Available online www.jsaer.com

Journal of Scientific and Engineering Research, **2021, 8(2):203-209**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Pollution Load Index of Heavy Metals in Soil around the Vicinity of Automobile Servicing Workshops in Bori Metropolis, Rivers State, Nigeria

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Abstract Heavy metals in soils are of great environmental concern. In order to determine the pollution load index of some heavy metal contents and their distribution in surface soil around the vicinity of automobile servicing workshops in Bori metropolis, sixteen surface soil samples were collected, prepared, digested and analysed for Cu, Mn, Cd, Pb, Fe, Cr and Ni using atomic absorption spectrophotometry (AAS). In the investigated soil samples, the mean recorded concentrations of the heavy metals were 9.344 mg/kg for Cu, 4.867 mg/kg for Ni, 0.022 mg/ kg for Cd, 138.556 mg/kg for Fe, 6.856 mg/kg for Mn, 7.632 mg/kg for Cr and 4.889 mg/kg for Pb. The obtained results indicates that the enrichment factors of the measured heavy metals were 4.31, 2.79, <0.02, 1.48, 1.85, 3.85, and 4.29 for copper, nickel, cadmium, iron, manganese, chromium and lead respectively. I-geo (geo-accumulation index) values of the metals in the soils under study indicates that they were uncontaminated to moderately contaminated with copper and lead, but highly contaminated with iron and manganese and moderately polluted with nickel and cadmium. The investigated soil samples from the results of the study does not pose any challenge for agricultural and any intended use for now.

Keywords Heavy metals contents, automobile servicing workshop, contamination, pollution etc

Introduction

There is increasing awareness that heavy metals present in soil may have negative consequences on human health and on the environment [1-4]. From the environmental point of view, all heavy metals are important because they cannot be biodegraded and are largely immobile in the soil system, so they tend to accumulate and persist in urban soils for a long time. The presence of heavy metals in an environment alters the structure and functions of the ecosystem. This is due to the fact that their presence has effect or influence on the nature of the physical and chemical properties of the soil. This results in levels that are harmful to humans upon both acute and chronic exposure [5]. The most frequently reported heavy metals with regards to potential hazards and the occurrence in contaminated soils are cadmium (Cd), chromium (Cr), lead (Pb), zinc (Zn), iron (Fe) and copper (Cu) [6]. The concentrations of these toxic elements in soils may be derived from various sources, including anthropogenic pollution, natural high background rocks and metal deposits [7]. Although heavy metals distribution in weathering of soils is well documented for many cities of developed countries, comparatively little is studied in less developed countries [8]. However, in recent years, a few of these countries have achieved significant strides in their quest for rapid economic growth through industrialization. Thus, a number of factories, usually sited haphazardly, have developed population explosion and the increased use of automobiles have become very common in urban areas. The impact of pollution in the vicinity of overcrowded cities and from industrial effluents and automobile servicing workshops has reached a disturbing magnitude and is arousing public awareness. At present, relatively little data are available on the extent of environmental pollution because there are few agencies with inadequate capacity charged with the routine monitoring and protection of the environment [9].

The present study covers the vicinity of automobile workshop in Bori metropolis, the head quarters of Ogoni in Rivers state, Nigeria. Therefore, contaminants, such as heavy metals arising from vehicular movement, washing of vehicular parts during serving, surface runoff and other activities around the vicinity of automobile workshop might have been released into the soil. Most of the land in this area is intensively used for different purposes including residence and agriculture. Thus, it is necessary to carry out an assessment of the concentration of these heavy metals in soils of this urban area.

In view of the fact that limited data are currently available on the heavy metal status of soils in the vicinity of automobile workshop, this study was undertaken to provide a detailed accounts of heavy metal distribution in soil from the vicinity of automobile servicing workshop in Bori metropolis of Khana local Government Area of Rivers state, Nigeria. In this work, the enrichment factor of the soil, anthropogenic input, contamination/pollution load index of heavy metals and geo-accumulation index are been quantified.

