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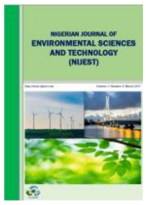

Heavy Metals in Soils around a Major Cement Factory in Southern Nigeria: Ecological and Human Health Risks

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ABSTRACT

This study was carried out to evaluate the ecological and health risks associated with metals in soils around major cement company in southern Nigeria. Twenty-one soil samples including a control sample were collected around the cement company. Metals such as Cd, As, Co, Cr, Cd, Pb, Ni, Fe, and Zn were analysed using Atomic Absorption Spectrometer (AAS). Results showed that the average concentration of Cu, Co, Cd, Cr, Ni, Pb, Zn is 7.95 mg/kg, 0.50 mg/kg, 3.00 mg/kg, 1.00 mg/kg, 0.95 mg/kg, 2.00 mg/kg and 6.80 mg/kg while the average concentration of Cu, Co, Cd, Cr, Ni, Pb, Zn around the cement production area is 6.30 mg/kg, 1.50 mg/kg, 1.75 mg/kg, 2.09 mg/kg, 2.62 mg/kg, 6.40 mg/kg and 3.58 mg/kg respectively. The concentration of metals in this area was lower than the recommended standards but higher than those in the background soil. Contamination assessment of metals in soils of Okpella area revealed that they pose a very high degree of pollution and deterioration of the environment. Furthermore, ecological risk assessment revealed that the metals pose medium ecological risks. Health risks assessment uncovered that children residing in this area are prone to non-carcinogenic health risks through dermal contact with Cobalt in contaminated soils of the area. The statistical evaluation showed that metals in the soils might have originated from related sources. It is recommended that proper environmental monitoring of the area be carried out reduce its impact on the health of the populace.

Keywords: Ecological risk; Cement processing factory; Health risk; Contamination assessment; Heavy metals

1.0. Introduction

The soil is one of the most significant natural resources on which man's life is predicated, either indirectly or directly. It functions as a living organism's habitat as well as a water storage and plant growth medium (Okoro and Chikuni, 2007). In addition to serving as a drain for impurities and poisons mostly from industrial operations, soils also serve as the foundation for building and agricultural production (Olasumbo *et al.*, 2016). Various nations have achieved environmental sustainability with some degree of environmental damage as a result of industrialisation (Adeyanju and Okeke, 2019). These procedures, on the other hand, have the potential to emit pollutants such as oils, acids, gases, cooling water, and so on. Where there is no genuine harm to the environment or processes to restrict these concerns, a variety of obstacles (illegal mining, indiscriminate garbage disposal, emission of toxic gases, and oil leakage) can make pollution and wastewater unavoidable (Adewumi and Laniyan, 2020; Thompson *et al.*, 2019).

A direct consequence of cement manufacture on the ecosystem is the dispersion of gasses and alkaline dust, which can permeate nearby plants, aquatic bodies, and soils as occult, humid, or dry deposits, decreasing their physicochemical constitution and utility. Heavy metals present in cement dust, such as lead, chromium, mercury, cobalt, nickel, and organic compounds, are detrimental to animals, humans, plants, and the environment as a whole (Laniyan and Adewumi, 2020).

Pollutants are emitted at all phases of the cement manufacturing process, including the extraction of raw materials, compression, and manufacturing (Laniyan and Adewumi, 2020; Olasumbo *et al.*, 2016). Cement dust alters the constituent makeup of the soil, as well as its physical and chemical characteristics. Heavy metals detected in dust include nickel, chromium, lead, mercury, and cobalt, which are hazardous to the environment and have an effect on animal and human health (Laniyan and Adewumi, 2021). Cement dust has been linked to an increased risk of acute ventilatory problems, cancer, acute respiratory symptoms, and a reduction in antioxidant capacity in both animals and humans (Ho *et al.*, 2010). Oral consumption, cutaneous contact, and inhalation are the three main routes through which metals enter the human body (Tchounwou *et al.*, 2012). In adults and children, metals in the body produce both carcinogenic and non-carcinogenic health problems (Haque *et al.* 2018; Saleh *et al.* 2019).

The influence of cement manufacture on environmental quality has been studied by a small number of scholars. Olayinka *et al.* (2016) investigated the influence of cement dust discharged from the Dangote cement industry on air quality and human health. According to the health risk assessment, all of the metals examined offered no harm to individuals, with the exception of Pb and Ni, which posed the greatest cancer risk to children. Furthermore, air, noise, and soil quality indicators were below the Federal Environmental Protection Agency's acceptable standards, according to Ufuoma and Omoyeni (2017). Similarly, Majolagbe *et al.* (2018) claimed that Co, Cr, Fe, Ni, and Pb levels in soils around cement plants are typical. Because metals are irreversible and have harmful impacts on living creatures, determining the heavy metal concentration of soils around cement plants should be part of the environmental monitoring and evaluation process. Despite the fact that Obaje *et al.* (2019) investigated the degree of heavy metal pollution in stream sediments in Okpella's active mining region, the results indicated that stream sediments in this location are heavily polluted by potentially harmful metals (PTM). However, no research had been done to identify the number of heavy metals in the area's soils. Furthermore, the degree of these metals' ecological and health consequences has yet to be identified. As a result, this research was conducted to establish the extent of heavy metal pollution and danger in soils within and surrounding the Bua cement plant.

