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ASSESSMENT OF HEAVY METAL CONCENTRATIONS IN SOIL AND THEIR HEALTH IMPACT ON COMMUNITIES OF EFFA IN OKPOKWU, BENUE STATE, NIGERIA

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Abstract

This study assessed heavy metal concentrations in soil from a coal mine in Effa communities and the health impacts associated with it. The study examined sixty-four (64) soil samples randomly collected from the accessible areas of the mine site and the villages that made up the communities. The concentration of heavy metals in soil samples were determined using PG500 atomic absorption spectrophotometer. The heavy metal (Cd, Cr, Cu, Fe, Mn, Pb and Zn) analysis revealed Cd ranged from 0.024 – 8.193 mg/kg, Cr from Bdl – 14.200 mg/kg, Cu from 0.018 – 2.926 mg/kg, Fe from 0.816 – 4.520 mg/kg, Mn ranged from 0.181 – 1.854 mg/kg, Pb from 0.032 – 0.454 mg/kg, and Zn ranged from Bdl – 3.141mg/kg with the average values of 0.76mg/kg, 2.22mg/kg, 0.35mg/kg, 2.20mg/kg, 0.65mg/kg, 0.26mg/kg and 1.36mg/kg respectively. The assessment of the contamination status of the study area was estimated for contamination factor with values range from 0.053-18.0007 for Cd, BDL-169.048 for Cr, 0.439-71.366 for Cu, 11.657-64.571 for Fe, 0.368-3.768 for Mn, 0.157-1.493 for Pb and BDL-4.660 for Zn. Enrichment factor average value for Cd (0.070), Cr (0.878), Cu (0.220), Mn (0.047), Pb (0.041) and Zn (0.087), geo-accumulation index with the average value -1.732, 2.489, 0.647, 4.090, -0.685, -1.189 and -1.042 for Cd, Cr, Cu, Mn, Pb, Fe and Zn respectively. The pollution load index range from 0.537-4.457. The PLI (value) investigated in this study showed the area was quite highly polluted. Therefore, periodic assessment and health risk of heavy metals is highly recommended to enable decision makers manage the environment in order to preserve public and ecosystem health.

Keywords: Heavy metal, soil pollution, health impact, coal mine, Effa communities.

Introduction

Heavy metals are relatively high density (typically exceeding 5g/cm^3) metallic or metalloid elements that are capable of inducing toxicity to humans and the environment at certain levels of exposure

(Tchounwou, *et al*., 2014). The heavy metals include arsenic (As), cadmium (Cd), chromium (Cr), zinc (Zn), lead (Pb), copper (Cu), manganese (Mn), mercury (Hg), iron (Fe) and nickel (Ni). They are not degradable chemically or microbial in nature (Gautam, *et al*., 2014). Heavy metals can be considered as trace elements because of their trace quantity in the environment. The bioavailability of heavy metals is usually influenced by physical factors (temperature, absorption and phase association), biological factors (biochemical adaptation physiological adaptation and species characteristics) and chemical factors. The chemical factors affect the formation of more ions in the course of their reactions (Tchounwou, *et al*., 2014; Gautam, *et al*., 2014).

Heavy metals are naturally contained in the earth crust. Their pollution is considered natural through weathering and volcanic eruptions, and anthropogenic (man-made) resulting from agricultural and domestic use of compounds containing metals, mining operations and smelting operations. Human activities serve as the major sources of heavy metals pollution.

Series of studies have been carried out on the assessment of urban soils for heavy metals contamination (Olowofila, 2021; Dogra, *et al.,* 2019). Soil is the main geochemical reservoir for all heavy metal pollutants discharged into the environment. Heavy metals in soil are as a result of deposition of waste on the soil which is the most important component of the biosphere through vehicular and other combustion engines emissions. Waste disposals, indiscriminate application of pesticides and fertilizers on farmlands, construction activities, oil drop, in mechanic workshops and other industrial activities also induce heavy metals into the environment. Atmospheric deposition which occurs during dry or wet seasons of the year majorly contributes to heavy metals deposition on the topsoil particularly in urban areas (Lala, *et al.,* 2022, Wuana and Okieimen, 2011). Prolonged exposure to heavy metals like Cd and Pb even at low concentrations could cause lung damage, cancer, kidney disease and nervous disorder. The above is most common with lead (Pb). Chromium (Cr), which exist in various valence states can cause gastrointestinal, lung and nasal irritation, small intestines and stomach ulcer, decreased sperm counts and dermatitis. Some health effects of Zn include; vomiting, abdominal pain, respiratory system irritation and nausea. Cu on the other hand causes cardiomyopathy and lung irritation (Ngole-Jeme, 2015).