Sample Collection and Analysis

Four (4) sampling automobile workshops were selected in order to cover the entire vicinity of the automobile servicing workshops in Bori metropolis. To provide a satisfactory geographical representation of each location, the workshops were divided into four zones; zone S_1 was to the north, S_2 to the south, S_3 to the east and S_4 to the west. Soil samples were collected from the four zones of each workshop randomly at a depth 0-15cm using soil auger. Samples collected within each workshop were mixed together to form a composite sample which represents the bulk sample of each location. Four (4) composite samples were collected from the four (4) sampling locations. The control sample (reference sample) was obtained from an agricultural farmland in Kaani community, about 2.5 kilometres away from Bori metropolis (A land devoid of automobile activities). The collected sample were kept in labelled plastic bags and transported to the Chemistry laboratotary of the Ignatius Ajuru University of Education, Rumuolumemi, Port Harcourt for laboratory preparation and analysis. The soil samples were air dried to constant weight for a period of one week, macerated to powder form and stones removed. The powdered samples were then passed through a 2 mm sieve and stored in a well cleaned and air-tight bottle and labelled accordingly until time for analysis. 2.0g of each of the sieved soil samples was weighed and digested with aquaregia (An acid mixture of Nitric acid and Hydrochloric acid of ratio three to one). The digest were filtered with whatman No.1 filter paper and transferred into 250ml sample bottles after being cooled. The digest was made-up to mark with de-ionised water in a 100ml Erlenmeyer flask. The digest was then subjected to heavy metals (Cd, Pb, Ni, Cu, Cr, Fe and Mn) analysis using the solar Thermo Elemental Atomic Absorption Spectrophotometer (AAS), flame model SE-71096. To overcome photolytic interference, the samples were placed in amber bottles. After every determination, blanks and certified reference materials were also run to determine the precision and instrumental uncertainty. The results obtained were further subjected to index model analysis.

Contamination/Pollution Load Index (C/PLI)

The contamination/pollution load index was derived by employing the contamination/pollution load index as defined by Lacutus, [10]

$$\mathrm{C/PLI} = \frac{\text{Concentration of material in soil}}{\text{Target value from reference table}}$$

The C/PLI gives a distinction between soil contamination and pollution range. The C/PLI represents a metal contents effectively measured in soil by chemical analysis and the reference value obtained using the standard table formulated by the department of petroleum resources [11] for maximum allowed concentration of heavy metals in soil.

C/PI value greater than unity (1) defines the pollution range, and when less than unity, it defines the contamination range.

Enrichment Factor (EF)

Heavy metal enrichment factor (EF) was derived based on equation described by Asaah *et al* [12] and Iwegbue [13]. Enrichment factor is a convenient measure of geochemical trend, and it's used for making comparison between areas sampled.

Quantitatively, enrichment factor (EF) can be expressed as;

$$EF = \frac{\text{Mean concentration of heavy metals in soil}}{\text{Background concentration (control)}}$$

Quantification of Anthropogenic Metals

Considering the metal content of the control (background sample) as representing lithogenic metal, the proportion of anthropogenic metal was determined for each metal by means of the equation described by Asaah *et al* [12].

$$\text{Anthropogenic metal} = \frac{X - Xc}{X}$$

Where X = Metal content representing the lithogenic metal (control)

Xc = Average concentration of metal in the soil

Geo-Accumulation Index (I-geo)

An index of geo-accumulation (I-geo) was originally defined by Muller [14]. Geo-accumulation index allows the evaluation of the degree of contamination of heavy metals in soil and sediments. The geo-accumulation index was calculated mathematically according to the formula proposed by Muller [14], as shown below:

$$\text{I-geo} = \log 2\ [Cn / 1.5 * Bn]$$

Where, Cn = concentration of heavy metal in the analysed soil.

Bn = Geochemical background concentration of the metals in average shale.

