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EVALUATION OF HEAVY METAL POLLUTION INDEX IN SOIL AROUND METAL WORKSHOPS IN POTISKUM, YOBE STATE, NIGERIA

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ABSTRACT
This study investigates the impact of metal workshop on the environment due to metal contamination. Soil samples from five metal workshops in Potiskum town, Yobe State-Nigeria were collected at the main workshops point, 30 m, 60 m and 90 m away from the workshop and a control sample at 250 m from the workshop point. Each sample was analyzed for ten heavy metals (Pb, Zn, Cr, Cd, Co, Mn, Ni, Fe, Se and Cu) using Atomic Absorption Spectrophotometer (AAS). The degree of contamination of heavy metals in the soil samples from the workshops ranged between 5.1 – 218.5, with Cu, Zn and Pb recording the highest degree of contamination values of 218.5, 20.7 and 13.4 respectively. While the lowest, 5.1 and 6.1 degrees of the contamination were recorded by Fe and Co respectively. Concentrations of the heavy metals follow order Cu>Zn>Pb>Mn>Cd>Ni>Se>Cr>Co>Fe. The soil samples analyzed are considered polluted with heavy metals with pollution load index far greater than one (PLI>>1) with pollution severity decreasing in the order GIM > GAS > GOA > NWC > GDH. Pearson correlation matrix between heavy metals levels in the soil samples with respect to distances from the workshops revealed gradual dispersion of the heavy metals to the nearest surroundings.
Keywords: Contamination, Heavy metal, Pollution index, Soil, Metal workshop

INTRODUCTION

Soil as an important part of the earth, plays a key role in maintaining the proper functioning and sustaining the earth's ecosystems (Young and Crawford, 2004). It is an essential sink for nutrients and pollutants (Luo *et al.,* 2007). Globally, more than 10 million soil sites are polluted, and more than 50% of these soil sites are contaminated with heavy metals (He *et al.,* 2015). Soil pollution by heavy metals is a global problem that has recently received a great deal of attention (Jiang *et al.,* 2017 and Peng *et al.,* 2017).

Anthropogenic activities are rampant phenomena of polluting the environment in developing countries, Nigeria inclusive, where there are no strict regulations to guide the activities, resulting in various health risks. Large quantities of pollutants are continuously being introduced into ecosystems as a result of urbanization and industrial processes (Begum *et al.,* 2009). The pollution of the environment has been found to result from human's determination to match desire with production through the establishment of industries with the potentials to pollute the environment (Jimoh *et al.,* 2020).

The release of heavy metals into environment by industrial activities such as workshops is one of the most significant environmental problems caused by human anthropogenic activities (Abah *et al.,* 2014).

Environmental pollution from workshops has become a serious issue in the recent past due to their locations and types of activities carried out in the workshops. In many cities in the developing countries in the world, especially in Africa, Nigeria in particular, many industrial workshops such as welding workshop, mechanical and electrical workshops are located by the roadsides within residential areas where their customers could easily have access to them. The wastes produced in these workshops are potential environmental pollutants that need to be given a serious attention. The phenomena contribute significantly to the pollution of the environment by heavy metals. This makes the study of workshops soil in Potiskum important for assessing the level of heavy metals in the workshops. However, the quantitative data on heavy metal concentrations, their contamination levels, and their pollution sources among others in Potiskim town, Yobe State have not been systematically gathered and inter-compared.

Therefore, this study focuses on assessing the concentrations of some heavy metals in the soil samples of these workshops to determine the contribution of the workshops to heavy metal pollution of the environment.

MATERIALS AND METHODS

Study Area

Potiskum town is the headquarter of Potiskum local Government Area of Yobe State, Nigeria. It is situated on the A3 highway (Maiduguri-Kano Road) at 11°43'N and 11°04'E. The town has a total population of 244,050 people with a population density of about 436.6 people per km^2 (NPC, 2006). The Local Government covers a land area of 559 km^2 (Daura *et al.,* 2006) and is bounded by Nangere LGA to the north, Fune LGA to the east and south and Fika LGA to the west. The town has an annual rainfall range of 600-800 mm that falls within four to five months and the onset of rain varies from May to June and terminates around September to October (NIMET, 2014).

