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Analysis of Heavy Metal Content in Soil Peripheral Along Lagos-Ibadan Railway Route, South West, Nigeria

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Abstract: In Nigeria, considering the period of passive functioning of railway transport along Ibadan - Lagos route but there is still notable commercial activities at each terminal and the agricultural activities along the route closed to the railway track continue increasing and with the recent reopening/construction of new rail. As such, the study aimed to determine the level of soil pollution with heavy metals from Railway Transportation in South West, Nigeria which focused on Oyo State (Bodija), Ogun State (Lafenwa) and Lagos State (Alajomeji). Four soil samples each were collected from study area making twelve (12) samples collected at a depth of 0-15 cm with minimum of 20-30 feet apart. A certain weight of each sample was weighed into beaker and 10mls of an acid mixture of nitric/perchloric acid was added and allowed to undergo digestion. The content was read on a Buck Scientific Atomic Absorption Spectrophotometer model 210/211 VGP to determine the present of heavy metals like Pb, Cd, Cr, Zn and Cu. The concentration of Pb, Cd, Cr, Zn and Cu at Bodija range from 15.4–121.6, 0.00-0.85, 49.40-69.35, 199.0-329.5 and 37.40-55.50. Lafenwa; 58.4-417.50, 0.00-3.85, 9.70-47.45, 192.5-3557.5 and 45.40-1337.50. Alagomeji; 63.2-457.40, 2.10-4.10, 11.70-51.65, 201.6-3767.6 and 55.30-1537.60 mg/kg respectively. The mean effect indicated Pb, Cu and Cd were above the World Health Organisation standard for heavy metal in soil while Pb, Cd, Zn and Cu were above the standard of Nigeria Department of Petroleum Regulation for heavy metal in soil in the Railway Stations with significant correlation among the heavy metal indicated similar source of pollution. The Geo-accumulation index indicated the soil in the Railway station is extremely contaminated. The contamination factor (CF) show contamination level of the heavy metals in the study areas are moderately polluted. The pollution load index (PLI) at Bodija with 0.7687 indicated unpolluted, Lafenwa and Alagomeji with 2.8681 and 3.6437 respectively indicated polluted. The Pb, Cu, Zn and Cd are the major heavy metals generating from railway transportation as such, needs for periodic environmental monitoring of environmental media and phytoremediation of the railway stations as well formulation of policy relating to railway transportation in term of planning, construction, operation in the face of new era in Railway transportation in Nigeria.

Keywords: Railway Transport, Soil Pollution, Heavy Metals, Lead, Cadmium, Zinc, Cooper, Chromium

1. Introduction

Pollution and contamination by pollutants and contaminants of the whole environment has increasingly attracted interest worldwide. In this regards, contamination of soil with toxic metals is been considered as a global critical challenge within the research community [2].

Soil being one of the major components of the environment, If exposed to degradation and does not get adequate attention, especially when we talk about contamination with heavy metals, pesticides and other organic pollutants, might come to the occurrence of so-called “chemical bomb” [10].

Since the late 1990s, some pollution investigations studies have found that air and soil alongside railway had higher heavy metal levels than outside the study area or control sites

[12, 6]. Rasa [12] revealed that friction processes between wheel sets and rails during railway transportation make railways released heavy metals including Zn, Cd, Pb and other related heavy metals into the environment with potential of contaminating vicinity.

Railway transportation serves as one of the major polluters of the natural environment. Most of the pollutant emissions from combustion processes are related to fuel consumption in the internal combustion engines of traction rolling stock and the emission due to friction of metals and degradation of rolling wheels, heavy metals are emitted into the atmosphere, soil, surface and ground water, etc. and heavily pollute the railway environment. The recent increase in the electrification of railways and in its operation, local environmental pollution is likely to be increased in the near future [12].