Coal mining operations began in Effa community in 2019. The underlying goal was to provide alternative source of power generation by using coal as the main source of fuel to drive industrial processes. However, the environmental degradation and heavy metal threat associated with coal exploitation and utilization cannot be overlooked. Coal mining activities begin from its excavation to loading and unloading, producing heavy metal pollutions which has a direct negative impact on the ecology and heath of the local population (Mishra & Das. 2020).

These activities have the capacity to relocate and redistribute metal contamination in the soil, air and water bodies in and around the mining area. During excavation, drilling and blasting, heavy metals are relocated from normally inaccessible locations to areas where humans are present. Dust and inhalable particulate matters are released causing air pollution in the vicinity of the coal mine. Plants and water bodies such as rivers, streams, lakes and underground water are also not spared from the negative impact of pollution and contamination with heavy metal hazard to consumers of such water.

Although several studies have been conducted on the contamination assessment of heavy metal in soil samples from a Nigerian University (Lala et al., 2022), in dust around tin mine (Abdulllahi, *et al*., 2017), soil from landfill and solid waste dumpsite (Adua, et al., 2020), in soil, water and vegetable grown in irrigated farm (Yebpella, *et* al., 2011), soil samples from developing areas (Hammed et al., 2017; Dogra et al., 2019) among others, no research reports exist for the heavy metal concentrations in soil of the coal mine and the villages of Effa communities in Okpokwu local government area of Benue state. It is against this backdrop that this study was carried out to evaluate the heavy metals concentrations of the coal mine and their possible health consequences on the people of the area.

Materials and methods

Effa is located in Benue State which lies within the lower river Benue trough in the middle belt region of Nigeria and is within the geographical points situated on longitude 7° 47' to 10° 0' East and Latitude 6° 25' to 8° 8' North. Benue State is endowed with solid mineral resources such as industrial minerals – barites, kaolin, gypsum, limestone; Energy mineral – coal, Chemical mineral – brine; Metallic mineral – wolframite, bentonite clay, lead and zinc etc, which are evenly distributed over the existing geographical location, some of which are not yet being mined but are being investigated (Olanrewaju & Avwiri, 2017). Effa is part of Okpokwu local government area of Benue State and the locations is 7°11'0''N 7°47'0''E. The area lies within the tropical climate and experiences two distinct seasons, Dry and wet seasons. Rainy season lasts from April - October with annual rainfall in the of 117 – 281mm. Dry season begins from November - March. The precipitation varies 272mm between the driest month and the wettest month (WMO, 2019). The geology of the area consists of sandstones, mudstones, shales and sandy shales with coal seams.

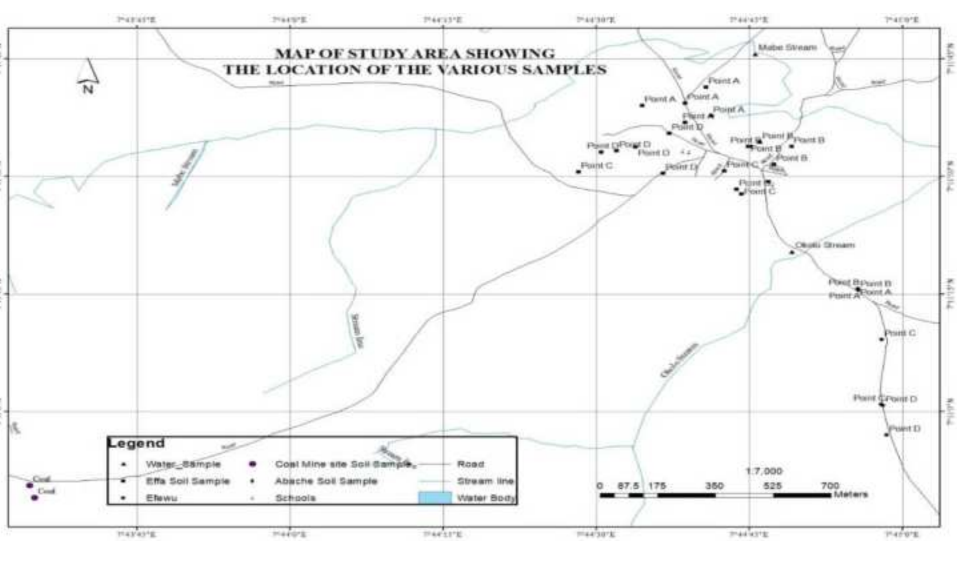

Figure 1. Map of study area showing sampling locations

Sixty-four (64) soil samples taken at a depth of about 15cm were collected randomly from Effa, Efewu, Abache and the coal mine site with sixteen samples per location, using cutlass and hand trowel with the points marked using a global positioning system