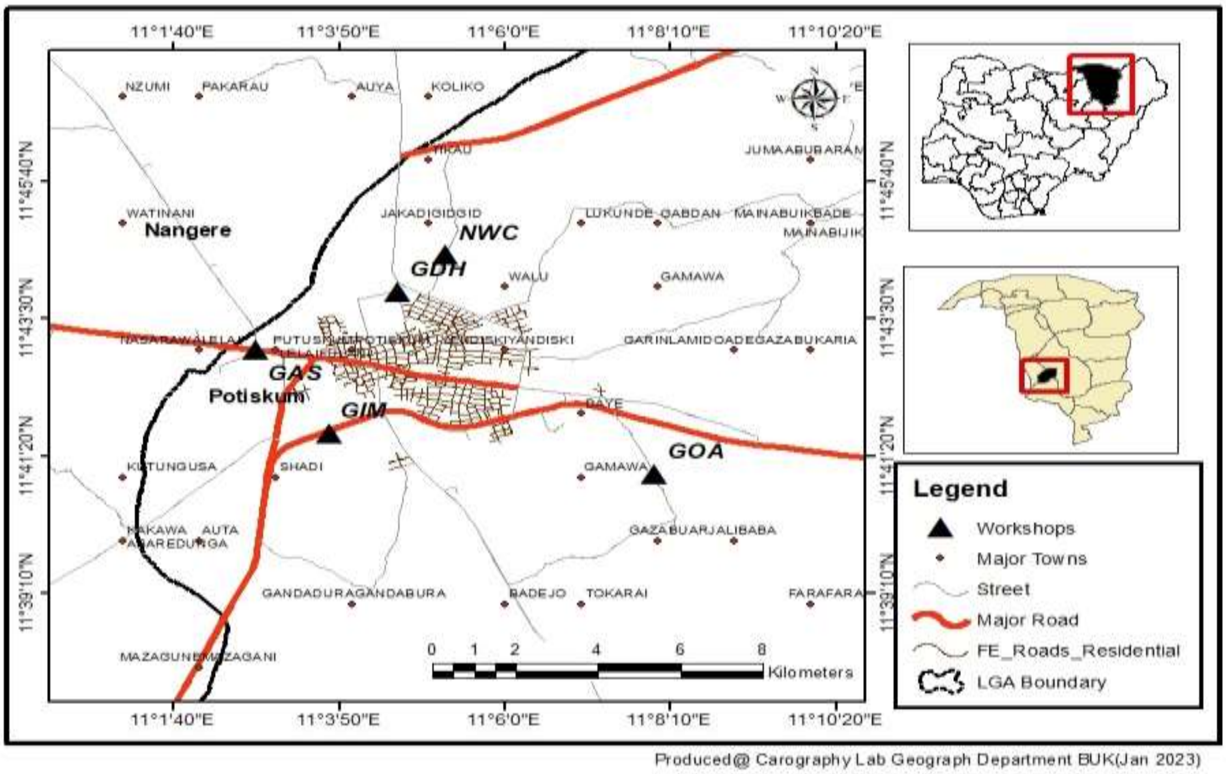

Figure 1: Map of Potiskum Showing the Workshops Sampling Site

Sample Collection

Composite soil samples were collected from five different workshops namely; Garejin Oga Abdul (GOA), Nakowa Welding Construction (NWC), Garejin Da'awa Opposite Higher Islam Centre (GDH), Garejin Adamu Salisu (GAS) and Garejin Alhaji Iliya Maina (GIM) in Potiskum town of Yobe State. At each workshop, five (5) soil samples (that is from the workshops point, 30 m, 60 m and 90 m and a control sample 250 m away from the workshop point) were collected. The samples were collected at 6–7 inches depths using plastic cup into polythene bags and transported to the laboratory for the analysis.

Sample Preparation and Analysis

The soil samples were ground, homogenized, sieved with 0.25 mm mesh sieve and dried for 72 hours in drying cabinets. To digest the sample, 5 g each of the finely divided soil samples were weighed and digested with tecator digestion system at 250°C in 15 cm^3 of 2:1 mixture of HNO_3 and HCl for about 40 minutes. After cooling, 20 cm^3 of distilled water were added unto the digested samples and filtered using Whatman no. 1 filter paper into sample bottles and filled to 100 cm^3 marks with distilled water. Blank solution was also prepared following the same procedure undergone by the sample solutions. Each sample was analyzed for the following heavy metals (Pb, Zn, Cr, Cd, Co, Mn, Ni, Fe, Se and Cu) using Atomic Absorption Spectrophotometer (AAS).

