtained for site K_2 where the high CEC showed high concentration all metals except of Zn.

The result obtained in the analysis *Funaria capsularis* revealed the presence of cadmium, lead, zinc, copper and iron in the samples (Table 4). Cadmium concentration were found to be 0.0487, 0.0246, 0.0326, 0.0101 and 0.0000 $\mu g\ g^{-1}$ for sites M_1, M_2, M_3, M_4 and the control site, respectively. The highest value of 0.0487 $\mu g\ g^{-1}$ was obtained from site M_1, while 0.0000 was obtained as the lowest concentration from the control site. The values obtained from M_1, M_2, M_3 and M_4 were higher than the 0.005 $\mu g\ g^{-1}$ limit given by USEPA (1993), but lower than 1 $\mu g\ g^{-1}$ limit by FEPA (1991) and 1-3 $\mu g\ g^{-1}$ limit by EC Council (1986) directive 86/278/EEC. The values were lower when compared with the range of 0.10-0.58 given by Sardans and Penuelas (2005) in a similar study using the moss *Hypnum cupressiforme*.

The result showed copper concentration of 1.3781, 1.3856, 1.4092, 1.0267 and 0.0726 μg g^{-1} for sites M_1, M_2, M_3 and M_4 and the control site, respectively. 1.4092 μg g^{-1} was obtained here as the highest concentration from site M_3, with 0.0726 μg g^{-1} was obtained as lowest from the control site. The concentration in sites M_1, M_2, M_3 and M_4 were higher than the 1 μg g^{-1} limits by USEPA and FEPA, but lower than the 50-140 limits by EC Council directive 86/278/EEC. The values were lower than the 20-115 μg g^{-1} range given by Sardans and Penuelas (2005) in a study in which the Moss *Hypnum cupressiforme* was used.

Lead concentration were found to be 0.1151, 0.9560, 0.1092, 0.0986 and 0.0026 μg g^{-1}, respectively for sites M_1, M_2, M_3, M_4 and the control sites. The highest value of 0.9560 μg g^{-1} was obtained from M_2, while the lowest concentration of 0.0026 μg g^{-1} was obtained from the control site. The values obtained were higher than zero limited given by USEPA, but lower than the 1 μg g^{-1} limit given by FEPA. The values obtained here were lower than the 5-57 μg g^{-1} range given by Sardans and Penuelas (2005) in a study using the moss *Hypnum cupressiforme*. The high level of lead may be as a result of the busy nature of the road.

Zinc concentration was found to be 1.0498, 0.9826, 1.2361, 1.5782 and 0.0098 μg g^{-1} for site M_1, M_2, M_3, M_4 and the control site, respectively. The highest concentration of 1.5782 μg g^{-1} was obtained from M_4 and the lowest of 0.0098 μg g^{-1} was obtained from the control site. The values for M_1, M_3 and M_4 were all higher than 1 μg g^{-1} limit by FEPA, but lower than the 5 μg g^{-1} limit by USEPA. The values obtained here were lower than the 30-180 μg g^{-1} range given by Sardans and Penuelas (2005) in a study using the moss *Hypuum cupresiforme*.

Iron concentration was found to be 0.9153, 0.8451, 0.5682, 0.6281 and 0.0005 μg g^{-1} for M_1, M_2, M_3 and M_4 and control site, respectively. The highest value of 0.9153 was obtained from site M_1 while the control site had the lowest with 0.005 μg g^{-1}. The value obtained in sites M_1, M_2, M_3 and M_4 were higher than the 0.3 μg g^{-1} limit by USEPA, but lower than 20 μg g^{-1} limit given by FEPA.

CONCLUSIONS

The result revealed that all the sites had values of soil pH, soil organic matter and cation exchange capacity higher than the 'unpolluted sites'. The level of cadmium, copper, lead and iron obtained in some sites were above the limits given by some international environmental protection agencies, but the levels of zinc obtained were less than these limits. The results also revealed that the constant burning of these dump sites could contribute significantly to the concentration of these trace metals in the environment and this could possibly enter into the food chain as revealed by the high concentration observed in *Funaria capsularis*.

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