(GPS). Each sampling point was carefully chosen to represent locations where human population is involved in various activities such as; leisure, occupational and others. Debris and all other forms of unwanted materials were removed and the samples packed in plastic polythene bags well sealed and labelled accordingly to sampling points and geographical coordinates. Samples were later transported to the soil and plant Analysis/Biochemistry laboratory at the Nasarawa State University, Keffi Shabu-Lafia campus for analysis.

The samples were air dried for three days then grinded and sieved through a 2 mm sieve. 2 g from each sieved samples were digested by weighing into a polyethylene centrifuge tube and 20 mL of 0.1N HCL was added into it. The solution was prepared at a ratio of 1:3 of HNO_3 to HCL (Adebayo, et al., 2017; Dogra, et al., 2019), the tube was closed but not with rubber stoppers, then shaken for 30 minutes on a horizontal shaker. The content was centrifuged for 10 minutes at 3500 rpm until a clear suspension was obtained which was decanted into polyethylene vial diluted with de-ionized water (Adebayo, et al., 2017) and store for metal analysis using PG500 atomic absorption spectrophotometer (AAS). The samples were analyzed in triplicate, during which standards and blanks were ran to ensure 95% reliability of the machine (Dogra, et al., 2019).

Heavy Metals Contamination Indices

Assessment of contamination with heavy metals for this study were carried-out using the following indices;

Contamination Factor (CF)

The contamination factor (CF) gives an indication of the degree of contamination of soil. This is defined as the ratio of concentration of metal in a sample to the concentration of metal in the background. The contamination factor of a sample by metal is expressed by Equation 2.1.

$$CF = C_{sample} / C_{Background} \quad 2.1$$

C_{sample} is the given metal in sample; $C_{Background}$ is the background value of metal. In this study, the $C_{Background}$ value is equals to the control values.

According to Hakanson (1980), contamination factor can be classified as CF< 1 indicates low contamination; 1< CF < 3 is moderate contamination; 3 < CF<6 is considerable contamination and CF > 6 is very high contamination.

Enrichment Factor (EF)

The enrichment factor is a relatively straightforward and simple tool used for evaluating the extent of soils contamination and to compare the contamination of different environmental media. It’s a universal method for calculating degree of soil enrichment by dividing the ratio of a particular metal and normalizing element by the ratio of the same metals found in a baseline and normalizing element (Rubio, 2000; Foley *et al.*, 2011; Benhaddya and Hadjel, 2013). This is calculated using

$$EF = \frac{\left(Trace\frac{metal}{Fe}\right)Soil\ sample}{\left(Trace\frac{metal}{Fe}\right)Natural\ background} \quad 2.2$$

Where (trace metal/Fe) soil sample = heavy metal to Fe in the soil sample taken from the study area and (trace metal/Fe) Natural background=heavy metal to Fe in the soil from control site.

EF values of one (1) or very close to one (1) show that the heavy metal originate from natural sources. Values more than one implies heavy metals are of anthropogenic sources (Zsefer, *et al.*, 1996; Ololade, 2014). According to Birth

(2003), EF is classified as EF<1 no enrichment, EF<3 minor enrichment, EF from 3 to 5 is moderate enrichment, from 5 to 10 moderate severe enrichment, from 10 to 25 is severe enrichment, 25 to 50 is very severe enrichment and EF >50 is extremely severe enrichment.

Index of Geo-accumulation (Igeo)

The index of geo-accumulation (Igeo) is used to assess the degree of metal contamination in terrestrial, aquatic as well as marine environment in comparison to background contents (Tijani & Onodera, 2009). The index of geo-accumulation is given as:

$$Igeo = \log_2 C_{metal} / 1.5\ C_{metal\ control} \quad 2.3$$

Where C_{metal} is the measured concentration of element and $C_{metal\ (control)}$ is the geochemical background value (Control). The constant 1.5 is possible natural fluctuations in background value due to lithologic effect.

