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Concentration of Heavy Metals in Soil from an Irrigated Farmland in Kaduna Metropolis, Nigeria.

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ABSTRACT

Concentrations of Cd, Cr, Cu, Pb and Zn in (mg/kg) were determined in topsoil from irrigated farmland around Kawo area in Kaduna, a town in Northern Nigeria using Atomic Absorption Spectrophotometer (AAS). The soil physico-chemical parameters, pH and percentage organic matter (% OM) content were also determined. The soil pH showed alkaline which ranged from 6.50-7.90 while the soil percentage organic matter ranged from 0.80-1.86 %. Concentration of Cd, Cr, Cu, Pb and Zn in all the soils samples ranged from 0.1-4.5, 0.50-30.50, 3.2-13.5, 4.0-28.00 and 5.5-49.7 mg/kg dry weight, respectively. The mean concentrations of soil samples studied were found to follow the decreasing orders; Zn > Pb > Cr > Cu > Cd. There is correlation between soil physico-chemical parameters and metals such as Cu and Pb in the soil samples. The concentrations of heavy metals are within tolerable levels except for Cd. The slightly high level of Cd could be ascribed to lubricating oils as well as the burning of old tyres that are frequently dumped close to the site.

Key words: Heavy metals; soil; irrigated farmlands;

Introduction

Heavy metals are normally natural components of the Earth's crust. They cannot be degraded or destroyed. To a small extent they enter human bodies via food, drinking water and air. As trace elements, some heavy metals (e.g. copper, selenium, zinc) are essential to maintain the metabolism of the human body. Heavy or toxic metals are trace metals that are at least five times denser than water. As such, they are stable (meaning they cannot be metabolized by the body) and bio-accumulative. These metals include mercury, nickel, lead, arsenic, cadmium, aluminum, platinum and copper (metallic form and ionic form). Most heavy metals have no beneficial functions to the body and can be highly toxic. Heavy metals are dangerous because they tend to bio-accumulate. Compounds accumulate in living things any time they are taken up and stored faster than they are broken down (metabolized) or excreted [1].

Metals like Cadmium is a modern metal whose production has increase in recent time and as such its effect on the environment especially in soils has called for concern. It is one of the less strongly adsorbed divalent metals [2]. It is more bio-available in soils and can therefore pose more danger than most other metals through the human food chain from contaminated soils. Cadmium is known to cause itai-itai disease; this disease is known to damage the joints, cause bones to soften and the body to shrink while the affected person dies a painful death [3]. Copper reduces the enzymatic activities in soils and it is particularly toxic to lower organism and has been used as an algaecide in lakes

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[4]. Lead accumulate in aquatic biomass, they are concentrated and passed up the food chain to human consumers. Lead is also known to damage the brain, the central nervous system, kidneys, liver and the reproductive system [3].

Soil contamination is caused by the presence of man-made chemicals or other alteration in the natural soil environment. This type of contamination typically arises from the rupture of underground storage tanks, application of pesticides, and percolation of contaminated surface water to subsurface strata, oil and fuel dumping, leaching of wastes from landfills or direct discharge of industrial wastes to the soil. The most common chemicals involved are petroleum hydrocarbons, solvents, pesticides, lead and other heavy metals. The occurrence of this phenomenon is correlated with the degree of industrialization and intensity of chemical usage. The concern over soil contamination stems primarily from health risks, both of direct contact and from secondary contamination of water supplies [5].

Animal manures have been applied to irrigated farmlands to derive benefit from the essential nutrients and organic matter contained in these materials. However, there is accumulation in the soil of heavy metals present in animal manures and other wastes because of increased and repeated use of manures in agriculture [6]. The aim of the present work is to evaluate the concentration selected heavy metals (Cd, Cr, Cu, Pb and Zn) of subsoil from an irrigated farmland.

Description of Study Area

Kaduna metropolis (Lat. 10.52_N, Long. 7.44_E) located in Kaduna state occupies central portion of Northern Nigeria [7]. Founded in 1917 as an administrative headquarters of Northern Nigeria, it is presently one of the most important cities in the country. As at 1991 census it had a population of 993,600 but projected to be about 1.56 million people [8].

Experimental

Materials and Methods

All the chemicals used for this work were of analytical grades obtained from BDH England. Double distilled water was used throughout the work. All glass wares used were soaked in 10% HNO_3 over night and then washed with detergent, thoroughly rinsed with tap water and then with double distilled water.

Sampling Sites

The research was carried out on soil samples collected from irrigated farmlands in Kawo around Kaduna metropolis between the months of June and July 2010. The sampling site was close to a source of water.

