CONCENTRATION OF CADMIUM, LEAD AND ZINC IN SOIL AND GRASS AROUND THE NAKURU MUNICIPAL DUMPING SITE, KENYA

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ABSTRACT

Concentrations of cadmium, lead and zinc in soils and vegetation in and around the Nakuru Municipal waste dumping site were determined. The metals were analysed using atomic absorption spectroscopy and the data analysed using a two-sample t-test.

The study revealed that the dumping site had significantly higher levels of metals than the surrounding for both soils and plants at $\mu = 0.05$. Mean levels of cadmium, lead and zinc in soils from the dumping site were 13.64 µg/g, 109.44 µg/g and 3751.74 µg/g while those from outside the dumping site were 11.85 µg/g, 56.84 µg/g, and 894.49 µg/g, respectively. Levels of cadmium, lead and zinc in grass from the dumping site were 10.61 µg/g, 115.00 µg/g and 1275.13 µg/g. Grass samples outside the dumping site recorded decreased values of 9.58 µg/g cadmium, 100.44 µg/g lead and 607.74 µg/g of zinc. Except for cadmium, there was a significant positive relationship between the levels of metals in soil and those in grass. There was a negative correlation between the levels of heavy metals in both soil and grass samples with distance from the dumping site.

1.0 INTRODUCTION

Nakuru town is the fourth largest urban centre in Kenya, situated in the Rift Valley Province, 160 km north-west of Nairobi. It is located at an altitude of 1,840 metres above sea level and lies between Lake Nakuru National Park to the south and Menengai Crater to the north. The municipality covers an area of 290 km^2, with a rapidly increasing population estimated at 300,000 (WWF, 1998). The town generates 200 tonnes of solid waste each day, part of which is collected and dumped at the municipal landfill 4 km from town on the slopes of the Menengai Crater. The landfill is located on a faultline and uphill, thus posing risk to both ground and surface water and the nearby soil and plants, WWF (1998); Assmuth and Standberg, (1993). As in most other cities in Africa the waste is disposed of in an open crude unsanitary landfill, as recorded by Mwangi (2000), where it is sometimes burned. Both hazardous and hospital waste are also disposed together in the landfill without any treatment, posing a great danger to human health and the environment, UNEP (1999).

A report by International Maritime Organisation (IMO, 1995) showed that a large percentage of these industrial and municipal wastes contain heavy metals. Zinc is mainly a cause of phytotoxicity to animals and man. Lead is a non-essential element, a neurotoxin and a multimedia pollutant. Cadmium is a highly toxic non-essential metal that accumulates in the kidney of mammals, causing kidney dysfunction. The toxicological effects of these metals to organisms will vary with species of plant and animal. Exposure to elevated levels has been linked to developmental retardation, cancer and birth defects, Zakrewski (1991). The behaviour of metals in soils is influenced by physico-chemical properties such as pH and reduction-oxidation status. Alloway and Ayres (1997) suggested that these factors including the extent of absorption determine rate of leaching and uptake by plant roots.

Muriithi (1995) found toxic elements such as lead, mercury, arsenic, iron and copper in residents of some parts of Nakuru District of Kenya. He attributed this to environmental pollution and suggested further research to establish concentrations of these trace elements in air, water and soil. The study revealed a correlation between the metal levels and donor age, an indication of prolonged exposure of donor to these elements. Increased respiratory infections in residents located on the windward side of Eldoret town were attributed to air pollution from industrial establishments by Ombura (1997). Although the study did not consider disposal of wastes, it should also result in environmental degeneration. Solid waste disposal in landfills remains the most economical form of disposal in most developing countries as noted by Carra and Cossu (1990).

Although the Nakuru site has been in operation since 1974, it lacks any leachate collection or treatment system practiced in sanitary landfills. The surface run-off from the dumping site is an important route for heavy metals pollution transfer. High levels of heavy metals comparable to those of effluents emanating from industries could lead to contamination, as observed by Brindley *et al.* (1982). This predisposes plants, water, soil, animals and human beings to heavy metal pollution. The indiscriminate dumping of wastes at the municipal dumping site requires urgent attention. It is therefore necessary to investigate the levels of these metals and the potential impacts of waste dumping on human beings and the environment in Kenya.