Quantification of Anthropogenic Metal Concentration (QoC)

The concentration of the heavy metals that is due to the anthropogenic activities in the workshop is calculated in accordance with Equation 1 (Victor *et al.,* 2006; Iwegbue *et al.,* 2013**).**

$$Anthropogenic\ metal = \frac{X - Xc}{X}\ x\ 100 \quad \text{Equ. 1}$$

Where X = average concentration of the metal in the soil under investigation and Xc = average concentration of the metal in the control samples.

Contamination Factor (CF)

Contamination factor quantifies the extent of contamination by each metal relative to measured background/control values. (Begum *et al.,* 2009; Ladigbolu and Balogun, 2011).

$$Contamination\ Factor = \frac{Metal\ Conc.in\ Sample}{Metal\ Conc.in\ Control} \text{ -Equ. 2}$$

Table 1: Contamination Factor Indicators

S/N	Contamination Factors Range	Indicator
1.	< 1	Low contamination
2.	1 – 3	Moderate contamination
3.	3 – 6	Considerable contamination
4.	> 6	Very High contamination

(Anegbe *et al.,* 2018)

Degree of Contamination (DC)

Degree of contamination is the sum of the contamination factors of all the elements examined. DC is determined using equ. 3.

$$DC = \sum CF \quad \text{------------ Equ. 3}$$

Table 2: Degree of Contamination Indicators

S/N	Degree of Contamination Range	Indicator
5.	< 8	Low contamination
6.	8 – 16	Moderate contamination
7.	16 – 32	Considerable contamination
8.	> 32	High contamination

(Sam *et al.,* 2015)

Pollution Load Index

The severity of pollution of the soils, pollution load index (PLI) gives a summative indication of the overall level of heavy metal toxicity in a particular workshop site. PLI is determine using equation 4.

$$PLI = \sqrt[N]{CF_1 \times CF_2 \times CF_3 \times ....\times CF_n} \quad \text{------------ Equ. 4}$$

Where, PLI = pollution load index, CF is the contamination factor of each metal, n is the number of metals investigated in each sample. Pollution load index assess the soil site by means of comparison (Ibrahim *et al.,* 2019).

Table 3: Pollution Load Index Indicators

S/N	Pollution Load Index Range	Indicator
1.	< 1	Denotes perfection
2.	PLI = 1	Denotes only baseline levels of pollutants are present
3.	PLI > 1	Denotes deterioration

Statistical Analysis

The data obtained were statistically analyzed using SPSS software package (version 20). Pearson correlation coefficient were used to statistically evaluate the relationship between heavy metals concentration in soil samples from the workshop and distance of sampling from the workshops in a two-tailed test (r < 0.01 and 0.05).

RESULTS AND DISCUSSION

The results in Tables 4 – 8 show the heavy metals concentrations of the workshops point marked as workshop-P and the surrounding soil samples taken at 30, 60, 90 and 250 m away marked as workshop-30, workshop-60, workshop-90 and workshop-C respectively. As shown in the results, the concentration of the heavy metals analyzed decreases with increase in distance of sampling site from the workshops point. While most of the heavy metals exhibit perfect straight decreasing trend with increase in distance from the workshop points, very few were seen to have irregular decreasing patterns. However, concentrations of all the heavy metals analyzed in workshop points were observed to decrease in one or the other as the sampling distance is increasing from the workshop point. A study on soil contamination status in garage and auto mechanical workshops by Demie (2015) also reported an observed variation in heavy metals concentration in soils collected at increasing depth. Decrease in the heavy metal concentrations from the workshop points to the nearest surroundings with increased sampling distance may be attributed to dispersions of the heavy metals from the workshops point to the nearest surroundings. This claim could be justified by the results in the Tables as the soil samples collected few metres away from the workshops are seen to have higher heavy metals concentrations compared to the soil samples collected from far distances away from the workshops point. Thus, implying that heavy metals contaminations from the workshops are gradually dispersing to the nearest environment, as such invokes a very serious environmental concern. Measures should be taken to monitor and prevent further deterioration of the surrounding environment.