The contamination criteria based on index of geo-accumulation are thus: unpolluted for Igeo ≤ 0, unpolluted to moderately polluted (0-1), moderately polluted (1-2), moderately to strongly polluted (2-3), strongly polluted (3-4), strongly to very strongly polluted (4-5) and very strongly polluted = 5.

Pollution load index (PLI)

Pollution load index (PLI) is used in evaluating the pollution level for an environment. The PLI for this current work was evaluated using the method proposed by (Usero, et al., 2000) given in Equation 2.4.

$$PLI = (CF_1 \times CF_2 \times CF_3 \times \ldots \times CF_n)^{1/n} \quad 2.4$$

Where, CF is the contamination factor and n is the number of metals investigated. If PLI value is > 1 it means polluted while PLI value < 1 indicates no pollution.

Results

The results of the assessment of heavy metal concentrations in soils is as presented in figure 1. The values ranged from 0.024 – 8.193 $mgkg^{-1}$ for Cd, BDL – 14.200 $mgkg^{-1}$ for Cr, 0.018-2.926 $mgkg^{-1}$ for Cu, 0.816 – 4.520 $mgkg^{-1}$ for Fe, 0.181 – 1.854 $mgkg^{-1}$ for Mn, 0.032 – 0.454 $mgkg^{-1}$ for Pb and BDL – 3.141 $mgkg^{-1}$ for Zn respectively, with the average values of (0.76, 2.22, 0.35, 2.20, 0.65, 0.26 and 1.36) $mgkg^{-1}$ respectively. The average concentrations followed the order Cr > Fe > Zn > Cd > Mn > Cu > Pb. The distribution of the results obtained are illustrated in Figure 3, showing that the concentrations of Chromium, Copper and manganese were higher at Effa A. The concentration of Cadmium was higher at Mine site D and zinc was higher at Abache D. Figure 2 compared the average value with the WHO limit and indicated, the mean values in this study were lower than the WHO limit with only cadmium (Cd) showing 20% and chromium (Cr) negligible based on the values.

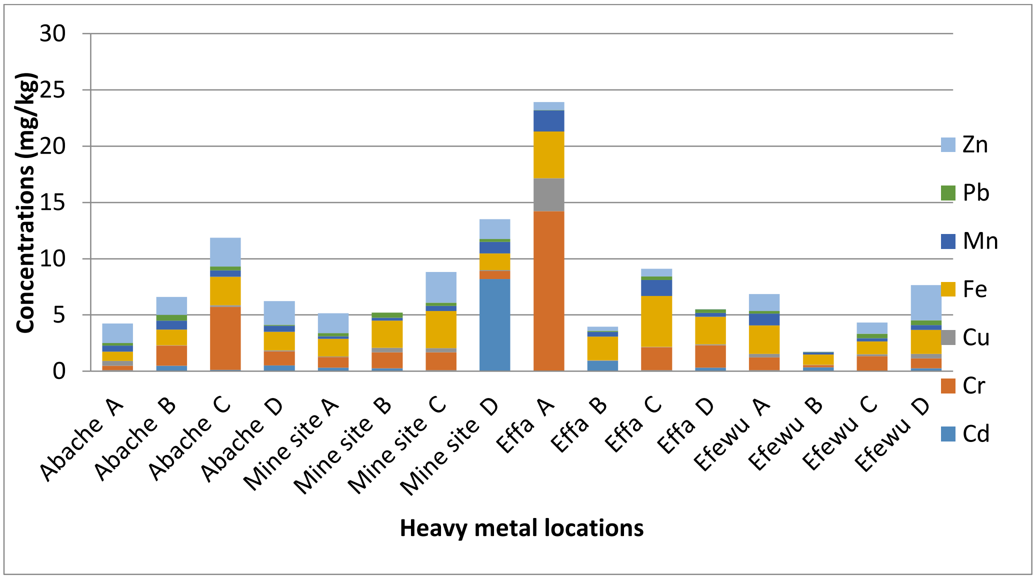

Figure 1: Distribution of concentrations of heavy metals in soil of the study area