Heavy metals are contaminants and pollutants of major environmental and health concerns. However, toxic metals are called heavy metal, irrespective of their atomic mass or density [8]. Based on the level of emission, the heavy metals are primarily contained in earth crust e.g. soils and disintegrate from their bound states through either the weathering of parent materials (natural process) or from anthropogenic activities. According to Amukali et al. [3], heavy metals majorly have become a worldwide or global concerns with potential of causing a serious potential threat to the environment. In his study, this had led to losses in agricultural produce and dangerous to health as they enter the food chain through accumulation and magnification. Heavy metals could be present in soils, sediments or other substrates bounded together from where they could be picked up by plants through bio-intake and later animals through food chain contamination.

The study on the percolation of water through soils and for determining the soluble constituents removed in the drainage on the arable land of turf sandy loam and heavy clay loam reviled that the soil polluted as a result of heavy metals (Cd, Zn and Pb) decontaminated very slowly during natural processes. It takes about 500 years for Zn, 500 for Cd and 1100 for Pb [13] for the half-life of being removed or eliminated from the soil naturally. Therefore, the study is aimed to determine the heavy metal content in the soil of Railway stations along Ibadan – Lagos route, South West, Nigeria.

2. Methodology

2.1. Study Area

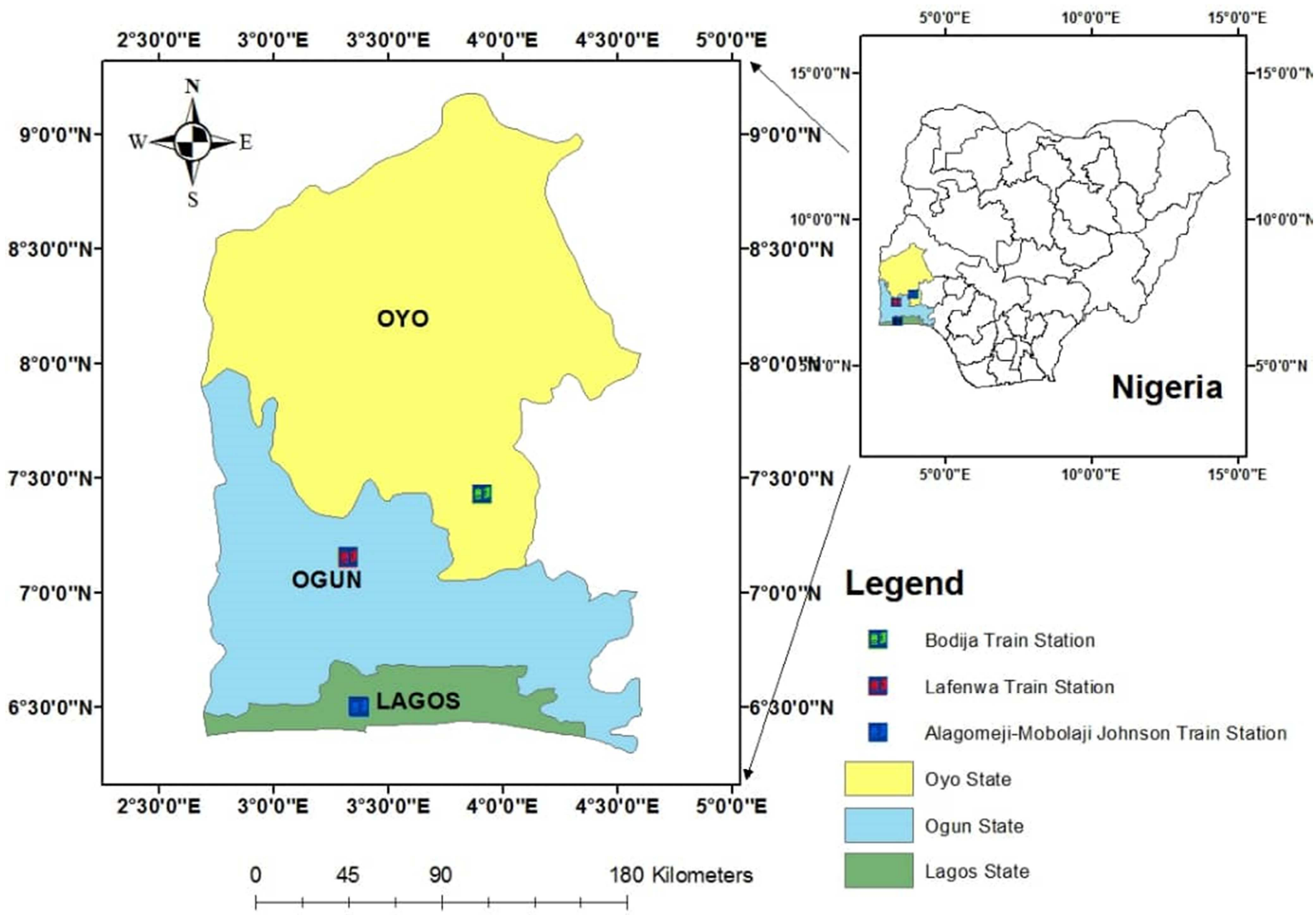

Figure 1. Map of Nigeria showing the study states; Oyo state, Ogun state and Lagos State (Source: Field Survey, 2022).

2.2. Sampling Method

Four (4) soil samples were collected from each three locations using a soil auger in each of the railway terminal as illustrated below:

Table 1. *Location of study area where soil samples were collected.*

S/N	TERMINAL	Type of gauge	Number of samples
2	Bodija in Ibadan	Narrow	Four
3	Lafenwa in Ogun State	Narrow	Four
5	Alagomeji (Yaba) in Lagos State	Narrow	Four

A total of Twelve (12) soil samples were collected at a depth of 0-15 cm with minimum of 20-30 feet apart. The soil samples were packed in clean polyethylene bags labeled and transported to the laboratory for analysis.