Dispersal of metals from pollution source into the ecosystems in the vicinity of pollution sites occurs primarily through dispersal of metal-bearing particles by erosion (wind/rainfall) or infiltration of metal-bearing leachates into the soil during rainfall/runoff processes and subsequent migration into nearby soils and groundwater (Yun *et al.,* 2020). Spatial transport and dispersion of metals in contaminated soils from nearby sources is determined by wind-driven erosion. Moreover, the closer the location of the site to the contamination source, the higher the concentration of the contaminants, and vice versa (Tembo *et al.,* 2006; Meza-Figueroa *et al.,* 2009; Kim *et al.,* 2014; Li *et al.,* 2017).

Table 4: Heavy Metal Concentrations of GAS Sampling Site and Environs (mg/kg)

Heavy Metal	GAS-P	GAS-30	GAS-60	GAS-90	GAS-C
Cd	0.340	0.260	0.320	0.300	0.200
Co	2.500	2.060	1.960	1.840	1.760
Cr	57.640	38.060	49.720	47.680	29.140
Cu	7.160	1.260	3.320	2.200	0.040
Fe	320.200	309.000	316.600	314.400	301.400
Mn	64.580	52.120	36.760	38.760	49.120
Ni	5.280	3.700	3.920	3.620	2.720
Pb	9.740	3.760	7.600	4.600	4.180
Se	580.400	563.200	501.800	526.000	305.600
Zn	23.340	10.700	13.880	10.040	5.180

Table 5: Heavy Metal Concentrations of GDH Sampling Site and Environs (mg/kg)

Heavy Metals	GDH-P	GDH-30	GDH-60	GDH-90	GDH-C
Cd	0.500	0.480	0.420	0.820	0.360
Co	4.180	4.140	2.600	8.540	3.480
Cr	113.760	95.860	81.520	138.200	82.560
Cu	16.160	44.020	14.360	10.140	15.740
Fe	330.400	327.600	324.800	342.800	325.200
Mn	55.480	68.280	47.420	107.440	51.020
Ni	11.800	9.600	6.600	16.660	7.300
Pb	33.840	26.420	14.680	14.500	16.560
Se	910.000	796.200	629.400	1551.200	642.000
Zn	31.460	61.080	38.140	27.540	34.380

Table 6: Heavy Metal Concentrations of GIM Sampling Site and Environs (mg/kg)

Heavy Metals	GIM-P	GIM-30	GIM-60	GIM-90	GIM-C
Cd	1.260	0.480	0.180	0.200	0.320
Co	3.360	3.180	1.120	1.280	2.420
Cr	86.900	86.960	24.160	28.380	74.400
Cu	52.500	21.880	0.300	0.080	2.580
Fe	326.400	325.200	292.800	297.600	322.000
Mn	130.220	72.560	24.980	23.300	29.900
Ni	10.600	9.460	2.280	2.480	4.840
Pb	30.140	227.400	2.600	1.460	5.660
Se	601.200	551.800	44.260	378.200	381.800
Zn	56.520	51.200	4.800	3.380	7.120

Table 7: Heavy Metal Concentrations of GOA Sampling Site and Environs (mg/kg)

Heavy Metals	GOA-P	GOA-30	GOA-60	GOA-90	GOA-C
Cd	0.440	0.360	0.380	0.240	0.300
Co	3.060	2.760	6.120	2.280	3.020
Cr	103.640	59.140	103.940	42.340	70.160
Cu	19.580	23.260	5.240	1.800	2.000
Fe	328.000	319.800	327.800	310.000	322.200
Mn	48.740	54.920	126.460	46.540	44.040
Ni	8.180	5.820	7.460	3.680	5.700
Pb	12.180	12.300	8.900	2.820	22.060
Se	774.400	445.600	611.800	250.400	577.800
Zn	32.100	47.260	7.760	5.060	5.360

Table 8: Heavy Metal Concentrations of NWC Sampling Site and Environs (mg/kg)

