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HEAVY METALS CONCENTRATION IN THE SUBSOIL OF REFUSE DUMP SITES IN BENIN CITY, NIGERIA

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Abstract

The concentrations of heavy metals: cadmium, chromium, copper, lead, manganese and nickel, in topsoil samples collected from three refuse dump sites in Benin City were determined by atomic absorption spectrophotometry. The determinations were done in order to assess the suitability of these landmasses for agricultural, residential or industrial purposes when reclaimed eventually. Results obtained indicate that the concentrations of all the metals in the three different locations were lower than the threshold values (Cd 20 $mgkg^{-1}$, Cr 800 $mgkg^{-1}$, Cu 500 $mgkg^{-1}$, Pb 1000 $mgkg^{-1}$, and Ni 500 $mgkg^{-1}$) for commercial and industrial application and, therefore, can be utilized for these purposes. However, the cadmium content 10.00 $mgkg^{-1}$ (Iyaro), 29.00 $mgkg^{-1}$ (Siluko) and 7.30 $mgkg^{-1}$ (West Circular) obtained in the study rendered the sites unsuitable for agricultural and residential application even when reclaimed, unless a level of remediation is administered to the soil. Manganese gave the highest concentrations of 244.50 $mgkg^{-1}$ (Iyaro), 344.00 $mgkg^{-1}$ (Siluko) and 228.00 $mgkg^{-1}$ (West Circular). Enhanced concentrations of the heavy metals were observed for soil samples from the dump sites than soil samples taken 50 m from the dump sites.

Résumé

UKPEBOR, E. E. & UNUIGBE, C. A.: *Concentration des métaux lourds dans le sous-sol des sites de dépotoir à la Cité Bénine du Nigéria.* Les concentrations des métaux lourds: cadmium, chrome, cuivre, plomb, manganèse et nickel dans les échantillons de sous-sol enlevés de trois sites de dépotoir à la Cité Bénine étaient déterminées par la spectrophotométrie d'absorption atomique. Les déterminations étaient faites pour vérifier si ces sous-sols sont convenables pour les usages agricoles, résidentiels ou industriels lorsqu'ils sont finalement récupérés. Les résultats obtenus indiquent que les concentrations de tous les métaux dans les trois différents emplacements étaient plus faibles que les valeurs de seuil (Cd 20 $mgkg^{-1}$, Cr 800 $mgkg^{-1}$, Cu 500 $mgkg^{-1}$, Pb 1000 $mgkg^{-1}$, et Ni 500 $mgkg^{1}$) pour usage commercial et industriel et pourrait donc être utilisé pour ces usages. Toutefois, le contenu de cadmium: 10.00 $mgkg^{-1}$ (Iyaro), 29.00 $mgkg^{-1}$ (Siluko) et 7.30 $mgkg^{-1}$ (West Circular) obtenu de l'étude rend les sites non-convenables pour les usages agricoles et résidentiels même s'ils sont récupérés à moins qu'un niveau de traitement de remède est appliqué au sol. Manganèse rendait les plus fortes concentrations de 244.50 $mgkg^{-1}$ (Iyaro), 344.00 $mgkg^{-1}$ (Siluko) et 228.00 $mgkg^{-1}$ (West Circular). Les concentrations augmentées des métaux lourds étaient observées pour les échantillons de sites de dépotoir que les échantillons de sous-sol enlevés 50 m des sites du dépotoir.

Introduction

Most recently, interest in researches at evaluating the levels of heavy metals around refuse dump sites in Benin City has been stimulated as a result of the growing concern expressed by the Government over the large acres of land covered by these dump sites, and the strong desire to reclaim these large expanses of land for agricultural, industrial or residential purposes. Soil quality determines its actual and potential use. For example, the quality of soil intended for agricultural use depends on the concentration of heavy metals in it.

Solid wastes dumped at the different sites include food wastes, chemicals such as pesticides, deposits of heavy metals, etc. Certainly, all solid wastes occupy space and, for many countries, the disposal and management of these wastes are ancient problems. Increase in population and development have led to a gradual change in the practice of disposal of solid wastes indiscriminately at dump sites to sanitary landfills and incineration in developed countries. One cannot over-look the possible hazards that can be created as a result of long term dumping of refuse in the soil. A residence time of about 1000-3000 years has been estimated for the heavy metals Cu, Ni, Pb and Zn in temperate zones (Bowen 1977). This means that these metals remain distributed for a very long time in the soil in large amounts.