2.3. Heavy Metals Determination

A certain weight of each sample was weighed into a beaker and 10mls of an acid mixture of nitric/perchloric acid was added, this was covered with a cover slip and allowed to undergo heating or digestion on a hot plate at a regulated temperature for about twenty to thirty minutes under a fume cupboard, a colour change was observed from black to brown until a final colour of colourless was obtained. This was allowed to cool and made up to 10ml volume with distilled water. The content was read on a Buck Scientific Atomic Absorption Spectrophotometer model 210/211 VGP to determine the heavy metals (Pb, Cd, Zn, Cr, and Cu) content at a various wavelength.

3. Result and Discussion

At Bodija Railway station, the Pb concentration range from 15.4–121.6mg/kg with mean effect of 57.475 and at location B4 shown notable amount above the standard set by WHO and DPR while other locations are below the standards same with the value of Cd and Cr that below the standards in the four locations except for Cd at B3 with 0.5 above the standard set by the DPR. However, the concentration of Zn are above the DPR standard in the four locations while against the WHO standard, it is only above the standard at B4. Cu values are above DPR standard and below WHO standard with mean effect of 43.375. This clearly demonstrated the consistency with the previous studies by [12, 10]; there is obvious environmental conditions at the Bodija Railway station that can affect the rate of deposition and concentration of the heavy metals vis-à-vis poor landscape, topography and rainfall.

Table 2. *Results of heavy metals from soil sample.*

S/N	ID	Pb	Cd	Cr	Zn	Cu
		mg/kg				
1	A. Bodija	15.4	0.05	69.35	250.5	37.40
2	B. Bodija	61.75	0.00	54.70	262.0	43.10
3	C. Bodija	31.15	0.85	53.35	199.0	37.50
4	D. Bodija	121.6	0.00	49.40	329.5	55.50
5	A. Lafenwa	157.3	2.25	47.45	1200.0	244.50
6	B. Lafenwa	141.4	0.00	21.15	1157.5	214.00
7	C. Lafenwa	58.4	0.00	9.70	192.5	45.40
8	D. Lafenwa	417.50	3.85	37.05	3557.5	1337.50
9	A. Alagomeji	187.5	3.15	51.65	1300.5	264.30
10	A. Alagomeji	151.3	4.10	31.15	1257.5	224.00
11	A. Alagomeji	63.2	2.10	11.70	201.6	55.30
12	A. Alagomeji	457.40	3.75	38.15	3767.6	1537.60

Assessment According to Department of Petroleum Resources (DPR) of Nigeria (1991) [4] and World Health Organization.