2.0 METHODOLOGY

Soil and grass (*Cynodon dactylon)* were sampled from 20 locations in and outside the dumping site between April and August 2002. About 500 g of soil was collected to 10 cm depth using a soil auger, while grass was clipped 1 cm above ground. Measurements for pH were made using a suspension of soil in the mass (g): volume (ml) ratio of 1:2.5 soil to water. A sample of 10.0 0.1 g of air-dried soil, was ground to pass through a 2 mm sieve and washed into a bottle with 25 ml of distilled water. The solution was shaken and a Fisher Accumet pH meter Model 610A electrode inserted. Exactly 0.3 ± 0.01 g of dry ground soil and plant material was placed in digestion tubes. 4.4 ml of a digestion mixture (selenium powder 0.42 g, lithium sulphate 14 g, 350 ml of 30% hydrogen peroxide and 420 ml of concentrated sulphuric acid) previously prepared as per Okalebo *et al.* (1993) was added. Each tube was heated in a block digester for 3 hours and allowed to cool. This was filtered and made up to 100 ml in a volumetric flask with distilled water. Calibration standards of appropriate concentrations and blanks were also prepared in a similar manner. All reagents used were of analytical grade. The samples were analysed by atomic absorption spectrometry (Model VGP 210, Buck Scientific). The detection limits were 0.1 μg/g for lead, 0.005 μg/g for zinc and 0.005 μg/g for cadmium.

3.0 RESULTS AND DISCUSSION

The mean concentrations of cadmium, lead and zinc in and out of the dumping site for soils and grass are shown in Tables 1 and 2. Zinc has the highest concentration of 3751.74 μg/g in the dumping site soil. This is consistent with observations elsewhere that zinc forms the highest percentage of metals in domestic as well as industrial wastes, El-Fadel *et al.* (1997).

Lead and cadmium are the next abundant metals at mean soil concentration levels of 109.44 μg/g and 13.64 μg/g respectively in the dumping site. The levels of lead in grass in the dumping site were not significantly different from those in grass away from dumping site at $\alpha = 0.05$ probability levels. This was possibly due to aerial deposition from traffic on the road at 50 metres away from the dumping site. However, cadmium and zinc levels in grass in the dumping site are significantly different from mean levels outside dumping site. These higher levels being an indication of elevated uptake from soils.

In soils, mean values of lead, cadmium and zinc in dumping site are significantly higher than their levels outside the dumping site. These are as a result of accumulation from prolonged dumping of wastes, both domestic and industrial. A similar trend was observed in grass samples in and out of the dumping site, where metal levels in grass were lower than corresponding values in the soil at each sampling station

At some stations, especially near industrial concerns and the road, grass samples had higher lead levels than those in respective soils. These elevated levels were attributed to aerial dust deposition from these polluted environments. In general, metals show a decrease in concentration as one goes away from the dumping site. This inverse proportionality of metal with distance from source of pollution has been reported by many workers (Nwanko and Elinder, 1979; Kashem and Singh, 1998). Cadmium does not seem to obey this direct relationship with soil as it remains relatively constant regardless of distance from the dumping site. This may imply that the cadmium observed is mainly from other sources such as the parent rock. Brady (1990) reported a similar lack of direct relationship for cadmium between soil and plants and attributed it to other soil factors including the presence of chloride ions

Table 3 shows that there exists a significant relationship between levels of heavy metals in soil as compared to corresponding levels in *C. dactylon*. A two tailed t-test at $\alpha = 0.05$ and 17 degrees of freedom gives a tabulated critical value of $t_2 = 2.110$. The higher calculated t values of lead ($t_c = 7.3104$) and zinc (t = 4.3549) indicate that high concentrations of these metals in soils correspond to high concentrations of the metals in *C. dactylon*. But this is not so for cadmium which has a lower calculated t value of 2.0576. This could be due to unavailability of cadmium to the plant as a result of such factors as pH, the chemical species and presence of chloride ions as suggested by Brady (1990). The strength of these relationships can be seen from Pearson's correlation values which are r = 0.8464 for lead and r = 0.7256 for cadmium. The high values indicate that amounts of these metals in *C.dactylon* is highly dependent on their concentrations in soils. These results are in agreement with what Page *et al.* (1987) observed. In their study, metal levels in plants had a highly positive correlation with levels present in the soil. The small value of r = 0.2377 for zinc indicates that the amount of zinc in *C. dactylon* is only to a very small extent dependent on its concentration in the soil.