The factor 1.5 is a correction coefficient that regulates the influence of natural fluctuations and the influence of anthropogenic sources. It is introduced to minimise the effect of possible variations in the background values which might be attributed to lithological variations in the soil.

The classification of the I-geo shows that values less than one i.e (< 1) are not polluted, while values greater than one i.e (> 1) ranges from slight pollution to extreme pollution. The values of I-geo are classified according to seven (7) degrees of classifications, where grade 1 correspond to uncontaminated soil (I-geo ≤ 0), grade 2 refers to soil without contamination to moderately contaminated (0 < I-geo ≤1). Grade 3 corresponds to soil with moderately pollution (1< I-geo≤2). Grade 4 indicates moderate to highly contaminated soil (2 ≤ I-geo <3). Grade 5 indicates high pollution (3 ≤ I-geo <4), Grade 6 indicates high to extremely contaminated soil (4 ≤ I-geo <5), and grade 7 indicates extremely contaminated soil (I-geo ≥ 5).

Results and Discussion

Heavy Metals

Concentrations of Pb, Zn, Cu,Mn, Cd, Ni and Fe in the soil samples from the vicinity of the automobile servicing workshops in Bori metropolis are shown in (Table 1) below together with their mean values, and standard deviations. Iron had the highest mean value of (138.556mg/kg), followed by copper (9.344 mg/kg), and in the following decreasing order chromium (7.362mg/kg), manganese (6.856mg/kg), lead (4.889mg/kg), Nickel (4.867mg/kg) and cadmium which has the least mean concentration value of 0.022mg/kg. The metals displayed quite homogeneous distributions across the sampling area. Iron has the highest standard deviation with the lowest found in cadmium, thus suggesting a major natural (i.e. indigenous lithologic) source. However, there were no significant differences in the distribution of lead and copper, and also in lead and nickel. Copper is both an essential and potentially toxic element [15].

From (table 1), it shows that the concentration of cadmium (Cd) in the soil sample from the control workshop was below the detectable limit (< 0.001), and so the concentration was negligible in the reference sample. The prominent and most abundant heavy metal in the control sample was Iron (Fe) whose concentration was

93.472mg/kg. The order of distribution of the selected heavy metals in control sample in increasing order can be represented by Cd<Pb<Ni<Cr<Cu<Mn<Fe.

Table 1: Mean concentrations (mg/kg) of heavy metals in selected automobile servicing workshop within Bori Metropolis (n=7), (m=4)

S/n	Heavy metals	Symbol	Control workshop	Workshop station 1	Workshop station 2	Workshop station 3	Workshop station 4	$\bar{X}$±SD
1.	Copper (mg/kg)	Cu	2.168	8.694	10.843	7.969	9.869	9.344±1.167
2.	Nickel (mg/kg)	Ni	1.743	4.693	5.036	3.584	6.156	4.867±1.059
3.	Cadmium (mg/kg)	Cd	<0.001	0.011	0.039	0.023	0.016	0.022±0.012
4.	Iron (mg/kg)	Fe	93.472	118.321	169.436	121.873	144.593	138.5±23.64
5.	Manganes e (mg/kg)	Mn	3.714	5.685	9.748	7.138	4.853	6.856±2.147
6.	Chromium (mg/kg)	Cr	1.912	6.511	8.134	6.897	7.906	7.362±0.781
7.	Lead (mg/kg)	Pb	1.137	5.399	3.617	4.169	6.369	4.889±1.237

Below Detectable Limit (BDL)

Table 2: Comparison of the Concentrations of Heavy metals (mg/kg) in the present study to some known standards

Metals	Present study	DPR Intervention value	World average in shale	China
Cu	9.344	190	45	35
Ni	4.867	210	68	-
Cd	0.022	17	0.3	0.5
Fe	138.556	38000*	47000	-
Mn	6.856	850*	850	-
Cr	7.362	380	90	-
Pb	4.889	530	20	60

***Target value**

Source: adapted from Marcus *et al* [16]

Comparing the concentrations of heavy metals in the present study to some known standards, such as DPR, world average in shale, and china, it was found that all the heavy metals investigated were within the threshold limits and hence no intervention is required.