Table 3. *Bodija Railway station in Ibadan, Oyo State.*

Sample (mg/kg)	Pb	Cd	Cr	Zn	Cu
B1	15.4	0.05	69.35	250.5	37.40
B2	61.75	0.00	54.70	262.0	43.10
B3	31.15	0.85	53.35	199.0	37.50
B4	121.6	0.00	49.40	329.5	55.50
Mean	57.475	0.225	56.7	260.25	43.375
Range	15.4–121.6	0.00-0.85	49.40-69.35	199.0-329.5	37.40-55.50
WHO STD	100	3	100	300	100
DPR STD	85	0.8	100	140	36

B mean Bodija. B1-B4 is the point at which samples were collected within the railway station.

Table 4. *Lafenwa railway station in Abeokuta, Ogun State.*

Sample (mg/kg)	Pb	Cd	Cr	Zn	Cu
L1	157.3	2.25	47.45	1200.0	244.50
L2	141.4	0.00	21.15	1157.5	214.00
L3	58.4	0.00	9.70	192.5	45.40
L4	417.50	3.85	37.05	3557.5	1337.50
Mean	193.65	1.525	28.8375	1526.875	460.35
Range	58.4-417.50	0.00-3.85	9.70-47.45	192.5-3557.5	45.40-1337.50
WHO STD	100	3	100	300	100
DPR STD	85	0.8	100	140	36

L mean Lafenwa. L1-L4 is the point at which samples were collected within the railway station.

The value of Pb at Lafenwa Railway station show significant concentration above the standards by WHO and DPR at L1, L2 and L4 with mean concentration 193.65. The Cd show concentration above WHO standard at L4 while just L1 and L2 location are above the DPR but in all the locations, all the values of Cr are below the standards. At L3, the concentration is of Zn is below WHO while others are notably above the Standards just like Cu that show the value below DPR at L3 and others show significant concentration above the standards set by the two regulation bodies. The result of concentrations of Pb, Cu and Zn are in consistent with findings reported by [1] based on the ranges with heavy pollution with Pb, Zn and Cu.

Table 5. *Alagomeji Railway station in Ikeja, Lagos State.*

Sample (mg/kg)	Pb	Cd	Cr	Zn	Cu
A1	187.5	3.15	51.65	1300.5	264.30
A2	151.3	4.10	31.15	1257.5	224.00
A3	63.2	2.10	11.70	201.6	55.30
A4	457.40	3.75	38.15	3767.6	1537.60
Mean	214.85	3.275	33.1625	1631.8	520.3
Range	63.2-457.40	2.10-4.10	11.70-51.65	201.6-3767.6	55.30-1537.60
WHO STD	100	3	100	300	100
DPR STD.	85	0.8	100	140	36

A mean Alagomeji. A1-A4 is the point at which samples were collected within the railway station.

The Railway station at Alagomeji shown heavy concentration of Pb except at A3 while Cd and Zn values were above the standards set by the WHO and DPR. The concentration of Cr are bellow standards but only Cu at A3 is below the standards. The results shown overall higher concentration of heavy metals in the in the soil at the Railway station as a result of railway transportation with indication of heavy pollution with Pb, Cd, Cr, Zn and Cu.