The study area is a significant cement plant in Okpella, Edo State, southern Nigeria, that spans latitudes 7°20'45.6"N – 7°21'28.8"N and longitudes 6°23'38.4"E – 6°23'38.4"E and is accessible by main and secondary highways (Figure 1). The region is characterized by a wet and dry season and is located in the warm-humid tropical climatic zone. It is part of the Guinea Savannah, which is characterized by scattered trees, shrubs, and grass savannah modified by human activity, mostly for agricultural purposes. Granite gneiss, calc-silicate gneiss, and granite are among the rocks found in this region (Figure 1). Cement manufacture and mining are important human activities in this region, and marbles constitute a major raw material for cement production.

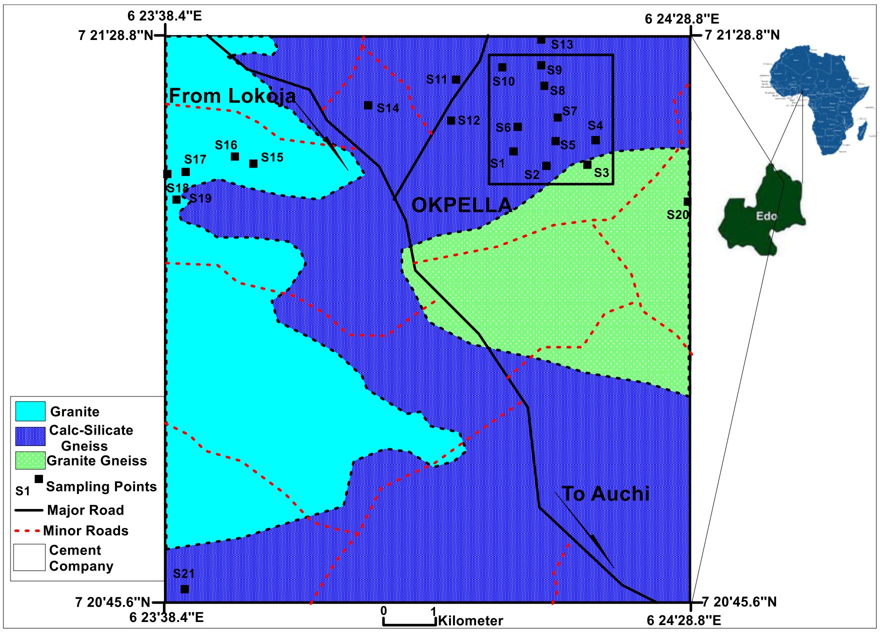

Figure 1: Location Map of the Study Area.

2.0. Methodology

2.1. Sample collection

In this location a total of twenty-one soil samples were collected. Ten (10) samples were obtained within the BUA cement manufacturing firm, ten (10) samples were gathered around the company, and one control sample was collected 10 kilometers southwest of the study where the company's operations may not be felt.

2.2. Sample preparation, digestion and analysis

Soil samples were subsequently kept at room temperature until they were completely dry. Following that, 100 g of each sample was weighed using an electric weighing scale, crushed, and sieved to collect clay particles with a diameter of 65 m. Chemical digestion of materials was performed using a wet digestion method in which 5 grams of platinum crucible were put on an analytical weighing scale with a 0.0001g sensitivity. 5ml of 10% $HClO_3$, HNO_3 and 15ml of Hydrofluoric acid (HF) were mixed and heated at 60^{o}C for 12 hours. The sample was then dissolved by adding 4ml of hydrochloric acid (HCl) to the chilled solution and warming it. After cooling, the solution was diluted to 50ml with deionized water and analyzed for As, Fe, Pb, Co, Cu, Cr, Ni, Zn, and Cd using an Atomic Absorption Spectrometry (AAS) Buck Scientific 210 VGP model.