Heavy metals have a great ecological significance due to their toxicity and accumulative behaviour (Purves, 1985). Metals of particular toxic significance are arsenic, zinc, manganese, chromium, lead, cobalt and molybdenum. These elements, unlike most pollutants, are not biodegradable and they undergo ecological cycle (Nurnberg, 1984). Some metals such as iron, zinc, copper, cobalt and manganese are essential to life but can be toxic in high doses. The total trace metal content provides an important information about the pollution level if the background or geochemical composition is known (Salmons & Forstner, 1980). The impact of heavy metals on the environment is a concern to government regulatory agencies and the public (Page & Chang, 1985; Feigin *et al.*, 1991; Tiller, 1992). The concern is the contamination of soil resources by potentially toxic metals from these dump sites located all over the city.

Uncontrolled inputs of heavy metals are undesirable because, once accumulated in the soil, these elements are generally very difficult to remove and potentially harmful effects that may arise in the future should not be ignored. Subsequent problems include toxicity to the plants growing on the contaminated soil, and uptake by the plant resulting in heavy metal levels in the plant tissue, considered to be harmful to the health of humans and animals that consume it.

Soil is very important in ecosystem research as it is the place where many kinds of interactions take place between minerals, air, water and biota. In the recent past, the soil system, has been subjected to physical stress by input of foreign substances such as heavy metals. This include the degradation of soil organic matter and lowering of the fertility of the upper soil layer due to erosion. Generally, soil reacts much more slowly to external influences than water and air, as it is able to bind substances into complexes. This is carried out mainly with the help of clay minerals and humic acids which are capable of binding ions superficially. In this process, the soil accumulates both organic and inorganic substances, and acts as a nutrient reservour for plants and microorganisms (Bloemen *et al.,* 1995). However, a side effect of its function as a depot is that the soil collects not only nutrients but also pollutants like the heavy metals. As a result, the increase in heavy metal concentrations in the soil caused by humans had lead to considerable accumulation in some cases (Al-Muzaini & Jacob 1996). Plants, which are the basic food of all animal and human life, grow and obtain their nutrition mainly in the top layers of the soil. It is in these top layers, the main rooting zone of the plants, that heavy metals are accumulated and reach high concentrations.

Since these heavy metals can become a threat to vegetation and animals, and ultimately affect the quality of human life (Harrison, 1982) through the food chain, it is important to continuously monitor the level of such pollutants in the environment. The present study was, therefore, initiated in an attempt to find out the concentration of heavy metals (Pb, Cd, Cr, Cu, Mn, Ni) in refuse dump sites soil environment.