Heavy Metals	NWC-P	NWC-30	NWC-60	NWC-90	NWC-C
Cd	0.300	0.280	0.300	2.200	0.240
Co	2.460	2.700	2.880	2.440	2.360
Cr	56.500	48.500	61.640	36.880	55.320
Cu	26.380	6.120	5.000	2.940	3.160
Fe	317.400	313.600	317.200	305.800	317.000
Mn	58.320	73.520	92.760	66.220	29.660
Ni	4.980	3.300	3.820	2.820	3.620
Pb	13.400	4.460	6.540	2.460	4.320
Se	496.400	360.000	399.400	301.200	496.000
Zn	20.520	6.220	11.160	4.060	15.320

Pearson Correlation Analysis

The results revealed a negative correlation between the heavy metals concentration and distance of sampling from the workshops at 0.05 and 0.01 significant level (2-tailed). The strength of the relationship varies across the heavy metals and the workshop sampling sites (Table 9). A negative correlation indicates an inverse linear relationship between the variables (i.e., as the value of one variable goes up, the value of the other tends to go down) with relationship strength ranging between −1 and +1. The stronger the relationship, the closer the correlation coefficient comes to ±1 (Mukaka, 2012).

The Pearson correlation (r) values revealed that the strongest negative and statistically significant relationship between heavy metals and sampling distance in soil samples of GAS workshop exist between Se and sampling distance with Pearson correlation value, $r = -0.98$, $P<0.01$ while the weakest relation was between Mn and sampling distance ($r = -0.278$, $P>0.05$). Mn and sampling distance relationship ($r = -0.595$, $P>0.05$) appears to be the strongest relationship in soil samples of GDH workshop as well as Co and sampling distance revealed to have the weakest to none relationship ($r = -0.06$, $P > 0.05$).

The pattern of relationship obtained in soil samples of GIM workshop shows that Zn and sampling distance relation (r = -0.637, P > 0.05) was the strongest relationship while Cr and sampling distance relationship (r = -0.054, P>0.05) was the weakest. Similarly, the Pearson correlation matrix of GOA workshop soil samples revealed that the relations between Cu and Co with sampling distances were the strongest and weakest relationships observed with correlation values of r = -0.696, P>0.05 and r = -0.122, P>0.05 respectively. Lastly, the strongest negative relationship in soil samples of NWC workshop was found to exist between Mn and sampling distance (r = -0.711, P>0.05) while the weakest between Cd and sampling distance (r = 0.003, P>0.05).

By implication, negative correlation values obtained between the heavy metals and the sampling distances indicated reduction in the heavy metal concentration from the workshop points to the nearest surroundings which may be linked to dispersions of the heavy metals to the nearest surroundings. This had statistically justified that the workshops are gradually deteriorating the workshop soils as well as that of the nearest surroundings. The workshops and its accompanying activities are possible sources of these metals as reported by similar studies (Ololade, 2014; Demie, 2015)

Table 9: Pearson Correlation Matrix between Heavy Metals Concentrations and Sampling Distance

		Distances from the Workshop Sampling Sites				
		GAS	GDH	GIM	GOA	NWC
Distances	Pearson Correlation	1	1	1	1	1
	Sig. (2-tailed)					
	N	5	5	5	5	5
Cd	Pearson –Correlation	-.836	-.265	-.495	-.592	-.003
	Sig. (2-tailed)	.078	.667	.396	.293	.996
	N	5	5	5	5	5
Co	Pearson Correlation	-.754	-.060	-.231	-.122	-.485
	Sig. (2-tailed)	.141	.923	.708	.846	.408
	N	5	5	5	5	5
Cr	Pearson Correlation	-.791	-.341	-.054	-.304	.011
	Sig. (2-tailed)	.111	.575	.932	.619	.986
	N	5	5	5	5	5
Cu	Pearson Correlation	-.713	-.303	-.603	-.696	-.569
	Sig. (2-tailed)	.177	.621	.282	.192	.317
	N	5	5	5	5	5
Fe	Pearson Correlation	-.833	-.173	.016	-.194	.055
	Sig. (2-tailed)	.080	.781	.979	.754	.930
	N	5	5	5	5	5
Mn	Pearson Correlation	-.278	-.108	-.607	-.230	-.711
	Sig. (2-tailed)	.651	.863	.278	.710	.178
	N	5	5	5	5	5
Ni	Pearson Correlation	-.840	-.290	-.458	-.401	-.342
	Sig. (2-tailed)	.075	.635	.438	.504	.574
	N	5	5	5	5	5
Pb	Pearson Correlation	-.536	-.595	-.378	.610	-.514
	Sig. (2-tailed)	.352	.290	.530	.275	.376
	N	5	5	5	5	5
Se	Pearson Correlation	-.980**	-.187	-.230	-.153	.279
	Sig. (2-tailed)	.003	.763	.709	.806	.650
	N	5	5	5	5	5
Zn	Pearson Correlation	-.788	-.266	-.637	-.628	.048
	Sig. (2-tailed)	.113	.666	.247	.257	.939
	N	5	5	5	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