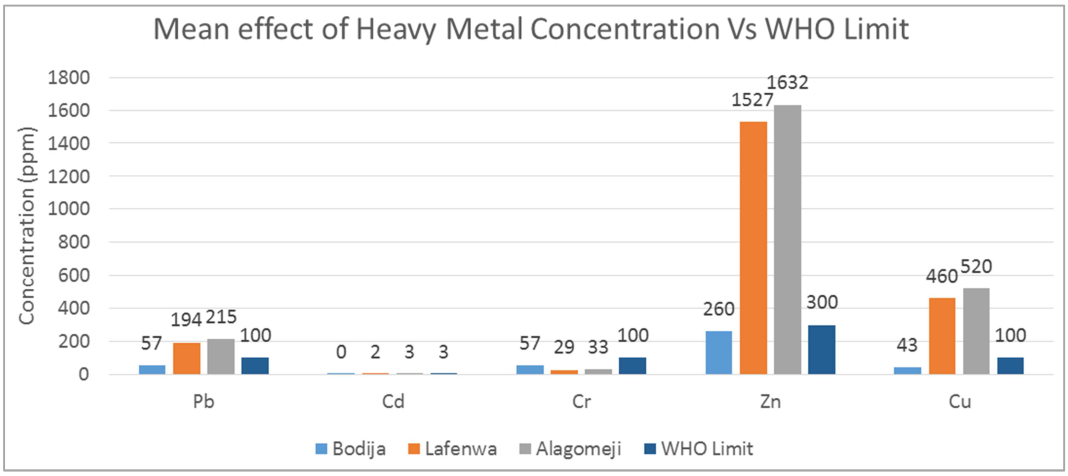

Figure 2. *Mean effect of heavy metal against WHO standard.*

The concentration of heavy metal in the sampled location is compared with the WHO allowable limit. It is observed that all heavy metals at Bodija are below WHO standard. At Lafenwa, only Pb and cu are above the standard while others are bellow. However, the Cr and Zn are below the WHO standard at Alagomeji Railway station.

The permissible limit of the Department of Petroleum Resources of Nigeria (DPR) is compared with observed heavy metal concentration at the Old railway station. It is crystal clear that at Bodija, Pb, Cd, Cr, are below the DPR standard however, Zn and Cu are above. The Railway station at the lafenwa and Alagomegi show heavy concentration of heavy metal pollution except Cr.

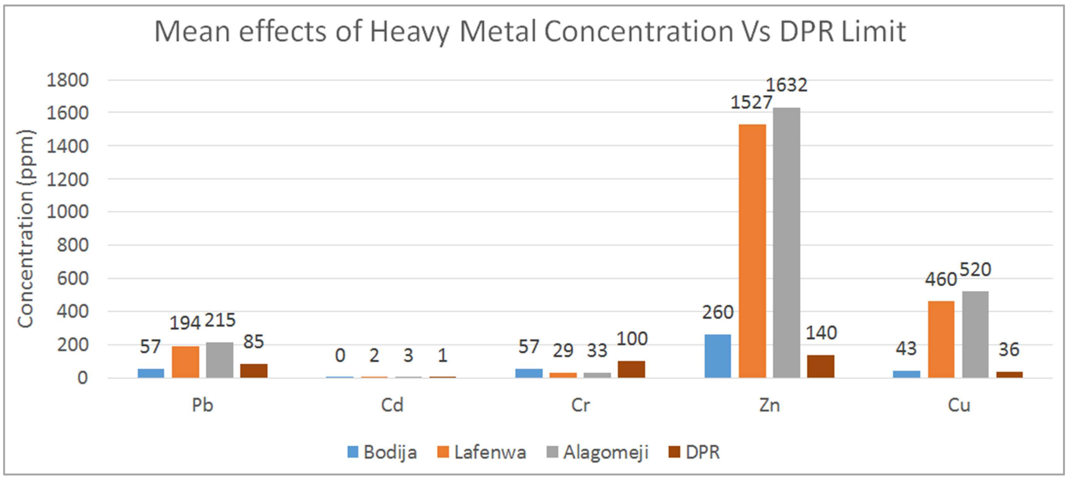

Figure 3. *Mean effect of heavy metal against DPR standard.*

Significant Difference Of Heavy Metals Between Sampled Locations.