2.3. Contamination assessment

The geo-accumulation index (Igeo), contamination factor (CF), enrichment factor (EF), contamination degree (CD), and pollution load index was computed to properly assess the quantity of metal contamination in the soils of these areas, as mentioned in the following sections:

i. Geo-accumulation Index (Igeo)

Equation 1 was used to obtain the Geo-accumulation index (Igeo). The geo-accumulation index is divided into sub-categories as shown in Table 1.

$$I_{geo} = log_2 \frac{C_n}{1.5 \times Bn} \tag{1}$$

The heavy metal concentration in the sample is C_n, while the metal concentration in the background sample is Bn. The factor 1.5 was created to investigate probable fluctuations in background levels for a certain metal in the environment (Oyebamiji *et al.*, 2018; Princewill and Adanma, 2011).

ii. Enrichment Factor (EF)

The heavy metals enrichment factor (EF) in the tested samples was calculated using the standardization of the detected elements for the reference element. In this research, iron (Fe) was used as a normalizer. EF was calculated using Equation 2.

$$EF = \frac{\left(\frac{Metal}{RE}\right)_{Soil}}{\left(\frac{Metal}{RE}\right)_{Background}} \tag{2}$$

RE stands for reference metal concentration. Five forms of contamination are predictable based on the enrichment factor (Table 1).

iii. Contamination factor (CF) and Contamination Degree (CD)

The contamination factor of heavy metals in the samples from the research region was calculated using Equation 3. The CF is categorized into four distinct classes: CF<1 (Low CF indicating low contamination); 1≤CF<3 (Moderate CF); 3≤CF<6 (Considerable CF) and 6≤CF (Very high CF).

$$ContaminationFactor = \frac{MeanMetalConcentration}{ConcentrationofElementinBackgroundSoils} \tag{3}$$

The contamination degree (CD) is calculated using the total of contamination factors for all components studied, as given in Equation 4 (Hakanson, 1980).

$$Contamination\ Degree\ (C_d) = \sum_{i=1}^{n} C_f^i \tag{4}$$

Where C_f is the Contamination Factor and C_d is the Contamination Degree

iv. Pollution Load Index (PLI)

The Pollution Load Index (PLI) was derived using Equation 5 and the approach of Oyebamiji *et al.* (2018). This gives a basic but comparable technique for evaluating the quality of a site.

$$Pollution\ Load\ Index\ (PLI) = \sqrt[n]{CF_1 \times CF_2 \times CF_3 \times \ldots CF_n} \tag{5}$$

Table 1: Classification of geo-accumulation index (Igeo), enrichment factor (EF), contamination factor (CF), contamination degree (CD), ecological risk index (ERI) and potential ecological risk index (PERI)

S/N	Indices	Classification	Interpretation
1.	Geo-accumulation Index (Igeo). Oyebamiji *et al.* (2018) Princewill and Adanma (2011)	Igo<0 0≤Igeo<1 1≤Igeo<2 2≤Igeo<3 3≤Igeo<4 4≤Igeo<5 Igeo>5	Unpolluted Unpolluted to moderately polluted Moderately polluted Moderately to heavily polluted Heavily polluted Heavily to extremely polluted Extremely polluted
2.	Enrichment Factor (EF) Ufuoma and Cynthia (2017) Princewill and Adanma (2011)	EF≤2 EF = 2-15 EF = 5-20 EF = 20-40 EF = >40	Deficient to little enrichment Moderate enrichment Major enrichment Very high enrichment Extremely high enrichment
3.	Contamination Factor (CF) Hakanson (1980)	CF<1 1≤CF<3 3≤CF<6 6≤CF	Low contamination Moderate contamination Considerable contamination Very high contamination
4.	Contamination Degree (CD) Hakanson (1980)	CD<8 8≤CD<16 16≤CD<32 CD≥32	Low contamination Moderate contamination Considerable contamination Very high contamination
5.	Pollution Load Index (PLI) Oyebamiji *et al.* (2018)	PLI<1 PLI=1 PLI>1	Perfection Baseline level of pollutants present Deterioration of site quality
6.	Ecological Risk Index (ERI) Li *et al.* (2019)	ER<5 5≤ER<10 10≤ER<20 20≤ER<40 ER≥40	Low risk Moderate risk Considerable risk High risk Very high risk
7.	Potential Ecological Risk (PERI) Li *et al.* (2019)	RI<5 5≤RI<60 60≤RI<120 RI≥120	Low risk Moderate risk Considerable risk Very high risk

2.4. Potential ecological risk assessment

The possible ecological risk index approach established by Hakanson (1980) was used to estimate environmental heavy metal pollution and ecological harm as a result of heavy metals in the soil around the cement manufacturing region. The evaluation approach was as follows: Equations 6 and 7

$$E_R^i = T_R^i \times C_f^i \tag{6}$$

Where Tr stands for toxic-response factor and CF stands for single-element pollution factor. TR for Zn = 1; Cr = 2; Cu = 5; Pb = 5 and Cd = 30. To produce a semi-quantitative assessment of regional pollution levels, the Potential Ecological Risk Index (PERI) is used. Equation 7 may be used to represent it:

$$RI = \sum_{i=1}^{m} E_R^i \tag{7}$$

2.5. Health Risk Assessment of Heavy Metals

Health risk assessment of heavy metals in soils of the area was carried out by applying the techniques outlined by USEPA (2012) and used by Adewumi and Laniyan (2020).

