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Risk Assessment of Heavy Metal Pollution of Topsoil in the Proposed Land for UNIOSUN Teaching Hospital

Anifowose, A. J., Adewuyi, A. R., Babalola, O. O., Ajayi, M. T. and Adeleke, A. E.

Abstract: Heavy metals which are released to the soil are found to be deleterious to environment and biota. Such soil quality, particularly in residential proximities, must be assessed periodically. This study investigated nine (9) heavy metals (Cu, Pb, Cd, Fe, Cr, Zn, As, Mn, Ni) in the surface soil of an agrarian land for Osun State University Teaching Hospital, Osogbo, with a view to establishing their potential threat. They were measured in twenty (20) composite soil samples of the site by inductively coupled plasma-optical emission spectrometry (ICP-OES). The results showed that the average concentrations of Cu (6.5 mg/kg), Pb (5.4 mg/kg), Fe (5831 mg/kg), Cr (22 mg/kg), Zn (14.8 mg/kg), As (1.4 mg/kg), Mn (575 mg/kg), Ni (2.6 mg/kg) were within the permissible range and posed no ecological risk. However, Cd ranging 0.1–1.3 mg/kg (average, 0.6 mg/kg) moderately posed ecological risk due to its positive geo-accumulation index and constituted 86.5% of risk index of all the metals. Applications of agrochemicals, fertilizers in the previous agricultural activities could be the primary sources of the elevated concentration of Cd measured in the soil. The overall pollution assessment of the surface soil indicated moderate pollution of the site soil by the heavy metals.

Keywords: heavy metals; pollution indices; geo-contamination; geo-accumulation index; anthropogenic activities

I. Introduction

The detrimental impacts of heavy metals on the health of flora and fauna cannot be overemphasized [1]. Although this group of environmental pollutants naturally constitute the earth's crust, it forms deposits in the soil through various human activities. Chiefly among these are the application of agrochemicals such as pesticides, fertilizers [2], [3] and industrial activities which include: metalfinishing, paint production, chemical and battery manufacturing, leather tanning, mining activities, foundries and smelters [4]–[6] improper disposal of wastes [7]. Traffic emissions and other human activities like urban

and municipal wastewater sludge depositions are other notable ways by which heavy metals are released to the environment. Domestic activities can also contribute to sources and spread of heavy metals. Mechanical sources of heavy metals include combustion of fuel (Pb), lubricant oil, brake and tire wears (Cu and Pb).

Heavy metals are persistent in the environment due to their inability to undergo microbial or chemical degradation unlike organic contaminants which are oxidized to CO₂ [8]; however, changes in their chemical forms (speciation) and bioavailability are possible [9]. Soil contamination by heavy metals, most oftentimes, leads to groundwater contamination and may pose risks and hazards to humans and the ecosystem. Significant classes of human diseases suspected to result from exposure to environmental chemicals are cancers, birth and immune system defects, mental retardation (low IQs), immunotoxicity, altered sex hormone balance, altered metabolism, low fertility, behavioural abnormalities, and explicit organ

Anifowose, A. J., Adewuyi, A. R., Babalola, O. O. and Ajayi, M. T. (Department of Pure and Applied Chemistry, Faculty of Basic and Applied Sciences, Osun State University, Osogbo, Nigeria)

Adeleke, A. E (Department of Basic Sciences (Chemistry Unit), Faculty of Science, Adeleke University, P.M.B. 250, Ede, Nigeria)

Corresponding author: adebanjo.anifowose@uniosun.edu.ng Telephone Number: +234-906-621-5382

dysfunctions [10]-[12]. In recent times, it has broadly been acknowledged that environmental chemicals do exhibit their harmfulness not only as single entities but also as mixtures [13]. Other negative impacts include a reduction in land usability for agricultural production causing food insecurity, and land tenure problem [14]. To protect human health from adverse effects of heavy international organizations set standards using individual metals. These safety standards are set with the assumption that there is a minimal interaction between metal or chemical species and, even if there are interactions, the degree will not exceed safety factors applied [15].