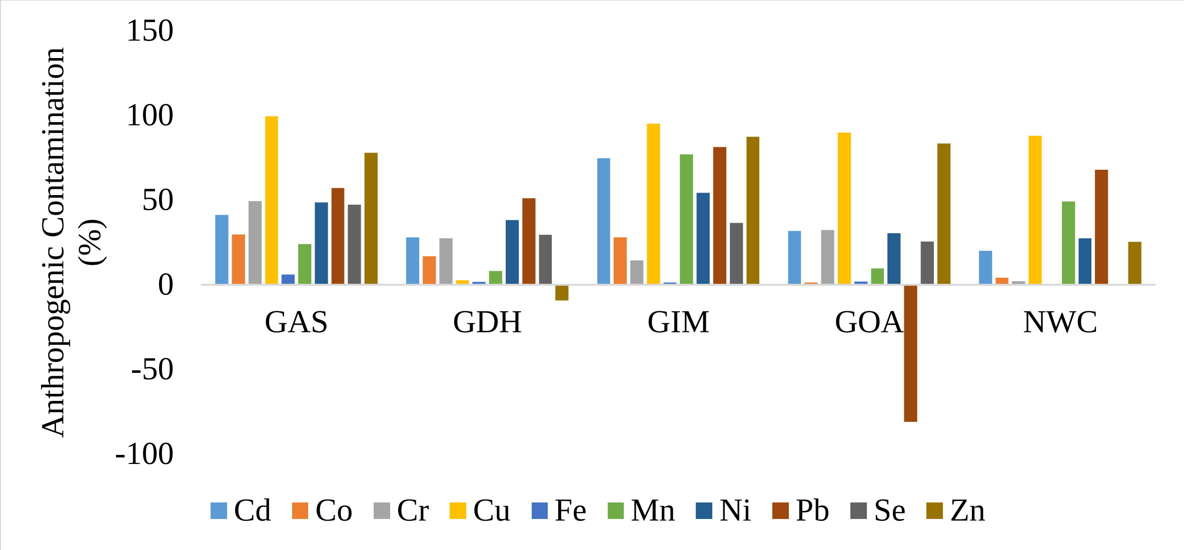

Figure 2: Quantification of Anthropogenic Contamination (QoC) in the Workshops

Figure 2 describe the quantification of anthropogenic contamination (the fraction of the heavy metal concentrations caused by anthropogenic activities) of the workshops. The results revealed that the greatest fraction of heavy metals concentration from anthropogenic origin in GAS workshop is that of copper which has 99.4% of its concentration from anthropogenic activities. While heavy metal with least fraction of concentration from anthropogenic origin is iron (5.9%). The QoC of the heavy metals proceeds in an order Cu>Zn>Pb>Cr>Ni>Se>Cd>Co>Mn >Fe. The result is in conformity with a similar study by Ibrahim *et al.* (2019) which reported the order of quantification of soil contamination (QoC) as follows: Cu (86.73 %) > Zn (63.23 %) > Cr (60.24 %) >Pb (49.24 %) > Ni (44.13 %) and Zn (62.99 %) > Cd (58.92 %) > Cr (51.79 %) > Ni (47.97 %) > Cu (45.26) >Pb (45.21 %) at Dugja and Kenken wards automobile mechanic workshop. High fraction of copper from anthropogenic origin in the soil sample of GAS workshops may be attributed to heavily presence of automobile wastes containing electrical and electronic parts and scraps, such as copper wires, pipes, electrodes and alloys from corroding vehicle scraps in the workshop.