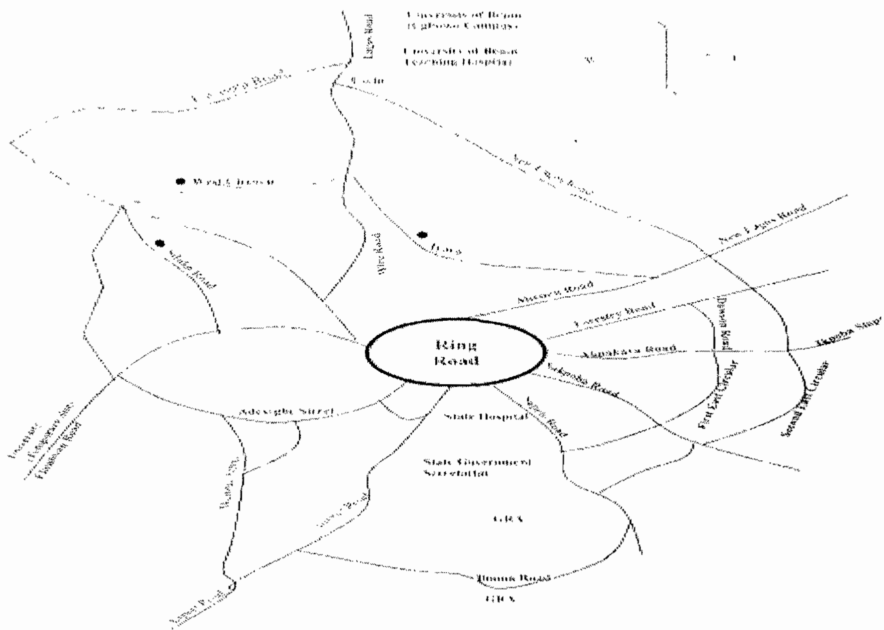

Fig. 1. Map of Benin showing sampling points

The data gathered from this study will assist the Government in arriving at decisions with respect to better and more profitable use of the dump sites.

Experimental

The three locations chosen in this study represent areas with high population density associated with increased commercial activities and high refuse disposal rates (domestic, metal scraps, industrial/heavy metal parts, etc).

From the dump sites (Fig. 1.) 20 composite topsoil (0-15 cm) samples representing three replicates from each point sampled in a transect was collected. The average distance between the midpoint (heap spot) and the periphery of the dump sites is 67.7 m, hence for purpose of uniform assessment, soil samples were collected at 0 m and 50 m from each of the dump sites and with each site having 20 samples. The soil samples were stored in carefully labeled polyethylene bags for easy identification and to reduce the effect of contamination. The samples collected were air-dried, ground in an agate mortar and sieved through a 1.73 mm nylon sieve. 1 g of sieved, air -dried soil samples were weighed in a 125-cm^3 hard-glass digestion tube. A few drops of high-purity HNO_3 were added slowly. After the effervescence, 5 cm^3 of high-purity HNO_3 and 15 cm^3 of $HClO_4$ were added slowly and kept overnight. The samples were then heated in a digester at 120 ^{0}C for 3 h. The contents were allowed to cool for 15 min after the appearance of white fumes, filtered into a 100-cm^3 volumetric flask, and diluted to volume with distilled water (Allen *et al.,* 1974). Concentration of the heavy metals were determined using a Varian spectra AA10 atomic absorption spectrophotometer.

Results and discussion

The results of the spectrophotometric analysis on the soil samples from Iyaro, Siluko and West Circular dump sites are summarized in Tables 1, 2, and 3. At Iyaro dump site (Table I), manganese concentration was the highest (244.50 mgkg^{-1}), followed by lead, nickel, chromium, copper and

TABLE 1
Concentration of heavy metals (mgkg^{-1} dry weight) in topsoil samples in and around the Iyaro refuse dump site

Metal	*Dump site concentration (mg kg^{-1})*	*Concentration 50 m from dump site (mg kg^{-1})*
Cd	10.00 ± 1.20	10.00 ± 1.14
Cr	120.00 ± 3.24	11.15 ± 1.30
Cu	30.00 ± 1.00	13.25 ± 1.02
Pb	159.50 ± 4.22	26.40 ± 1.98
Mn	244.50 ± 5.83	40.00 ± 1.58
Ni	130.20 ± 3.31	11.40 ± 0.70

TABLE 2
Concentration of heavy metals (mg kg^{-1} dry weight) in topsoil samples in and around the Siluko refuse dump site

Metal	*Dump site concentration (mg kg^{-1})*	*Concentration 50 m from dump site (mg kg^{-1})*
Cd	29.00 ± 0.98	6.90 ± 0.82
Cr	24.00 ± 2.30	9.20 ± 0.94
Cu	16.70 ± 0.64	11.05 ± 1.22
Pb	63.90 ± 2.00	4.80 ± 0.09
Mn	344.00 ± 15.20	211.30 ± 11.46
Ni	708.00 ± 17.46	62.10 ± 2.00

TABLE 3
Concentration of heavy metals (mg kg^{-1} dry weight) in topsoil samples in and around the refuse dump location at West Circular Road