In 2018, Osun State University, Osogbo (Nigeria), cleared the newly acquired site for its Teaching Hospital, called Osun State University Teaching Hospital (hereafter referred to as OSUNTH). For some years, the land has been in use for farming activities (yam, maize and cassava cultivation) during which various agrochemicals have been applied. Several domestic and municipal wastes have been dumped on the land over the years. Hence, it is plausible that the site soil has been severely impacted. Literature indicates some studies that have been carried out to evaluate heavy metals pollution on Osogbo soils [16]-[18] were carried out to evaluate their pollution by heavy metals. However, no such study has been extended to the soil of the proposed site which necessitates this study. Being a prospective public health facility, background concentrations of heavy metals in the site soil are needed for continuous assessment of the eventual impacts of the hospital activities. This is in addition to the fact that the groundwater quality of the Teaching Hospital will be influenced by the soil heavy metals.

II. Materials and Method

A Study Area

The study area is about 130,146 m² and located in the peri-urban area of Osogbo (Figure 1). It is located at 1.5 km from Osun State University (Osogbo campus).

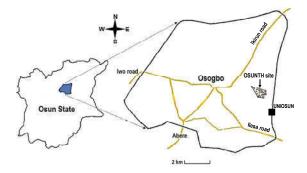


Figure 1: Map showing soil sampling at Osun State University Teaching Hospital (OSUNTH), Osogbo

The southern boundary of the site is about 600 m away from Osogbo–Ibokun major road. High-tension electricity lines (132 and 330 kV) bordered the site at the West. The Osun State Broadcasting Corporation (OSBC) is 600 m distant from the southwestern part of the site. Iludun Community is about 500 m away from the northwestern border of the site. The immediate neighbouring environment of the site is undeveloped with some maize, cassava and yam farms. The site was used for farming in the past decades. To the Northeast is a small portion of the site previously used as a dumpsite.

B Soil Sampling and Analysis of Heavy Metals

Surface soil samples (0–10 cm depth) covering the entire site, were taken at various points for the study. The soil samples were obtained with a hand auger (Darham Geo Slope Indicator Narodown). Twenty (20) composite samples were taken; a composite soil sample is a thorough mixture of ten soil samples randomly taken within about 6,500 m² area. Foreign objects such as stones, glass, plant debris,

wood, and other residues, were removed from the sample before mixing thoroughly. The samples were kept in airtight bags (zip lock) labelled and transported to the laboratory. The samples were air-dried at ambient temperature in the laboratory and sieved to 425 µm particle size using a standard laboratory sieve. A map showing the sampling locations is shown in Figure 1.

One gram (1 g) of the prepared soil sample was digested with concentrated nitric acid till the clear solution was observed. After cooling, the mixture was filtered. The filtrate was diluted to 100 ml with distilled water and subsequently analyzed for Fe, Zn, Mn, Cu, Cd, Cr, As, Ni and Pb using an inductively coupled plasma-optical emission spectrometer (ICP-OES; Agilent 720). Quality control of the analysis was ensured by running a blank and standard solution of heavy metals (AccuStandard Inc, USA). Analyses were done in triplicate to ensure the precision of the analytical procedure and instrument used.

C Assessment of the Soil Pollution Level and Ecological Risk

As established in literature, various pollution indices which include geo-accumulation index (I_{geo}) and ecological risk assessment (E_r) were used to assess the pollution degree of the soil. Geo-accumulation index shown in equation (1) was employed to assess the individual metal contamination [19]–[23].

$$I_{geo} = \log_2(\frac{c_n}{1.5_n}) \tag{1}$$

where C_n and B_n are the soil concentration (measured) and geochemical background concentration (reference value) of metal "n", respectively. To lessen the effect of likely variations in the background values due to lithogenic variations in the soil, the factor "1.5" was introduced [19], [20], [23]. In this study, the mean concentrations (Cr = 135, Ni = 20, Cu = 135, Cu = 13

26, As = 1.5, Cd = 0.2, Zn = 66 and Pb = 15) of metals in the earth's crust [24] were used as geochemical background concentration [25].

The ecological risk assessment of the individual heavy metal was done using equation 2:

$$E_{r} = T_{i} \times \left(\frac{C_{n}}{B_{n}}\right) \tag{2}$$

Where E_r is the ecological risk factor, T_i is the toxic response factor of the individual metal (Zn = 1, Cr = 2, Ni = Cu = Pb = 5, As = 10 and Cd = 30) [26], [27].