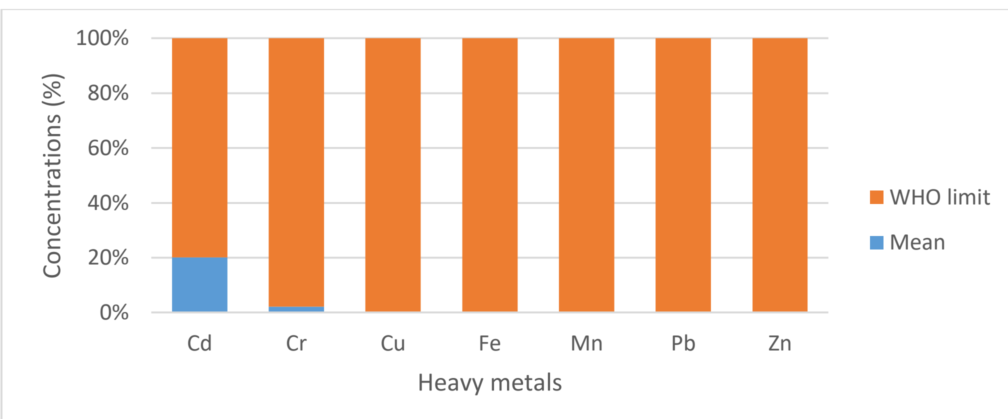

Figure 2: Comparison of mean concentration of heavy metals in soil of study area with WHO limit

Contamination status of heavy metals

Inter-elemental correlation analyses of the metals content are expressed in Tables 1 which indicated that Cd showed a less negative relationship with Cr, Cu and Fe; Pb showed same with Cd, Cr, Cu, Fe and Mn while Zn also showed with Cr, Cu and Mn, the rest metal relationships are positive. Cu-Cr, Mn-Cr, Mn-Cu and Mn-Fe showed strong positive correlation across the sampling areas.

Table 1: *Correlation Coefficient for the Heavy metal Concentrations in Soil Samples*

HM	Cd	Cr	Cu	Fe	Mn	Pb	Zn
Cd	1.000						
Cr	-0.148	1.000					
Cu	-0.115	0.892	1.000				
Fe	-0.169	0.525	0.446	1.000			
Mn	0.198	0.662	0.641	0.629	1.000		
Pb	-0.036	-0.241	-0.325	-0.209	-0.255	1.000	
Zn	0.047	-0.102	-0.118	0.055	-0.112	0.198	1.000

Table 2: *Enrichment Factor (EF) of Heavy Metals Across the Study Area*

Sample Code	Enrichment Factor (EF)					
	Cd	Cr	Cu	Mn	Pb	Zn
Abache A	0.018	0.415	0.877	0.093	0.058	0.222
Abache B	0.052	1.075	0.022	0.083	0.075	0.119
Abache C	0.006	1.841	0.097	0.031	0.029	0.104
Abache D	0.049	0.632	0.091	0.047	0.010	0.134
Coal A	0.125	4.517	0.417	0.172	0.216	0.001
Coal B	0.006	1.047	0.037	0.015	0.033	0.113
Coal C	0.057	0.001	0.002	0.015	0.081	0.281
Coal D	0.005	0.506	0.059	0.023	0.010	0.071
Mine site A	0.031	0.495	0.045	0.019	0.037	0.117
Mine site B	0.017	0.494	0.286	0.016	0.039	0.000
Mine site C	0.004	0.398	0.198	0.019	0.018	0.086
Mine site D	0.857	0.406	0.092	0.100	0.037	0.123
Effa A	0.001	2.846	1.201	0.063	0.003	0.018
Effa B	0.067	0.000	0.051	0.030	0.007	0.019
Effa C	0.003	0.380	0.007	0.045	0.014	0.016
Effa D	0.019	0.687	0.045	0.021	0.024	0.001
Efewu A	0.005	0.378	0.199	0.059	0.017	0.061
Efewu B	0.059	0.164	0.099	0.028	0.007	0.001
Efewu C	0.003	0.945	0.261	0.034	0.072	0.091
Efewu D	0.018	0.342	0.318	0.028	0.042	0.152