The results also revealed that lead (Pb) appears to be the heavy metal with highest fraction of concentration from anthropogenic inputs in soil sample of GDH workshop followed by nickel (Ni) having 51.1 and 38.1% QoC respectively. While iron (Fe) was found to be metal with least fraction (1.6%) as well as zinc (Zn) having a negative QoC value -9.3% further implying that zinc concentration obtained in control soil sample is even higher than the one detected in the workshop soil sample. High level of Zinc in the control soil sample may be resulted from other activities that can contaminate the environment with Zinc such as smelting activities, municipal waste disposal, sludge and fertilizer among others. The result corresponds with another similar study by Pam *et al.* (2013) that reported Zn with least QoC value in soil sample of GBK workshop cluster of Benue State.

The results in the figure 2 also shows that high fractions of most of the heavy metals analyzed in GIM soil samples were of anthropogenic origin as seven out of ten (7/10) of the heavy metals analyzed have QoC values above 35%. The anthropogenic input of heavy metals with high QoC due to activities of the workshop proceeds in an order of Cu (95.1%) > Zn (87.4%) > Pb (81.2%) > Mn (77%) > Cd (74.6%) > Ni (54.3%) > and Se (36.5%). By implication it could be said that GIM workshop have contaminated the environment with the heavy metals and thus calls for great concern. Similarly, high values of QoC of most of the heavy metals in GIM workshop could be due to metal build-up in the workshop soil, since it is the oldest among the workshops investigated. The results are in concord with a study by Orosun *et al.* (2020) who reported greater fractions of Zn, Mn, Mg, Cd, Cr, Cu, Ag, Fe and Pb in the soil samples analyzed. Orosun *et al.* (2020) further concluded that that the automobile spare part and recycling market in Ilorin, Nigeria is highly polluted and the pollution is more of anthropogenic than pedogenic and lithogenic.

Also from the results, the metal with highest concentration of anthropogenic origin in GOA workshop soil samples is Cu (89.8%) and immediately followed by Zn (83.3%) while the lowest is Fe (1.8%).

The results also reveals that only two out of the ten heavy metals (Cu and Zn) have QoC above 35% while the remaining Pb have negative QoC of -81.1% owing to lead contamination of the control sample from other sources. This could be an indication that the anthropogenic sources of the metals in GOA workshop soil sample is low when compared with the other workshops and may be due to less activities being carried out in the workshop compared to the other ones.

Lastly the result in the figure 2 revealed that the fractions of the heavy metals concentrations resulting from anthropogenic activities of the NWC workshop ranges between 0.1 – 88%. While Cu was found to be the heavy metal with highest fraction of its concentrations from anthropogenic origin, Se and Fe were found to be the lowest each. High fractions of copper from anthropogenic origin in the soil samples from workshops were reported by various studies (Pam *et al.,* 2013; Ibrahim *et al.,* 2019; Orosun *et al.,* 2020).

Contamination Factor Assessment

Table 10 shows the contamination factors (CF) of the heavy metals in the workshops soil samples. The results revealed that Cu had the highest contamination factor of 179 in GAS workshop among all the heavy metals analyzed while Fe had the least value of 1.1. In general, the trend of the heavy metals contamination factor of GAS workshop is Cu>Zn>Pb>Cr>Ni & Se>Cd>Co>Mn>Fe. Thus, GAS workshop can be said to be very highly contaminated with Cu, considerably contaminated with Zn and moderately contaminated with the other heavy metals analyzed. The results is in line with that of Pam *et al.* (2013) who reported that the contamination factor of soils around auto mechanic workshop for Pb and Cu ranges from considerable contamination to very high contamination, while Zn, Mn and Cd had minimal to moderate contamination.

The result in Table 10 also revealed that the heavy metal contamination status of GDH workshop ranges between low to moderate contamination. While Zn have low contamination status, all the other heavy metals analyzed have moderately contaminated the soil. Pb had the highest contamination factor (2.0) in the workshop followed by Ni (1.6) as well as Zn with the lowest contamination factor (0.9). High contamination of the workshop by Pb might be due to presence of automobile emissions, and expired motor batteries inappropriately dumped in the workshops. Another study by Jimoh *et al.,* (2020) on application of pollution load indices, enrichment factors, contamination factor and health risk assessment of heavy metals pollution of soils of welding workshops at old Panteka market, Kaduna Nigeria also observed Pb with the highest contamination factor and the least in Cr.