The potential ecological Risk Index (RI) of all the measured metals in the soil, calculated as the sum of environmental risk factors of all the metals was determined according to equation 3 [26], [28]:

$$RI = \Sigma E_{r} \tag{3}$$

Table 1 categorizes the soil pollution levels based on $I_{\rm geo}$, Er and RI calculated results.

III. Results and Discussion

A Concentrations of Heavy Metals in OSUNTH Soil

The concentrations of the measured heavy metals in the topsoil of the proposed OSUNTH site are presented in Table 2. Concentrations of the heavy metals varied widely in the site soil, except for Cu, Cr and As. This indirectly signifies non-homogeneity in the composition of the soil sample considering the land expanse. Being among the most abundant elements in the soil, Fe and Mn have the highest concentrations in this study ranging 2230-9423 (average, 5831 mg) and 145-932 mg/kg (average, 575 mg/kg), respectively. The average concentrations (mg/kg) of the toxic in metals increased order of: Cr(22)>Zn(14.8)>Cu(6.5)>Pb(5.4)>Ni(2.6)>As(1.4)>Cd(0.6).

Table 1: Soil pollution categories based on Igeo, Er and RI values

I_{geo}	Pollution level	Er	Ecological risk	RI	Ecological risk		
Igeo	Unpolluted	Er< 40	Low	RI < 55	Low		
≤ 0							
0-1	Unpolluted to	$40 \le \text{Er} < 80$	Moderate	$55 \le RI < 110$	moderate		
	moderately polluted						
1–2	Moderately polluted	$80 \le \text{Er} \le 160$	Considerable	$110 \le RI \le 220$	considerable		
2–3	Moderately to	160 ≤ Er<	High	$RI \ge 220$	very high		
	strongly polluted	320					
3-4	Extremely polluted	$Er \ge 320$	Serious				
4–5	Strongly to very						
	strongly polluted						
≥5	Very strongly						
	polluted						

Source: [26]-[29].

Table 2: Comparison of the heavy metals in OSUNTH soil with other studies

Study location	Heavy metals (mg/kg)											
100411011	Cu	Pb	Cd	Fe*	Cr	Zn	As	Mn*	Ni			
Osogbo,	6.5±0.6	5.4±1.1	0.6 ± 0.3	$0.58\pm0.$	22±2.6	14.8±4.6	1.4±0.3	0.06 ± 0.0	2.6±0.8	This study		
Nigeria	(4.8-7.7)	(1.3-	(0.1 -	2	(17-28)	(7.6-26)	(0.8-1.9)	1	(0.6-4.5)	•		
		7.5)	1.3)	(0.2– 0.9)				(0.01- 0.1)				
Ibadan,	46.8±44.	95.1±14	$8.4\pm19.$	- ′	$64.4\pm50.$	228.6±366	3.9 ± 4.44	0.11 ± 0.0	$20.2\pm14.$	[35]		
Nigeria ^a	1	.6	8		5			5	6	. ,		
Osogbo,	110±90.	137±64	-	-	3.6 ± 2.46	1133±897	_	-	26.3±51.	[16]		
Nigeriaa									1			
Cambridge	2-250	2-300	0.01 - 2.0	-	5-1500	1-900	0.1-40	-	2-750	[36]		
City												
Brisbane,	20-110	25-126	0.6 - 0.9	5.1 - 7.7	82-332	-	=	0.03 - 0.1	20-34	[37]		
Australia												
Earth's shale ^a	45	20	0.3	4.7	90	95	13	0.08	68	[30]		
UCC ^a	14.3	17	0.1	3.09	35	52	=	0.05	18.6	[31]		
WHO	36	85	0.8	-	100	50	_	_	35	[38]		
Worldwide soils ^a	20	15–28	0.5	3.5	54	63	≤30	≤0.9	19–22	[24]		

Results of the present study were of triplicate analysis and expressed in average (range). *values expressed in (%); a(average concentration); UCC = Upper continental crust.