Sample Collection

Soil samples were collected random; at each sampling point four (4) sub-samples from the top layer were collected at a depth of 0-20cm and 20m apart using a stainless steel auger. The collected sub-samples were then pooled together to form a composite of each individual sample. The soil samples were collected from Kawo area with a source of

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water close to the farmland which gave thirteen (13) samples. Control soil samples where also collected from a less suspected contaminated soil and these gave four (4) samples. All samples were collected in clean polythene bags, lebelled and transported to the laboratory for further processing.

Sample Pre-Treatment

The different soil samples were air-dried in the laboratory for a week to avoid possible effect of sunlight on the samples, after which it was pulverized and passed through a 2.0-mm sieve (this is for pH and Total Metal) while for Organic Matter, some portion of the individual sieved soil samples were further pulverized to fine powder and passed through 0.5-mm sieve.

Soil Properties

Soil pH

Soil pH was determined using standard methods. Deionized water in the ratio 1:1 (soil: water) suspension was used [9].

Determination of Organic Matter

The presence of organic matter has a significant effect on the mobility and bioavailability of heavy metals [10]. Soil organic matter (OM) is quite effective in retaining metals. Metal-organic associations can occur both in solution and in the solid surfaces of native soil constituents [11]. Percentage organic matter was determined according to Walkley-Black titration method [12].

Digestion of Soil Samples

One gram (1g) of the air- dried ground soil samples was mixed with $20cm^3$ (1:1) HCl / HNO_3 acid mixtures and the content was heated on a hot plate until dryness. The residue was dissolved using 2M HCl and filtered into $50cm^3$ volumetric flask for metal analysis. A Unicam Atomic Absorption Spectrophotometer (AAS) equipped with an air – acetylene burner was used to determine the metal contents. The acid mixture was adopted according to [13]. Triplicate samples were prepared and a blank was incorporated into a batch of every 5 triplicate samples.

Analysis of Soil Samples

Appropriate working standards were prepared for each of the metal solution by serial dilution of the stock solutions. Each of the sets of serial dilutions was then aspirated one after the other into the Atomic Absorption Spectrometry and their absorbance recorded. The sample solutions were also aspirated one after the other and the absorbance recorded. Calibration curves were plotted for each of the trace metals standard using absorbance against concentrations (ppm) and the actual concentration of the metal interpolated from the curves.

RESULTS AND DISCUSSIONS

Table (1) shows the concentrations of Cd, Cr, Cu, Pb and Zn, pH and percentage organic matter content of the soil. The values of soil pH obtained shows that the soil is alkaline with a range of 6.50- 7.90 which was lower than the pH range of 6.22-8.40

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reported by [14] in 2007 on soils in Kaduna State and higher than the pH range of 5.0-7.5 reported by [15] in agricultural soil of Niger State. This could be attributed to the soil type. The mean pH of 7.28± 0.33 in this study is similar to the mean value reported by [16] in their study. The percentage organic matter ranged between 0.80-1.86% with a mean percentage organic matter (%OM) of 1.21±0.31. This study has %OM range lower than that reported by [15]. The mean %OM in this study was lower than the mean value (3.47±0.41) reported by [16] in soils from Abia State. This could be due to low ability of the organic materials to retain the heavy metals.

Table 1: Total metal contents (mg/kg) and soil properties of irrigated farmlands

Samples	Cd	Cr	Cu	Pb	Zn	pH	%OM
1.	0.20	14.0	6.00	5.40	47.50	7.00	1.20
2.	0.5 0	11.0	7.80	12.5	49.70	7.50	1.19
3.	1.1 0	1.00	7.90	16.0	9.30	7.23	1.11
4.	3.0 0	5.00	7.90	17.5	12.7	7.80	0.80
5.	2.0 0	9.00	8.00	19.6	25.2	7.90	1.50
6.	2.1 0	15.0	9.00	16.0	27.1	7.40	1.13
7.	0.1 0	25.0	10.0	16.0	11.5	7.50	1.86
8.	0.1 0	16.0	11.0	9.00	10.9	7.44	1.56
9.	4.5 0	8.50	6.00	22.0	6.90	7.26	1.22
10.	3.4 0	30.0	9.80	20.0	6.60	7.23	0.88
11.	4.5 0	28.0	10.0	21.3	8.30	7.39	1.00
12.	4.0 0	26.0	12.0	15.3	10.0	7.25	1.22
13.	2.5 0	30.0	13.5	28.0	9.80	7.25	1.67
Control Site							
1.	ND	11.00	5.50	4.60	5.50	6.50	0.80
2.	0.10	11.50	4.40	4.90	6.00	7.20	0.90
3.	ND	19.60	4.80	4.00	8.00	7.23	1.00
4.	ND	10.00	3.20	7.00	11.0	6.75	1.50