2.5.1. Non-carcinogenic risk assessment

The Hazard Quotient is a dimensionless number that quantifies the probability of someone being hurt. The toxicity threshold is determined by dividing the ADI or dose by the toxicity threshold. This is known as the chronic reference dose (RfD) for a certain heavy metal, and it is expressed in mg/kg^{-day} (See Adewumi and Laniyan, 2020), as indicated in Equation (8)

$$HQ = \frac{ADI}{RfD} \tag{8}$$

The total of all HQs from particular heavy metals is responsible for heavy metal's non-carcinogenic influence on the population. This is supposed to be another phrase called the Hazard Index, according to the USEPA (2002). (HI). Equation 9 shows the mathematical expression of this parameter.

$$HI = \sum_{k=1}^{n} HQ_K = \sum_{k=1}^{n} \frac{ADI_K}{RfD_k} \tag{9}$$

Heavy metal's non-carcinogenic effect on the population is attributed to the sum of all HQs from specific heavy metal bands. This is called the Hazard Index. (HI) shown in Equation 9.

2.5.2. Carcinogenic risk assessment

Carcinogen hazards are defined as an increase in the chance of a person developing cancer for the remainder of their life as a result of exposure to potentially carcinogenic substances. Equation (10) is used to determine the additional cancer risk throughout a lifetime:

$$Risk_{pathway} = \sum_{k=1}^{n} ADI_k CSF_k \tag{10}$$

A person's lifetime cancer risk is defined as the likelihood of acquiring cancer during his or her lifetime. ADIk (mg/kg/day) and CSFk $(mg/kg/day)^{-1}$ are the average daily intake and cancer slope factor of the k-th heavy metal among n heavy metals, respectively (See Adewumi and Laniyan, 2020). The slope factor transforms an additional risk of cancer from an expected daily intake of heavy metals over a lifetime of exposure (Adewumi and Laniyan, 2020). Using the following Equation 11, the average contribution of each heavy metal to all pathways is then used to calculate an individual's total risk of additional lifetime cancer:

$$Risk_{(total)} = Risk_{(ing)} + Risk_{(inh)} + Risk_{dermal} \tag{11}$$

The risk contributions from ingestion, inhalation, and skin routes are represented by risk (ing), risk (inh), and risk (skin).

2.6. Statistical analysis

This study's data was subjected to descriptive, factor analysis, bivariate correlation, and hierarchical cluster analysis statistical analysis. The findings of comparable research in Nigeria were compared to the mean of the data gathered. The probable sources of heavy metal in soils were investigated using component analysis, bivariate correlation, and hierarchical cluster analysis.

3.0. Results

3.1. Heavy metal concentration in soils

The concentration of heavy metals in soils within and around the cement production company is presented in Table 2 and Figure 2. Within the cement company, the average concentration of As, Cu, Co, Cd, Cr, Ni, Pb, Zn and Fe is 0.049 mg/kg, 7.95 mg/kg, 0.50 mg/kg, 3.00 mg/kg, 1.00 mg/kg, 0.95 mg/kg, 2.00 mg/kg, 6.80 mg/kg and 4502.00 mg/kg while the average concentration of As, Cu, Co, Cd, Cr, Ni, Pb, Zn and Fe around the cement production area is 0.041 mg/kg, 6.30 mg/kg, 1.50 mg/kg, 1.75 mg/kg, 2.09 mg/kg, 2.62 mg/kg, 6.40 mg/kg, 3.58 mg/kg and 3525.40 mg/kg respectively. The concentration of As, Cu, Co, Cd, Cr, Ni, Pb, Zn and Fe in control sample is 0.02 mg/kg, 5.00 mg/kg, 0.25 mg/kg.

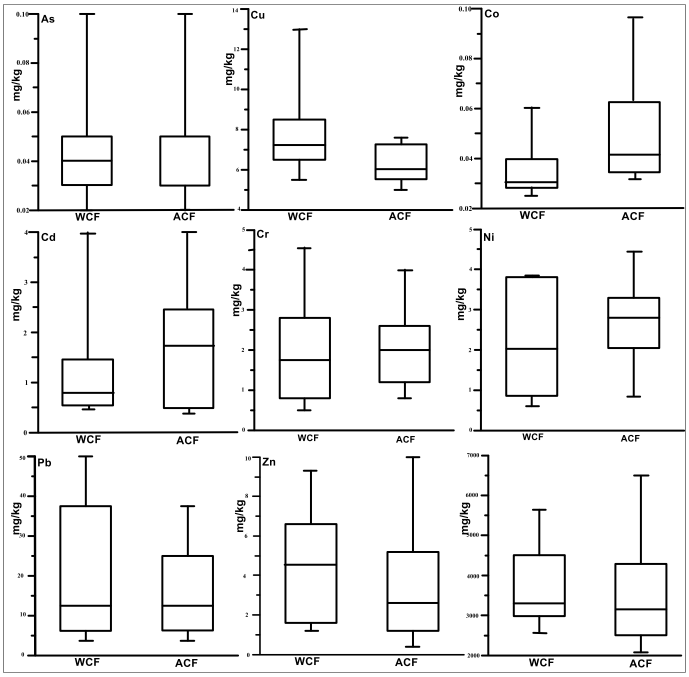

Figure 2: Boxplots of metal concentrations within and around the study area

Table 2: Average concentration of heavy metals in soils of the study compared to similar studies in Nigeria