Table 6. *Concentration of heavy metals between Bodija, Lafenwa and Alagomeji.*

Source of Variation	SS	df	MS	F	P-value	F crit.
Locations	479613.1	2	239806.6	2.295073	0.163018	4.45897
Heavy Metals	2634470	4	658617.5	6.303312	0.013587	3.837853
Error	835900.3	8	104487.5			
Total	3949983	14				

To examine if there is a significant difference in mean effect of heavy metals recorded in the locations (Bodija, Lafenwa and Alagomeji), the ANOVA test is carried out and shown in Table 6 above. The P-value (0.013587) of the heavy metals is less than the significance level (0.05), which indicate that the mean effect of heavy metals is not the same (i.e. the mean effect of Pb differ from the mean effect of others, the mean effect of Cd differ from the mean effect of others, and so on). Also, the P-value (0.163018) of the locations is more than the significance level (0.05), which indicate that the mean effect of heavy metals observed in Bodija, Lafenwa and Alagomeji do not have significant difference. The result indicates that although heavy metal concentration in the sampled soil differ by type but they have the same significant concentration in Bodija, Lafenwa and Alagomeji, this clearly demonstrated the consistency with the previous studies by [1].

3.1. Heavy Metal Contamination of Soil Using Geo-Accumulation Index

According to Sulaiman, Santuraki & Babayo [9], and the background value for maximum allowable concentration of heavy metals in Nigeria soil are 85 for Pb, 0.8 for Cd, 36 for Cu, and 140 for Zn. Kenechukwu, E. U. & Anthony, C. O. [5] proposed 90 for Cr. The Geo-Accumulation index (GI) is thus computed and compared with Muller classification scale for Geo-Accumulation index. To access the contamination level of the soil sampled from the different sites in the new and old railway, Geo-Accumulation index (GI) is used as a criterion. The GI can be computed by using:

$$GI = log_2\left[\frac{C_n}{1.5B_n}\right]$$

where: C_n is measured concentration of the measures metal and B_n is background value of metal.

Table 7. *Muller's classification for the geo-accumulation [7].*

Igeo value	class	Soil quality
<0	0	Unpolluted
0-1	1	From unpolluted to moderately polluted
1-2	2	Moderately polluted
2-3	3	From moderate polluted to strongly polluted
3-4	4	Strongly polluted
4-5	5	From strongly polluted to extremely polluted
>6	6	Extremely polluted

Table 8. *Result of Geo-accumulation assessment.*

Heavy metals/ location	Pb	Cd	Cr	Zn	Cu
Bodija	11.66929	-3.05889	11.73217	14.56807	10.02375
Lafenwa	13.42174	-0.29808	10.75676	17.12069	13.43155
Alagomeji	13.57161	0.804604	10.95837	17.21657	13.60816

The concentration of Pb ranges between 11.7 – 13.6, of Cd ranges between -3.1 – 0.8, of Cr ranges between 10.8 – 11.7, of Zn ranges between 14.6 – 17.2, and the concentration of Cu ranges between 10.0 – 13.6. The observed Geo-Accumulation index of all the considered heavy metals, except for Cd, when compared with Muller's classification scale shows that the soil in old railway (Bodija, Lafenwa and Alagomeji) is very extremely contaminated in close agreement with the findings of [13] but in agreement with the conclusion of [1].