Table 3: *Geo-accumulation Index (Igeo) of Heavy Metals Across the Study Area*

Sample Code	Geo-accumulation Index (Igeo)						
	Cd	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
Abache A	-2.876	1.688	2.768	2.958	-0.469	-1.155	0.788
Abache B	-0.526	3.838	-1.773	3.734	0.145	-0.007	0.663
Abache C	-2.673	5.478	1.227	4.598	-0.435	-0.530	1.338
Abache D	-0.384	3.301	0.500	3.963	-0.443	-2.624	1.064
Coal A	-1.129	4.050	0.612	1.874	-0.663	-0.338	-8.982
Coal B	-3.415	3.976	-0.855	3.911	-2.110	-1.022	0.765
Coal C	-0.815	-6.977	-5.943	3.312	-2.707	-0.313	1.482
Coal D	-2.633	4.127	1.023	5.110	-0.313	-1.466	1.285
Mine site A	-1.106	2.898	-0.550	3.913	-1.786	-0.832	0.812
Mine site B	-1.398	3.503	2.716	4.520	-1.467	-0.155	-9.982
Mine site C	-2.907	3.647	2.635	4.974	-0.710	-0.812	1.429
Mine site D	3.585	2.509	0.361	3.807	0.487	-0.937	0.788
Effa A	-4.245	6.816	5.572	5.307	1.329	-3.254	-0.528
Effa B	0.421	-6.977	0.012	4.316	-0.727	-2.937	-1.385
Effa C	-3.040	4.031	-1.695	5.428	0.950	-0.748	-0.555
Effa D	-1.172	4.000	0.057	4.543	-1.024	-0.822	-5.227
Efewu A	-3.093	3.196	2.272	4.601	0.514	-1.260	0.569
Efewu B	-0.959	0.507	-0.215	3.117	-2.028	-3.982	-6.812
Efewu C	-4.830	3.373	1.517	3.454	-1.440	-0.349	0.004
Efewu D	-1.455	2.804	2.698	4.351	-0.800	-0.237	1.635

Table 4: *The Minimum, Maximum and Average Values of Enrichment Factor and Geo Accumulation Index of the Study Area*

	HM	**Cd**	**Cr**	**Cu**	**Fe**	**Mn**	**Pb**	**Zn**
EF	Min.	0.001	0.000	0.002	NA	0.015	0.003	0.000
	Max.	0.857	4.517	1.201	NA	0.172	0.216	0.281
	Ave.	0.070	0.878	0.220	NA	0.047	0.041	0.087
	Std Dev.	0.188	1.080	0.307	NA	0.039	0.047	0.077
Igeo	Min.	-4.830	-6.977	-5.943	1.874	-2.707	-3.982	-9.982
	Max.	3.585	6.816	5.572	5.428	1.329	-0.007	1.635
	Ave.	-1.732	2.489	0.647	4.090	-0.685	-1.189	-1.042
	Std Dev.	1.858	3.478	2.352	0.875	1.051	1.123	3.624

NA= Not Applicable

Table 5: *Contamination Factor and Pollution Load Index for the Study Area*

Sample Code	Cd	Cr	Cu	Fe	Mn	Pb	Zn	PLI
Abache A	0.204	4.833	10.220	11.657	1.083	0.674	2.591	2.164
Abache B	1.042	21.452	0.439	19.957	1.659	1.493	2.375	2.737
Abache C	0.235	66.845	3.512	36.314	1.110	1.039	3.792	3.658
Abache D	1.149	14.786	2.122	23.400	1.104	0.243	3.136	2.555
Mine site A	0.697	11.179	1.024	22.600	0.435	0.843	2.634	2.090
Mine site B	0.569	17.000	9.854	34.414	0.543	1.347	BDL	BDL
Mine site C	0.200	18.786	9.317	47.143	0.917	0.855	4.039	3.397
Mine site D	18.007	8.536	1.927	21.000	2.102	0.783	2.591	4.285
Effa A	0.079	169.048	71.366	59.400	3.768	0.157	1.040	4.457
Effa B	2.009	BDL	1.512	29.886	0.907	0.196	0.574	BDL
Effa C	0.182	24.524	0.463	64.571	2.898	0.893	1.021	2.313
Effa D	0.666	24.000	1.561	34.957	0.738	0.849	0.040	1.554
Efewu A	0.176	13.750	7.244	36.400	2.142	0.626	2.226	2.941
Efewu B	0.771	2.131	1.293	13.014	0.368	0.095	0.013	0.537
Efewu C	0.053	15.536	4.293	16.443	0.553	1.178	1.504	1.780
Efewu D	0.547	10.476	9.732	30.614	0.862	1.273	4.660	3.656

Discussion of Findings

The concentrations of Cd and its average values in the study area were much lower than the WHO limit of 3.0 mgkg^{-1}, except for the mine site D with 8.193 mg/kg for soil. This value indicated that the soil at the mine site D was polluted. The very high value of Cd at the mine site D could be attributed to used batteries at the site. The Effa site A had the highest Cr concentration value of 14.20 mg/kg in the study area for soil. The significant difference in Cr value at Effa site A calls for attention as to why that much gap within the same locality. However, the concentrations of Cr in the study areas were found to be lower than the permissible limit of 100 mgkg^{-1}, similar to the result obtained by Adua *et al.* (2020). Chromium is not required by plant for growth and it has low rate of uptake by pant shoot (Ogundele *et al*., 2015).