Location	As	Cu	Co	Cd	Cr	Ni	Pb	Zn	Fe	References
Ewekoro	-	0.54	-	-	0.64	-	0.23	4.85	412.12	Okoro *et al.,* 2017
Ibese	-	-	-	0.76	11.91	1.82	1.41	2.06	-	Akpambang *et al.,* 2022
Obajana	-	10.25	ND	0.50	5.52	ND	-	-	-	Olatunde *et al.,* 2020
Nkalagu	-	-	-	3.02	26.00	-	-	212.40	186.30	Princewill and Adanma, 2011
Okpella	0.04	7.13	1.16	1.57	2.06	2.43	7.25	3.98	3642.55	This Study
Control Sample	0.02	5.00	0.25	0.40	0.50	0.60	1.50	0.40	2075.08	This Study
USEPA	0.11	270.00	-	0.48	11.00	72.00	200.00	1100.00	-	USEPA, 2002

3.2. Contamination of soil by heavy metals

The contamination assessments result of heavy metals in soils of the area is shown in Figure 3. The results indicated that the average Igeo for As, Cu, Co, Cd, Cr, Ni, Pb, Zn and Fe in soils within the cement company is 0.87, -0.04, 1.36, 1.35, 1.82, 1.63, 2.33, 4.38, and 0.39 respectively while around the cement production area it is 0.41, -0.66, 2.83, 1.78, 2.12, 2.28, 1.83, 3.29 and 0.66 each. Average EF for As, Cu, Co, Cd, Cr, Ni, Pb and Zn in soils within the cement company is 1.34, 0.89, 1.79, 1.96, 2.48, 2.29, 3.13 and 6.87 respectively while around the cement production area it is 1.36, 0.90, 4.14, 3.02, 2.97, 3.06 and 6.11 each.

Also, the mean contamination factor (CF) for As, Cu, Co, Cd, Cr, Ni, Pb, Zn and Fe in soils within the cement company is 2.45, 1.59, 3.26, 3.45, 4.05, 3.71, 5.40, 10.95 and 1.81 each while in soils around the company it is 2.15, 1.36, 6.10, 4.48, 4.28, 4.46, 4.37, 9.05 and 1.79 respectively. Average contamination degree (CD) and pollution load index (PLI) for heavy metals in soils within the cement production area are 36.68 and 2.87 each while for soils around the company are 38.04 and 3.09 respectively.