Metal	*Dump site concentration (mg kg^{-1})*	*Concentration 50 m from dump site (mg kg^{-1})*
Cd	7.30 ± 0.99	5.00 ± 0.78
Cr	35.00 ± 3.00	6.15 ± 0.80
Cu	30.00 ± 2.36	5.90 ± 0.64
Pb	80.00 ± 3.22	18.00 ± 1.30
Mn	228.00 ± 4.40	54.00 ± 2.27
Ni	54.00 ± 1.74	15.00 ± 1.18

cadmium (10.00 mgkg^{-1}), respectively. The manganese content was 1.5 times higher than that of lead, while the lead content was 1.2 times higher than that of nickel. The nickel concentration was 1.1 times higher than that of chromium, whereas the chromium level was 4.0 times higher than that of copper. The copper concentration was 3.0 times higher than that of cadmium. Generally, the concentrations of most of the metals decreased with increased distance from the dump. This suggests that the dump site contributes significantly to the level of these metals in that environment.

The results (Table I) show that the soil is highly polluted by these metals. A probable explanation for this observation is the location of this refuse dump in an area with very high commercial activities and traffic density. Iyaro area of Benin City serves as a transit area for commercial vehicles. The high content of manganese is associated with its use in electroplating of some parts of motor vehicles which form a substantial part of the refuse dumped at this location. The high concentrations of lead (average concentrations of Pb in soil are between 15 and 25 mgkg^{-1} (Miroslav & Vladimir, 1999), nickel, cadmium and chromium recorded at the dump site may be attributed to contribution from aerial deposition from motor vehicle emission. Numerous studies have shown a clear impact of road traffic on levels of heavy metals in the environment (Daniel *et al.*, 1997; Lagerweff & Specht, 1970; Frion-Frenet *et al.*, 1994; Singh *et al.*, 1983; Olajire & Ayodele, 1997). Naturally, chromium is ubiquitous in soils. Although the level of chromium observed at Iyaro dump site (120.00 mg kg^{-1}) appears high, it falls within the general concentrations of chromium (from <1 to 1000 mg kg^{-1} (Miroslav & Vladimir, 1999) in soils.

At Siluko dump site, nickel was highest (708.00 mg kg^{-1}) followed by manganese (344.00 mgkg^{-1}), lead (63.90 mgkg^{-1}), cadmium (29.00 mgkg^{-1}), chromium (24.00 mgkg^{-1}) and copper (16.70 mg kg^{-1}) (Table 2). At this location, the nickel content was 2.1 times higher than that of manganese, while the manganese level was 5.4 times higher than that of lead. The lead content was 2.2 times higher than that of cadmium, whereas cadmium was 1.2 times higher than that of chromium. The chromium concentration was 1.4 times higher than that of copper. The concentrations of all the metals obtained in this site were relatively high, especially for nickel and manganese. The composition of the solid waste and the location of this dump affected the levels of the heavy metals to a large extent. Though this dump site is in an environment with high commercial activities, the traffic density in this area is not as high as in Iyaro. This could probably be responsible for the reduced level of lead (63.90 mgkg^{-1}) obtained. The relatively high concentration of cadmium may be due to the presence of cadmium in lubricating oils and tyres at the dump. A decrease of metal concentration with distance from the dump was observed.

TABLE 4
Comparison of metal concentration in the topsoil of the different sites

Cd	*Cr*	*Cu*	*Pb*	*Mn*	*Ni*
Siluko	Iyaro	West Circular	Iyaro	Siluko	Siluko
Iyaro	West Circular	Iyaro	West Circular	Iyaro	Iyaro
West Circular	Siluko	Siluko	Siluko	West Circular	West Circular

Sites concentrations are listed in increasing order from the top to bottom of each column.

TABLE 5
Composite correlation between the elements Cd, Cr, Cu, Pb, Mn and Ni[a]

	Cd	*Cr*	*Cu*	*Pb*	*Mn*	*Ni*
Cd	1	0.64	0.61	0.59	0.56	0.50
Cr		1	0.99	0.94	0.66	0.49
Cu			1	0.93	0.70	0.44
Pb				1	0.60	0.37
Mn					1	0.94
Ni						1

a: based on all 20 samples

At the refuse dump site at West Circular, the concentration trend of the metals obtained from the analysis is Mn >Pb >Ni >Cr >Cu >Cd. The reduced commercial activities and decreased traffic density near the location of this dump is reflected in the result obtained from the soil samples collected at the dump-site. The levels of metals at this site were generally lower than those obtained for the Iyaro site. The highest concentrations measured were 228.00 mg kg^{-1} for manganese and 80.00 mgkg^{-1} for lead. Cadmium had the least concentration of 7.30 mgkg^{-1}.The concentration of the metals showed a marked decrease at a distance of 50 m from the dump. Siluko refuse dump site had the highest cadmium, manganese and nickel contents while Iyaro had the highest lead and chromium contents and West Circular dump location recorded the highest copper content (Table 3).