Copper (Cu) is readily absorbed following oral ingestion, absorption being greatest for the most soluble salts. The Joint Committee on Food Additives has recommended a provisional maximum tolerable daily intake (PMTDI) of 0.5 mgkg^{-1} per day. Cu concentrations in the soil samples were below the permissible limit, indicating no pollution of the study areas with Cu. The results corroborate with Adua *et al*. (2020). Iron (Fe) concentrations in the soil samples were below the world limit of 5000 mgkg^{-1}, BDL, 300 mgkg^{-1} respectively. The results were illustrated in Figure 4 which showed that the soil is unpolluted with Fe. Iron is an abundant nutrient element required by plants and humans; its toxicity is not common in animals and human. It exists in water as Fe^{2+} or Fe^{3+} in suspended form. Its presence is evident by staining in clothes and imparting a bitter taste.

Manganese (Mn) is the 12th most abundant heavy metal in the Earth's crust, and excess Mn can cause a wide variety of harmful effects (Andrade *et al*., 2015). Mn investigated in this study were found to be lower (value) than permissible limit 500 $mgkg^{-1}$. The UK Food Standard Agency's Experts Group on vitamins and Minerals concluded that supplementary intake of up to 4 mg/day in addition to the diet would likely produce adverse effects in the general population (FSA 2003). Mn is essential for plant and animals but an elevated level can pose threat to life. Though Mn absorbed, is excreted largely through the bile and is eliminated in the faeces, it can accumulate in the brain at high intake levels (EMEA, 2008). The activities of automobiles, machines workshops, power generators and petrol station in these areas may have contributed to the amount of Mn in the area.

Lead (Pb) as a soil contaminant is a global issue, it does not have any benefit to living organisms. It is rather regarded as very harmful metal to both plants and animals. It accumulates with age in bones, aorta, kidneys, spleen and liver. This metal can enter the body through uptake of food, water and air. Concentration of Pb for the samples in the study area were lower than the permissible limit of 100 $mgkg^{-1}$ as shown in Figures 4. The concentrations of lead in this study were lower than the values of (0.36mg/kg to 1.38mg/kg and 0.57mg/kg to 2.163mg/kg) obtained by Okoro et al. (2016) and Adua et al. (2020) in the roadside dust of IIorin and soil of Keffi respectively.

Zinc metal is essential for animals and human health (Alysson & Fabio, 2014), its shortages may cause certain birth defects (Wuana & Okieimen, 2011). It is a component of proteins as well as greater number of enzymes (Plum *et al*. 2010). High concentration of zinc leads to phyto-toxicity, reproduction problem, and brain disorder (USEPA 1999). The concentrations were below the limit permitted by WHO (2001) for soil. Zinc is an indispensable trace element not only for human, but also for all organisms. Zn is released from brake linings during mechanical abrasion of vehicles, engine oil combustion and tyres of motor vehicle (Ogundele, *et al.,* 2015).

The average concentrations of heavy metals recorded in this study were generally low which can be attributed to the nature of the soil which is generally sandy. Sandy soil does not allow for the accumulation of heavy metals leading to low metal concentrations as it was the case in the current study. This agrees with (Horowitz, 1991; Mohiuddin *et al.,* 2009) that heavy metal concentration showed a general increase in clay minerals content and a decrease in the sandy minerals content in the soils. Kabata – Pendias (2011) also reported that soils with a high proportion of sand have a minimal ability to hold metal ions. This is so because of the high porosity that allows for ease transport of metals as water infiltrates through the pores. Organic matter content helps retain metals but is low in sandy soil and high pH in making sandy soils more alkaline, reducing the available metals in the soils. The result was similar to the work of Akomolafe and Lawal (2019) in specific polluted sites in Lafia urban centre; Adua *et al* (2020) in soil from Keffi, landfill and solid waste dumpsite. Comparing the present results with other works such as the assessment of metal contamination in sediment samples collected from Lagos dockyard by Basheeru *et al.* (2022), the contamination level of lagoon sediment with lead, iron and copper were higher compared to the ones obtained in this work whereas cadmium and chromium are higher in this work.