3.2. Contamination Factor and Pollution Load Index of Heavy Metals

The contamination factor and Pollution Load Index are potent tools in evaluating heavy metal pollution. CF and PLI give proper assessment of the degree of contamination of each site by individual metals. The PLI represents the number of times by which the metal content in the soil exceeds the average natural background concentration, and gives a summative indication of the overall level of heavy metal toxicity in a particular site. The Pollution Load Index (PLI) is obtained as contamination Factors (CFs) of all the analysed heavy metals. This CF is the quotient obtained by dividing the concentration of each metal in the sample by the background concentration of the metal. The PLI of each site is calculated by obtaining the n-root from the n-CFs that is obtained for all the metals in that particular site. Pollution load index (PLI) was developed by [11, 1] which is as follows:

$$CF = \frac{C_{metal}}{C_{background\ value}}$$

The Pollution Load Index is computed below,

$$PLI = (CF_1 \times CF_2 \times \ldots \times CF_n)^{1/15}$$

Table 9. *The significance of interval of contamination factor/pollution index [11].*

Class	Range	Description
1	<1	Very slightly contamination
2	0.10-0.25	slightly contamination
3	0.26-0.5	Moderate contamination
4	0.51-0.75	Severe contamination
5.	0.76-1.00	Very severe contamination
6.	1.10-2.0	Slight pollution
7.	2.1-4.0	Moderate pollution
8	4.1-9.0	Severe pollution
9.	9.10-16.0	Very severe pollution
10	>16.0	Excessive pollution

Table 10. *Result of contamination factor (CF) and pollution load index (PLI).*

	CF Pb	CF Cd	CF Cr	CF Zn	CF Cu	PLI Index	
Bodija	0.6762	0.2813	0.63	1.8590	1.2049	0.7687	Unpolluted
Lafenwa	2.2783	1.9063	0.3204	10.9063	12.7875	2.8681	Polluted
Alagomeji	2.5276	4.0938	0.3685	11.6557	14.4528	3.6437	Polluted

The contamination factor of each heavy metal in the three location is shown in the table above. In Bodija, the CF lies between 0.2 and 1.9, which shows moderate contamination factor. Also, in Lafenwa, the CF lies between 0.32 and 2.28 for Pb, Cd, and Cr, but the CF is more than 3 for Zn and Cu. Finally, in Alagomeji, CF of Cr and Pb lies between 0.36 and 2.53, CF of Cd, Zn and Cu on the other hand are more than. This result shows moderate concentration of heavy metals in Bodija, indicating that the soil is modeterately contaminated. On the other hand, there is high concentration of heavy metals in Lafenwa and Alagomeji, indicating that the soil is highly contaminated.

The pollution load index value in Bodija < 1, which indicate that the soil in this sample point is not polluted and this could be as a result of occurrence of erosion during the raining season that wash away the top soil aided by the topography of the area. On the other hand, the pollution load index value of Lafenwa and Alagomeji > 1, which shows that the study locations are highly polluted, still in support of research work from [1] who concluded that the CF and PLI of Mina Railway station range from moderate to highly contaminated/polluted.

4. Conclusion

The levels of Pb, Cu, Cr, Zn and Cd in soil samples collected from different Railway Stations in South West, Nigeria (Lafenwa, Bodija and Alagomeji) were assessed. The relationship between the heavy metals at same station and among other station show that railway contributed to the heavy metals content within the vicinity of the railway station because the heavy metal in each station increase at same rate. The Pb, Cu, Zn and Cd are the major heavy metal generating from the railway stations as the level of the heavy metals above the permissible limits set by both WHO and DPR**.** The Geo-Accumulation shown extremely contaminated of the sample soil with heavy metal from railway and the contamination factor (CF) show moderate pollution while the Pollution Load Index (PLI) indicated that, the study area is highly polluted with Pb, Cu, Cr, Zn and Cd. With ineffective railway transportation in Nigeria recently but the active years of railway transportation and the slow rate of natural decomposition of heavy metals in the soil still indicated the present of heavy metal above the standards. This calls for serious concern as progressive and continuous deterioration of soil quality stands to induce and increase negative impact on health and environmental.

Conflict of Interest Statement

The authors declare that they have no competing interests.

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