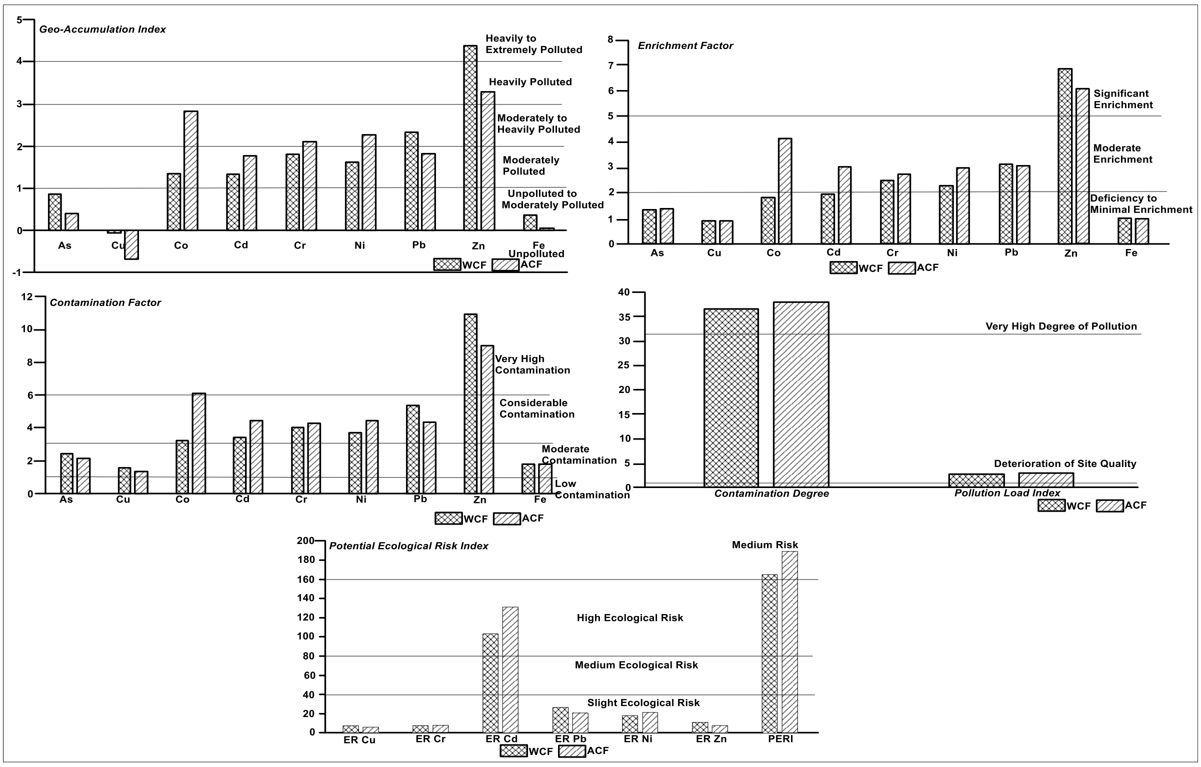

Figure 3: Average Geo-accumulation index (Igeo), Enrichment factor (EF), Contamination factor (CF), Contamination Degree (CD) and Ecological Risk Index of heavy metals in soils with and around the cement production site

3.3. Sources of heavy metals

Multivariate analysis was used to uncover possible causes of heavy metals in soils of the study area. Bivariate correlation revealed that strong relationship exist between As and Co (0.889), Ni (0.781), Pb (0.781) and Zn (0.808) (Table 3). Cu has a strong and positive relationship with Co (0.508), Cd (0.834), Cr (0.988), Ni (0.946) and Fe (0.761). Likewise, Co has a strong and positive correlation with Cd (0.705), Ni (0.851), Pb (0.839) and Zn (0.769). Also, Cr has a strong and positive relationship with only Zn (0.778) while Ni has a strong and positive relationship with Fe (0.994). Pb has a strong and positive relationship with Fe (0.500) while Zn has a strong and positive relationship with Fe. Hierarchical cluster analysis (Figure 4) showed that Pb, Zn, Cd, Co, Ni, As, Cu and Cr might have originated from similar sources possibly from the cement processing company and mining activities while Fe might have originated from mixed sources which is possibly both anthropogenic and geogenic. The existence of strong and positive relationship between As-Co-Ni-Pb-Zn in soils of this area showed that they probably originated from the dispersion of heavy metals in particulates from the cement factory and this also true for Cu-Co-Cd-Cr-Ni-Fe and other metals in soils of the area (Table 3).

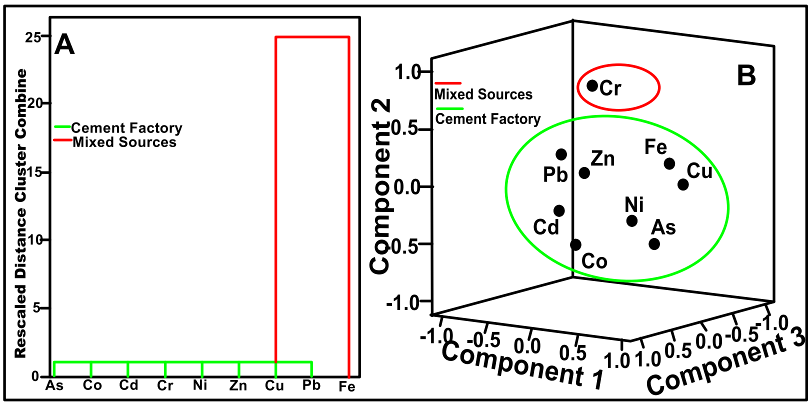

Figure 4: (A) Hierarchical cluster analysis of heavy metals in soils of the study area and (B) Plot of component 1, component 2 and component 3 of heavy metals in soils of the study area

Table 3: Bivariate correlation of heavy metals in soils of the study area

	As	Cu	Co	Cd	Cr	Ni	Pb	Zn	Fe
As	1								
Cu	0.453*	1							
Co	0.889	0.508	1						
Cd	0.294	0.834	0.705	1					
Cr	0.291	0.988	0.361	0.896	1				
Ni	0.781	0.946	0.851	0.631	0.123	1			
Pb	0.764	0.402	0.839	0.439*	0.362	-0.384	1		
Zn	0.808	0.397	0.769	0.936	0.778	0.253	0.525	1	
Fe	0.371	0.761**	-0.259	0.238	0.202	0.944	0.500	0.977	1

*Correlation Significant at the 0.05 level (2-tailed); ** Correlation Significant at the 0.01 level (2-tailed)

3.4. Ecological risk of heavy metals

Results of the ecological risks assessment are presented in Figure 3. The average ecological risks of Zn, Cr, Cu, Pb, Cd and Ni in soils within the cement company area are 11.49, 8.10, 7.95, 27.00, 103.50 and 18.58 each and the average overall potential ecological risk index of these metals is 176.63. For soils around the cement production company site, the mean ecological risks of Zn, Cr, Cu, Pb, Cd and Ni are 8.08, 8.36, 6.30, 21.33, 131.25 and 21.79 each and the mean overall potential ecological risk index of these metals is 197.12.