R^2 is the ratio of model variability to the total variability. These values indicate that the models relating to lead are only a small portion of total variability. Hence there are other factors apart from the total concentration of this metal in soil which impact on its concentration in *C. dactylon*. The regression data also tells us the usefulness of the models in predicting the amount of metal in *C. dactylon* growing in a soil which contains a known amount of metal. This F value is obtained as the ratio of mean sum of squares for the model to mean sum of squares due to error. F greater than 1 means that the contribution of the model is greater than that of the error. Since all the models have F greater than 1 at $\alpha = 0.05$ they are adequate and useful for such prediction.

There was a decrease in concentration of metals with soil depth in the dumping site. The top-soil (10 cm) which is rich in organic matter binds a higher concentration of metals as seen in Table 4 when compared with lower subsoil levels. The pH range of soils from the dumping site was between 7.92 to 8.52 with a mean of 8.15, while soils outside had a pH range of 5.80 to 7.28. The high pH leads to immobilisation of these metals in the surface soil, Ge *et al.* (2000). This has been explained by noting that adsorption of metal on the negative sites on the organic colloid increases with pH, hence making the metal less soluble and exchangeable, Miner *et al.* (1997). Although the pH changes of soils during the seasons are rarely significant the influence of man through disposal of substances that create acidic or alkaline conditions may alter the mobility of the heavy metals drastically.

The transfer coefficient (TC) is a convenient way of quantifying the differences in bioavailability of metals to plants, Alloway and Ayres (1997). This ratio of heavy metal in plant compared to the soil was 1.83 ± 0.92, 0.80 ± 0.05 and 0.71 ± 0.37 for lead, cadmium and zinc respectively. This implies lead is more bioavailable than cadmium or zinc, which is inconsistent with studies carried out by Alloway and Ayres (1997) and Mclaughlin *et al.* (2000). In their work cadmium and zinc had higher (TC) values than lead hence more bioavailable. This anomaly was attributed to a number of reasons such as optimum pH for absorption of metal, part of plant considered and plant genotype. In addition, soil samples depicted less acidic conditions thus hampering the transfer of cadmium and zinc from soil to grass. Adams (1990) proposed the optimum pH range for absorption of zinc and cadmium to be below 6.

4.0 CONCLUSIONS

The very high values of heavy metals in the dumping site which progressively decreases with distance in both soil and grass is an indication of the dumping site as a source of pollution to the environment. The direct correlation between heavy metals in soil and grass implies that toxic metals can easily find their way into plant foliage and subsequently get into animal products posing public health concerns. Leachate and surface run-off from the dumping site could also lead to heavy metal pollution of ground waters and the adjacent ecosystem.

In order to minimise potential environmental and public health risks, the Municipal Council of Nakuru must, as a matter of urgency, put in place control measures to protect the ecosystem. Waste separation, composting and soil bioremediation are possible immediate solutions. A long-term solution would be to relocate the dumping site to a remote location where its impacts through soils, food crops and water resources will be minimal on the population of Nakuru town and its surroundings.

Table 1: Mean concentrations of cadmium, lead and zinc for in soils and out of the dumping site

Metal	*Inside dumping site (n=5) Mean concentration (mg/g)*	*Outside Dumping site (n=15) Mean concentration (mg/g)*
Cadmium	13.64 ± 1.33	11.85 ± 0.49
Lead	109.44 ± 46.47	56.84 ± 17.42
Zinc	3751.74 ± 547.29	894.49 ± 764.33

Table 2: Mean concentration of cadmium, lead and zinc for grass in and out of the dumping site

Metal	*Inside dumping site (n=5) Mean concentration (mg/g)*	*Outside Dumping site (n=15) Mean concentration (mg/g)*
Cadmium	10.61 ± 0.86	9.58 ± 0.59
Lead	115.00 ± 43.16	100.44 ± 26.77
Zinc	1279.13 ± 241.13	605.74 ± 355.72

Table 3: Correlation data of heavy metals levels in soil and grass

Metal	r	t_c	R^2	F
Cadmium	0.7256	2.0576	0.5265	18.8994
Lead	0.8464	7.3104	0.0565	1.1018
Zinc	0.2377	4.3549	0.7165	42.958

Table 4: Heavy metals concentration (μg/g) with depth in the dumping site

Metal	*Soil depth (cm)*				
	10	20	25	35	50
Cadmium	15.47	14.03	13.90	13.77	13.46
Lead	117.20	99.07	92.23	76.37	46.90
Zinc	5973.33	4270.00	4083.33	3840.00	1990.00

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