Contamination indices

The values of contamination factor (CF) and pollution load index (PLI) of the study areas were presented in Table 5. With regards to classifying the degree of contamination based on contamination factor by Hakanson (1980), this study showed that Effa B is not polluted because of the very low CF values. Efewu B is moderately polluted while the rest locations are highly contaminated. Effa A is very highly contaminated with CF value of 169.048. This contamination with high chromium could be as a result of geogenic chromium, fertilizer and pesticide application in the area that is chromium-based and the presence of coal mining in the area. The CF of Fe was high, indicating that the locations are highly contaminated with Fe showing Effa C having the highest value of 64. CF for Cu in Abache B and Effa C showed low contamination. Abache D, mine site A, D, Effa B, D and Efewu B were moderately contaminated. Abache C and Efewu C were considerably contaminated while the rest locations were highly contaminated. Effa A had CF of 71.366 for Cu. The CF of Cd was highest at Mine site D indicating highly contaminated site. Effa B, Abache B and D were moderately contaminated while the remaining locations showed low contamination. The value of CF for Mn at Effa A showed a considerable contamination of the site. Abache A-D, Coal D, mine site D, Effa C and Efewu A were moderately contaminated while the rest sites were of low contamination. The CF of Pb in the study area indicated that Abache A, D, mine site A, C, D, Effa A-D and Efewu A-C were of low contamination while Abache B, C, mine site B, Efewu C and D were moderately contaminated. For Zn, the CF at mine site B, Effa B, D and Efewu B were of low contamination. Abache A, B, mine site A, D, Effa A, C, Efewu A and C, moderate contamination while Abache C, D mine site D and Efewu D are contaminated considerably. The contaminations could be natural and or man-made.

The Enrichment Factors of Cd, Cr, Cu, Mn, Pb and Zn for each location of the study area were presented in Table 2 with the consideration to assess the study area soils' contamination level. The average EF of Cd (0.070), Cr (0.878), Cu (0.220), Mn (0.047), Pb (0.041) and Zn (0.087) as shown in Table 4, were found to be less than unity, inferring that there is no enrichment for any of the metals investigated, which agreed with (Oboshenure & Airen, 2021). The Cd enrichment factor ranges from 0.001 to 0.857, Cr from 0.000 to 4.517, Cu from 0.002 to 1.201, Mn from 0.015 to 0.172, Pb from 0.003 to 0.216 and Zn from 0.000 to 0.281. Table 2 showed no enrichment for Cd, no enrichment or moderate enrichment for Cr, no enrichment or minor enrichment for Cu which is similar to (Lala et al., 2022), no enrichment for Mn, no enrichment for Pb and no enrichment for Zn According to Birth (2003).

Geo-accumulation index (I_{geo}) values obtained were presented in Table 3 and was considered to evaluate the contamination level of the soils in the study area by comparing the results of the present concentrations of heavy metals with the work of others. Table 4, shows the average I_{geo} of Cd (-1.732), Mn (-0.685), Pb (-1.189) and Zn (-1.042) were evaluated to be less than zero which indicated unpolluted soils. Lead (Pb) and Mn agreed (Lala et al., 2022). Cu with Igeo of 0.647 indicated that the soil is moderately polluted while Cr and Fe with Igeo of 2.489 and 4.090 respectively, indicated strongly to very strongly polluted. Invariably, the soils were contaminated with Cu, Cr and Fe and not with Cd, Mn, Pb and Zn, unlike (Onjefu, et al., 2016) where apart from Cd which was moderately polluted, the rest metals were unpolluted as their values were less than zero.

The pollution load index (PLI) was calculated and the summarised results are presented in Table 3. If PLI value is > 1 it means polluted while PLI value < 1 indicates no pollution. The study showed that the PLI range from 0.537 to 4.457. The lowest PLI was calculated for Efewu B 0.537, which indicated not polluted and the highest value of 4.457 was found at Effa A. The PLI investigated in this study showed the area was quite highly polluted which could be as a result of the mining activity in the area. Please compare your findings with other related studies.

Conclusion

Seven (7) heavy metals were analyzed from the soil sample locations and their concentrations determined. The average concentrations of the heavy metals recorded were generally low which can be attributed to the nature of the soil which is generally sandy. However, from the contamination status based on the pollution index (PLI) showed that the area is highly polluted which could be as a result of the mining activity in the area.

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