3.5. Health risk of heavy metals

Outcome of health risks assessment of heavy metals in soils of the area for carcinogenic and non-carcinogenic health risks through oral ingestion, inhalation and dermal contact for adults and children is presented in Table 4. The results showed that the total hazard quotient (HQ) for As, Cd, Co, Cd, Cr, Ni, Pb, Zn and Fe for non-carcinogenic health risk is 2.4E-3, 4.9E-8, 3.3E+0, 5.1E-2, 6.1E-5, 7.1E-3, 4.7E-5, 9.2E-4 and 2.5E-3 respectively while the total hazard index (HI) was 3.3E+0. For children, HQ for As, Co, Cd, Cr and Pb for carcinogenic health risk is 7.0E-8, 4.7E-10, 4.1E-10, 1.0E-6 and 6.0E-8 each with a total of HI of 1.1E-6. For adults, HQ for As, Cd, Co, Cd, Cr, Ni, Pb, Zn and Fe for non-carcinogenic health risks is 3.2E-7, 5.1E-5, 8.4E-6, 1.1E-5, 2.9E-5, 1.7E-5, 5.0E-5 and 2.7E-3 with a total HI of 3.3E-11. For carcinogenic health risks, total HQ for As, Co, Cd, Cr, and Pb for adults is 4.9E-7, 5.1E-9, 4.4E-9, 7.7E-10, 1.4E-10 each with a total HI 5.0E-7.

Table 4: Hazard Quotient (HQ) and Hazard Index (HI) of heavy metals in soils of the study area

	PW	HQ As	HQ Cu	HQ Co	HQ Cd	HQ Cr	HQ Ni	HQ Pb	HQ Zn	HQ Fe	HI
Non-CC	OI	3.0E-7	4.8E-5	7.9E-6	1.0E-5	2.8E-5	1.6E-5	4.7E-5	5.1E-5	2.5E-3	2.7E-3
	IN	7.3E-8	-	9.9E-5	1.3E-5	3.3E-5	-	-	-	-	1.4E-4
	DC	2.4E-3	4.8E-3	3.3E+0	5.1E-2	-	7.1E-3	-	8.6E-4	-	3.3E+0
	Total	2.4E-3	4.9E-3	3.3E+0	5.1E-2	6.1E-5	7.1E-3	4.7E-5	9.2E-4	2.5E-3	3.3E+0
CC	OI	7.0E-8	-	-	-	1.0E-6	-	6.0E-8	-	-	1.1E-6
	IN	2.8E-11	-	4.7E-10	4.1E-10	3.5E-11	-	1.2E-11	-	-	9.7E-10
	DC	1.5E-12	-	-	-	-	-	-	-	-	1.5E-12
	Total	7.0E-8	-	4.7E-10	4.1E-10	1.0E-6	-	6.0E-8	-	-	1.1E-6
Non-CA	OI	4.6E-12	6.2E-12	1.6E-11	9.7E-12	2.7E-11	3.0E-11	1.5E-9	-	1.8E-13	1.5E-9
	IN	2.0E-11	3.2E-9	5.2E-10	7.0E-10	1.8E-9	1.0E-9	3.1E-9	3.3E-9	1.68E-7	1.8E-7
	DC	3.2E-7	5.1E-5	8.4E-6	1.1E-5	2.9E-5	1.7E-5	5.0E-5	5.4E-5	2.7E-3	1.8E-7
	Total	3.2E-7	5.1E-5	8.4E-6	1.1E-5	2.9E-5	1.7E-5	5.0E-5	5.4E-5	2.7E-3	3.6E-7
CA	OI	6.9E-12	-	-	-	1.4E-11	-	1.2E-11	-	-	3.3E-11
	IN	3.0E-10	-	5.12E-9	4.4E-9	7.6E-10	-	1.3E-10	-	-	1.0E-8
	DC	4.9E-7	-	-	-	-	-	-	-	-	4.9E-7
	Total	4.9E-7	-	5.12E-9	4.4E-9	7.7E-10	-	1.4E-10	-	-	5.0E-7

Non-CC- Non-Carcinogenic Children; CC – Carcinogenic Children; Non-CA- Non-Carcinogenic Adult; CA – Carcinogenic Adult; OI – Oral Ingestion; IN – Inhalation; DC – Dermal Contact; PW – Pathway