Table 3: Geo accumulation index (Igeo) and ecological risk (Er) of heavy metals in OSUNTH Soil

	Cu		Pb		Cd		Cr		Zn		As		Ni		RI
	Er	I_{geo}	Er	I_{geo}	Er	I_{geo}	Er	I_{geo}	Er	I_{geo}	Er	I_{geo}	Er	I_{geo}	
Average	1.3	-2.6	1.8	-2.1	90	1.0	0.3	-3.1	0.2	-2.7	9.3	-0.7	0.7	-3.5	104
Minimun	0.9	-3.0	0.4	-4.1	15	-1.6	0.3	-3.5	0.1	-3.6	5.3	-1.5	0.2	-5.6	22
maximum	1.5	-2.3	2.5	-1.6	195	2.1	0.4	-2.8	0.4	-1.9	12.7	-0.2	1.1	-2.7	214

Er = Potential ecological risk; I_{geo} = geo-accumulation index; RI = Potential ecological risk index

The average concentrations of heavy metals are compared with other studies and acceptable standards (Table 2). Except for cadmium, the measured concentrations of the heavy metals were not higher than permissible metal concentrations (standards) in soil [24], [30], [31]. The elevated cadmium concentration (0.1–1.3 mg/kg)) in site soil could be traced to the previous applications of phosphate fertilizers, batteries, refuse incineration, coal and wood

combustion [32]. Pesticides and insecticides application, especially during the previous agricultural activities, would also increase the natural Cd concentration in the site soil [33].

It is well known that metals are natural components of soil. However, there were diverse anthropogenic activities that could contribute to other metals measured in this study. Agricultural activities such as application of phosphate fertilizers would introduce Cu, Ni, Pb and Zn [33], while coal and wood combustion could release Zn. Application of agrochemicals such as insecticides pesticides are potentials sources of Cu, Pb and Zn; fungicides being a good source of Cu [33]. Anthropogenic refuse incineration, dumping of metal scraps and used batteries are capable of discharging toxic heavy metals like Pb, Cd, Zn and Cd into the soil. Spillage of automobile oils such as lubricating oil, transmission fluid, and grease is a potential cause of heavy metals accumulation in soil [33]. Though could be insignificant, the release of automobile exhaust from the nearby Osogbo-Ibokun road on the site would have impacted on the natural levels of the soil heavy metals. A recent study [32] confirmed that some of the soil polycyclic aromatic hydrocarbons (PAHs) originated from the automobile exhaust from the road.

B Assessment of Pollution Risk of the Heavy Metals in OSUNTH Soil

The results of the three pollution indices used in assessing the soil pollution level and potential ecological risk are presented in Table 3. Only cadmium was found to possibly pose a pollution threat among the heavy metals measured.

This is because, the calculated I_{geo} values of all the other heavy metals (except Cd) were less than zero; I_{geo} for Cd ranged -1.6–2.1 (average, 1.0). Similarly, the ecological risk factor of the individual metal was less than 40, indicating low potential ecological risk by each metal. However, cadmium with an average ecological risk factor of 90 (range, 15–195) poses a considerable ecological risk and constitutes 86.5% of the risk index (RI). RI would characterize the sensitivity of the local ecosystem to the toxic metals and represents the ecological risk resulting from the overall contamination [39]. The overall potential ecological risk (RI) of the measured metals in

the soil was calculated as the sum of all the ecological risk factors of the measured metals (Table 3). The RI ranged from 22 to 214 (average, 104) and considered moderate pollution of the soil.

IV. Conclusion

This study shows that previous agricultural and anthropogenic activities contributed to an environmentally tolerable amount of heavy metals to the site soil.

Summarily, the surface soil composition of the proposed site for the Osun State University Teaching Hospital was relatively unpolluted by the heavy metals, though cadmium could pose a potential threat in the future preventive/prohibitive measures are not taken. The low pollution level, notwithstanding previous agricultural/anthropogenic activities, portends good development for the site as clean soil environment is required for such public institution. This is in addition to the fact that underground water (borehole) will be a major water source for the hospital. The health safety of the patients and workers in the hospital, as well as the sustainability of farming activities around the site, will indirectly depend on the soil quality at this site. Continuous monitoring and periodic evaluation of the cadmium level in the Teaching Hospital soil are important. Thus, the data in this study will form background concentrations of the heavy metals in the subsequent, related studies.

Competing Interest

The authors declare no competing financial interest or conflict of interest.

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