Contamination/Pollution Load Index (C/PLI).

Analysis of soil sample obtained from automobile workshop 1 for contamination/pollution load assessment as shown in Table 3 revealed that copper, nickel, cadmium, iron, manganese, chromium, and lead, have index values of 0.24, 0.13, 0.01, 2.52, 0.01, 0.07 and 0.06 respectively. Comparing these values with the reference shown in table 4 below, it was observed that the soil sample of workshop 1 was slightly contaminated with these heavy metals. The index value of 2.52 recorded for iron in the soil sample of workshop one (1) shows that the soil was moderately polluted with iron.

Analysis of soil sample from workshop two (2) have also shown that the soil sample was slightly contaminated with nickel, cadmium, manganese, chromium, and lead with index values of 0.14, 0.05, 0.01, 0.08, and 0.04 respectively. Soil sample from workshop two (2) was moderately contaminated with copper and slightly polluted with iron with both index values of 0.30 and 3.61 respectively.

Analysis of soil sample from workshop three (3) have also shown that the soil sample was slightly contaminated with copper, nickel, cadmium, manganese, chromium, and lead with index values of 0.22, 0.10, 0.03, 0.01, 0.07, and 0.05 respectively. The soil sample from workshop three (3) was moderately polluted with iron with index value of 2.59.

Analysis of soil sample from workshop four (4) have shown that the soil sample was slightly contaminated with nickel, cadmium, manganese, chromium and lead with index values of 0.18, 0.02, 0.01, 0.08, and 0.07 respectively. The soil sample from workshop four (4) was moderately contaminated with copper and moderately polluted with iron with both index values of 0.27 and 3.08 respectively.

Table 3: Contamination and pollution load index of heavy metals from automobile servicing workshop in Bori metropolis, Rivers state

Station	**Contamination and pollution load index of Heavy metals**							**Depth**
	Cu	**Ni**	**Cd**	**Fe**	**Mn**	**Cr**	**Pb**	**(cm)**
Workshop 1	0.24	0.13	0.01	2.52	0.01	0.07	0.06	0-15
Workshop 2	0.30	0.14	0.05	3.61	0.01	0.08	0.04	0-15
Workshop 3	0.22	0.10	0.03	2.59	0.01	0.07	0.05	0-15
Workshop 4	0.27	0.18	0.02	3.08	0.01	0.08	0.07	0-15

Table 4: Significance of intervals of contamination/pollution load index (C/PLI)

S/n	**Contamination/pollution load index**	**Significance**
1	< 0.1	Very slight contamination
2	0.10 – 0.25	Slight contamination
3	0.26 – 0.50	Moderate contamination
4	0.51 – 0.75	Severe contamination
5	0.76 – 1.00	Very severe contamination
6	1.1 – 2.00	Slight pollution
7	2.1 – 4.0	Moderate pollution
8	4.1 – 8.0	Severe pollution
9	8.1 – 16.0	Very severe pollution
10	➢ 16.0	Excessive pollution

Source: Adapted from Lacutus [10].

Enrichment Factor

Analysis of enrichment factor of heavy metals as shown in (table 5) below, shows that the surface soil in the vicinity of automobile workshop was most highly enriched with copper with factor value of 4.31 and the least enriched heavy metal was cadmium with factor value of less than 0.02. The decreasing order of factor value for the heavy metals are Cu>Pb>Cr>Ni>Mn>Fe>Cd.