ND = Not Detected

The results of the soil samples showing the range, median and the mean (±SD) are presented in Table 2. The ranges of Cd (0.1-4.5 mg/kg), Cr (0.5-30.5 mg/kg), Cu (3.2-13.5 mg/kg), Pb (4.0-28.0 mg/kg) and Zn (5.5-49.7 mg/kg) and the mean concentration of the heavy metals Cd, Cr, Cu, Pb and Zn for soil are Cd (2.01± 1.68 mg/kg), Cr (15.39±9.70 mg/kg), Cu (8.05±2.83), Pb (14.15±7.23 mg/kg) and Zn (15.65±13.78 mg/kg). The concentration level of Cd in the soil is higher than the recommended value of 0.2 mg/kg by [17]. The value is also higher than that obtained by [18] in soils from Sri Lanka. The concentration range of Cr in this study were however lower than the range reported value of 7-65 mg/kg by [19]. Furthermore, mean values of Cu of this study is lower than that reported by [18] in a similar study. Iyaka and Kakulu [15] reported higher Cu range of 12-89 mg/kg in Minna agricultural soil but had lower Cu range of 2.4-6.5 mgkg in Bida agricultural soil than that obtained in this study.

The concentration range of Pb in soil of this study is higher than the reported value of 0.14 mg/kg by [20] but has Pb values lower than 8-235 mg/kg recorded by [19]

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and also lower than the reported mean value of 60±58 reported by [18] in their study. Furthermore, the value of Pb in the soil is lower than that reported by [21] in a similar study. However, the values of Cr and Pb in soil of this study are higher than the values reported by [22] in their study of Agricultural soil. Furthermore, the Zn level of this study is higher than the values of 2.8-41mgkg and 0.57-36 mgkg reported by [15]. Although, the mean value of Zn is lower than that reported by [18] in a similar study.

Table 3 shows the correlation results between physico-chemical properties with metals and between metals in soil. pH of the soil correlated positively and significantly with Cu and Pb. Also, there was positive correlation between % OM and Cr this is an indication that pH and % OM is the major factor controlling the mobility and availability of these metals in the soil. Among metals, Cd correlated positively and significantly with Pb. Cr on the other hand correlated positively and significantly with Pb and Cu while Pb correlated positively and significantly with Cu which means these metals has the same source (sources) in the soil.

Table 2: Summary of Total Metal Contents in Soils (mg/kg), pH and Percentage Organic Matter of Irrigated Farmland in Kaduna

	Cd	Cr	Cu	Pb	Zn
Samples					
Mean	3.75	16.85	9.15	16.30	18.12
Median	2.10	15.00	9.00	17.50	10.90
SD*	1.66	10.01	2.21	5.81	14.96
Min	0.10	1.00	6.00	5.40	6.60
Max	4.50	30.00	13.50	28.00	49.70
Control Samples					
Mean	0.10	10.65	4.48	3.88	7.63
Median	0.10	11.25	4.60	4.75	7.00
SD*	0.00	7.83	0.96	0.88	2.50
Min	0.10	0.50	3.20	4.00	5.50
Max	0.10	19.60	5.50	7.00	11.00
pH				**%OM**	
Mean	7.28			1.21	
Median	7.25			1.19	
SD*	0.33			0.31	
Min	6.50			0.8	
Max	7.90			1.86	

SD* = Standard Deviation
%OM = Percentage Organic Matter

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Table 3: Correlation between some Soil Properties and Heavy Metals in Soil

factor	pH	%OM	Cd	Cr	Pb	Cu	Zn
pH	1						
%OM	0.20290	1					
Cd	0.03708	-0.37353	1				
Cr	0.05582	0.40024	0.2959	1			
Pb	0.50772	0.28255	0.6791	0.4339	1		
Cu	0.41869	0.37395	0.2599	0.59908	0.5969	1	
Zn	0.19914	0.107716	-0.4386	-0.1352	-0.1488	-0.0676	1

Conclusion

The results indicate that the soil had slightly high levels of Cd while the levels of soil Cr, Cu, Pb and Zn are still within tolerable levels. However, the obtained mean values of heavy metals in the site studied are higher than that found in the control site. The slightly high values of Cd in the soil could be ascribed to lubricating oils as well as the burning of old tyres that are frequently dumped close to the site.

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