Correlation analysis was carried out to determine the extent of relationship between the elements investigated (Table 5). The correlation matrix shows that the highest correlation was between Cr and Cu with r = 0.99. The lowest correlation was between Pb and Ni with r =0.37. Correlations decreased between Cr and Pb, Mn and Ni, Cu and Pb, Cu and Mn, Cr and Mn, Cd and Cr, Cd and Cu, Pb and Mn, Cd and Pb, Cd and Mn, Cd and Ni, Cr and Ni, and Cu and Ni (in the order given).

When compared with values obtained in previous studies of heavy metal pollution in roadside sediments and soil in Benin City

(Ihenyen, 1998; Ndiokwere, 1984), values obtained in this study were found to be higher for some of the metals and lower for others. While lead levels of 159.50 mgkg^{-1} (Iyaro), 63.90 mg kg^{-1} (Siluko) and 80 mg kg^{-1} (West Circular) were obtained in this study, previous study gave 753.14 mg kg^{-1} Pb (Ihenyen, 1998). The nickel concentration obtained in this study were however, higher than values obtained from previous studies. The chromium concentrations compare favourably with previous values, whereas the copper values in a previous study were about twice the values of the present study.

TABLE 6
Environmental quality criteria in the UK. Soil quality criteria recommendations to the national government (Visser, 1993)

Element	Soil (mg kg^{-1}) threshold	
	Domestic gardens, play areas	*Landscapes, buildings*
Cd	3	15
Cr	600	1000
Cu	-	130
Pb	500	2000
Ni	-	-

TABLE 7
Environmental quality criteria in Canada. Interim environmental quality criteria for contaminated sites. Recommendations to sub-national authorities (CCME, 1991)

	Soil (mg kg^{-1})		
Element	*Agriculture*	*Residential*	*Commercial/ Industrial*
Cd	3	5	20
Cr	750	250	800
Cu	150	100	500
Pb	375	500	1000
Ni	150	100	500

Soil quality determines its actual and potential use. For example, the quality of soil intended for agricultural use depends on the content of heavy metals such as Pb, Zn, Cd, Cr, etc. This is because these toxic substances can accumulate in the soil where they can have harmful effects on crops, as well as entering the food chain. A major and growing concern is the exposure of children playing in parks, gardens and other soil –covered locations to toxic substances present in the soil, especially toxic metals such as lead. In view of the significance of the concentration of heavy metals in determining the actual and potential use of a given land area, standards giving critical concentrations of various pollutants in soils have been adopted by many countries (Tables 6 and 7). These generally specify threshold values which should not be exceeded in order to avoid any potential health hazard or other harmful consequences.

To be able to recommend the best use the refuse dump sites evaluated in this study can be put when eventually reclaimed, values obtained were compared with recommended standards. From the comparative analysis carried out, the three dump sites can be effectively utilized for commercial and industrial purposes without any treatment, since the concentration of all the metals were found to be lower than the threshold values for commercial and industrial applications. But for residential and agricultural applications, some level of treatment will be required so as to bring the concentrations of some of the elements, especially cadmium, to an acceptable level. A maximum allowable level of 3 mg kg^{-1} (Visser, 1993; CCME, 1991) has been set for cadmium for soils meant for agricultural and residential purposes. Cadmium levels of 10.00 mgkg^{-1} (Iyaro), 29.00 mgkg^{-1} (Siluko) and 7.30 mgkg^{-1} (West Circular) were obtained in this study. Treatment methods recommended include leaving the soil in place while limiting the use of the site. Secondly, the soil must be remediated if it must be used for agricultural and residential purposes.

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