Table 5: Quantification of Enrichment Factor (EF) of some selected heavy metals in soil in the vicinity of automobile workshop in Bori metropolis, Rivers state

S/n	**Heavy metals**	**Symbol**	**Enrichment Factor (EF)**
1.	Copper	Cu	4.31
2.	Nickel	Ni	2.79
3.	Cadmium	Cd	< 0.02
4.	Iron	Fe	1.48
5.	Manganese	Mn	1.85
6.	Chromium	Cr	3.85
7.	Lead	Pb	4.29

Anthropogenic Input

From the analysis of anthropogenic input for heavy metals in soil as shown in (table 6) below, it is clearly seen that Cadmium concentration in soil occasioned by human activities was the highest of all other heavy metals, with a concentration of 21mg/kg. This is followed by copper whose concentration was 3.309mg/kg and then in the following decreasing order of concentrations lead (3.299 mg/kg), chromium (2.850mg/kg), Nickel (1.792mg/kg), manganese (0.846mg/kg) and iron (0.482mg/kg).

Table 6: Anthropogenic input for heavy metals in soil in the vicinity of automobile workshop in Bori metropolis

Depth (cm)	Cu Mg/kg	Ni Mg/kg	Cd Mg/kg	Fe Mg/kg	Mn Mg/kg	Cr Mg/kg	Pb Mg/kg
0-15	3.309	1.792	21	0.482	0.846	2.850	3.299

Geo-Accumulation Index (I-GEO)

The geo-accumulation index for the various sample stations showed that copper (Cu) was lowest at automobile workshop station 2 and highest at station 1. Nickel (Ni) was lowest at automobile station 4 and highest at station 3. Cadmium (Cd) was least at automobile station 4 and highest at station 1, while manganese (Mn) was lowest at automobile station 2 and highest at station 4. Chromium (Cr) was also found to have the lowest geo-accumulation value at workshop station 2 and highest at station 1. Lead (Pb) was lowest at workshop station 4 and highest at station 2. Iron (Fe) was observed to be the metal with the highest geo-accumulation value of all the metals with the least value observed at the automobile workshop station 2 while the highest value was at station 1. The geo-accumulation values for copper (Cu), lead (Pb), chromium (Cr), and cadmium (Cd) were very low see (table 7). The calculated I-geo data when compared to the seven degrees of contamination (ranging from 0-6) of the geo-accumulation index as proposed by Muller [14], showed that the automobile workshops were practically uncontaminated with cadmium (Cd) at automobile workshop stations 4 and lead (Pb) at stations 1 and 4, but uncontaminated to moderately contaminated with copper (Cu) at stations 1, 3 and 4, nickel (Ni) at stations 4, cadmium (Cd) at stations 2 and 3, chromium (Cr) at stations 2, 3 and 4, and lead (Pb) at stations 2 and 3 respectively. Automobile workshops stations 1, 2 and 3 are moderately polluted with nickel (Ni), cadmium (Cd) at station 1, manganese (Mn) at stations 2 and 3, chromium (Cr) at station 1. And finally moderate to highly contaminated with Iron (Fe) at all the automobile stations (1, 2, 3, and 4) and manganese (Mn) at stations 1 and 4.

Table 7: Geo-accumulation Index (I-geo) of Heavy metals from automobile workshops in Bori metropolis, Rivers state

Workshop	Heavy metals						
	Cu	Ni	Cd	Fe	Mn	Cr	Pb
Station 1	0.5890	1.0361	1.3269	2.4741	2.0497	1.0156	0.4438
Station 2	0.4931	1.0056	0.7611	2.3182	1.8155	0.9189	0.6177
Station 3	0.6268	1.1532	0.9886	2.4613	1.9509	0.9906	0.5561
Station 4	0.5340	0.9183	0.3269	2.3870	2.1185	0.9313	0.3720

Conclusion

Heavy metals concentrations in soil at different automobile servicing workshops in the study were all lower than the recommended or permissible concentrations by the relevant agencies (DPR, world average value in shale and china). Hence there is no need for intervention by the regulatory agencies. The anthropogenic activity is a contributory factor to the heavy metal contents of the soil in the vicinity of the automobile workshops as shown by the index model approach. Enrichment factor analysis shows that copper was the most predominant heavy metal amongst all the heavy metals investigated in the study.

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