4.0. Discussion

It has been well documented that potentially toxic metals are threat to soils well-being through contamination and pollution (Adewumi, 2022; Adewumi *et al.,* 2021; Laniyan and Adewumi, 2020; Oyebamiji *et al.,* 2018). In this study, geo-accumulation index (Igeo) revealed that soils within the cement factory are unpolluted by Cu but are unpolluted to moderately polluted by As and Fe. Soils within the cement factory are moderately polluted by Co, Cd, Cr, Ni and Pb while they were heavily to exteremly polluted by Zn. Soils around the cement production company in the study area are unpolluted by Cu while they are unpolluted to moderately polluted by As and Fe (Figure 3). The soils were also moderately to heavily polluted by Co, Cr and Ni while they were moderately polluted by Cd and Pb. These were also heavily polluted by Zn. Enrichment factor (EF) uncovered that the soils within the cement company were minimally enriched by As, Cu, Cd and Fe while they were moderately enriched by Cr, Ni and Pb but were significantly enriched by Zn (Figure 3). Soils around the cement factory were minimally enriched by As, Cu and Fe while they were moderately enriched by Co, Cd, Cr, Ni and Pb and were significantly enriched by Zn. Contamination factor (CF) uncovered that soils within and around the cement company were moderately contaminated by As, Cu and Fe while they were considerably contaminated by Co, Cd, Cr, Ni and Pb (Figure 3). These soils were very highly contaminated by Zn. Contamination degree (CD) also revealed that metals in within and around the cement company posed very high degree of pollution (Figure 3). Pollution load index (PLI) confirmed the deterioation of environmental quality in the study area (Figure 3). Other related studies around cement production company areas such as Ewekoro (Okoro *et al.,* 2017), Ibese (Olatunde *et al.,* 2020), Nkalagu (Princewill and Adanma, 2011) and Obajana (Akpambang *et al.,* 2022) confirmed this proposition.

Hierachical cluster analysis (HCA) uncovered that As, Co, Cd, Cr, Ni, Zn, Cu and Pb emanated from similar human activities which is mainly cement production in the area (Figure 4). Iron in soils of this area might have originated from mixed anthropogenic and geogenic sources. Principal component analysis (PCA) also showed that As, Co, Cd, Fe, Ni, Zn, Cu and Pb originated from similar anthropogenic sources especially the production of cement in this area. PCA further showed that the concentration of Cr in soils of this area might have be contributed by both human and geogenic sources (Figure 4).

Ecological risk assessment were used to assess the extent to which heavy metals in soils of the study area may affect the ecosystem. The study showed that Cu, Cr, Pb, Ni and Zn in soils within and around the cement production company pose slight ecological risks while Cd in both soils pose high ecological risk (Figure 3). Overall potential ecological risk index uncovered that metals in the soils in this area posed medium ecological risk. The presence of Cd in suds when extreme can influence soil processes which can affect the presence of microrganisms and threatens the whole soil ecosystem (Lennetech, 2022a).

Health risk assessment of heavy metals in soils of the area revealed that As, Cu, Cd, Cr, Ni and Zn does not pose any non-carcinogenic human health risk because the HQ are <1. However, Co with HQ greater than 1 may increase human health risks in children in the study area (Table 4). The non-carcinogenic health risks in the area might be instigated by dermal contact with soils contaminated by cement dusts. It has been shown that skin contact with soil may increase the chances of contacting non-carcinogenic health risks (USEPA, 1989). Intake of cobalt may cause lung diseases such as lung diseases as asthma and pneumonia (USEPA, 1989). Other non-carcinogenic health risks associated with Co are vomiting and nausea, vision, heart and thriod problems (USEPA, 1989). In this study, heavy metals in soils of this area do not pose any non-carcinogenic health risks in adult (Table 4). Heavy metals in soils of the area do not pose any carcinogeni health risks in both children and adults because the HI index fallls below the acceptable standard of 1E-4 suggested by DEA (2010).

5.0. Conclusions

Heavy metals in soils within and around the Bua cement production company in Okpella are lower than the average shale and crustal values while they are above results obtained from similar studies in Nigeria. The research revealed that soils in the area are minimally to moderately enriched by heavy metals. Contamination assessment of metals revealed that soils in the area are contaminated especially by Pb and Zn. Sources of heavy metals in soils originated from anthropogenic activities, especially cement production and mining activities. Enrichment of soils by heavy metals poses moderate to very high ecological risk but pose no carcinogenic and non-carcinogenic health risk to people living in the area as at the time of conducting this study except for Cr which may cause non-carcinogenic health risks in children through dermal contact. Unabated production cement and mining activities in the area will increase the concentration of heavy metals and thus increase their risk in both the ecosystem and human health. It is recommended that the contamination level of environmental media should be controlled to forestall health problems in both children and adult lining in this area.

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