Based on the result in Table 10, GIM workshop is heavily contaminated with heavy metals ranging from very high to moderate contamination. Cu and Zn have very high contamination status on the soil sample having the highest contamination factors of 20.3 and 7.9 respectively. Pb, Mn and Cd have moderately contaminated the soil sample of the workshop with a contamination factor of 5.3, 4.4 and 3.9 respectively. Lastly, the remaining heavy metals analyzed have a moderate contamination status in the soil sample of the workshop in an order; Ni (2.2) > Se (1.6) > Co (1.4) > Cr (1.2) and then Fe (1.0). These high contamination factor values (mostly above 1.5) of the heavy metals in the soil sample of GIM could be due to the facts that the workshop is in existence for about 20 years, more than any other workshop investigated, thus have high heavy metals accumulation tendency over long period of operation in the workshop. The results is in conformity with a similar study by Ololade (2014) that reported very high contamination factors ranging from 1.38 to 67.50 for all the heavy metals analyzed in different soil layers of Auto-Mechanic Workshops.

Similarly, the results shows that heavy metal contamination factors of GOA workshop ranges within 0.6 to 9.8. The highest contamination factor was recorded by Cu while Pb records the lowest. The soil sample of GOA workshop was found to be very highly contaminated with Cu, slightly contaminated with Pb and moderately contaminated with the remaining heavy metals analyzed with decreasing order of Zn > Cd & Cr > Ni > Se > Mn > Co & Fe. High values of the contamination factors (>1) in all the metals may be due to influence of mechanic activities such as indiscriminate disposal of metal containing compounds such as used engine oil, vehicle spare parts, welding activities etc. A study by Ibrahim *et al.* (2019) reported similar result. Their findings observed that the order of anthropogenic source metals indicated in the study is Cu> Cr > Zn > Cd > Ni and Zn > Cd > Cr > Ni > Cu >Pb at Dugja and Kenken ward mechanic workshops of Borno State.

Finally, the results in Table 10 shows that Cu have the highest contamination factor (8.3) over all the metal analyzed in soil sample of NWC workshop. Co, Cr, Fe, and Se are heavy metals with the least contamination factor value of 1.0 each. In between, are Pb, Mn, Ni, Cd and Zn with contamination factors of 3.1, 2.0, 1.4, 1.3 and 1.3 respectively. The result also shows that the heavy metals contamination status of the workshops ranged between Moderate to Very high contamination. The soil may be classified as very highly contaminated with Cu, considerably contaminated with Pb, and moderately contaminated with all the other heavy metals analyzed in the soil sample of the workshop. The results correspond with a similar study by Anegbe *et al.* (2018) which classify the soil samples as moderately contaminated with respect to Fe, Cu, Zn, Pb, and very highly contaminated with respect to Cd in site A and site C Soils sample around Some Selected Auto Repair Workshops in Oghara, Delta State, Nigeria.

Table 10: Heavy Metal Contamination Factors of the Workshops

Heavy Metal	GAS	GDH	GIM	GOA	NWC
Cd	1.7	1.4	3.9	1.5	1.3
Co	1.4	1.2	1.4	1.0	1.0
Cr	2.0	1.4	1.2	1.5	1.0
Cu	179.0	1.0	20.3	9.8	8.3
Fe	1.1	1.0	1.0	1.0	1.0
Mn	1.3	1.1	4.4	1.1	2.0
Ni	1.9	1.6	2.2	1.4	1.4
Pb	2.3	2.0	5.3	0.6	3.1
Se	1.9	1.4	1.6	1.3	1.0
Zn	4.5	0.9	7.9	6.0	1.3

Degree of Contamination Assessment

Table 11 shows the degree of contamination (DC) of heavy metal on the study area and pollution load index (extent of soil pollution) of each workshop. The degree of contamination of the heavy metals on all the soil samples of the workshops ranged between 5.1 – 218.5. The highest degrees of contamination of the heavy metals on the soil sample of the workshops were recorded by Cu, Zn and Pb having degree of contamination value of 218.5, 20.7 and 13.4 respectively. While the lowest, 5.1 and 6.1 degrees of contamination were recorded by Fe and Co. In general, the trend of the degrees of contamination of the heavy metals in the soil sample of the workshops is Cu>Zn>Pb>Mn>Cd>Ni>Se>Cr>Co>Fe. By implications, the soil samples of the workshops are said to be very highly contaminated with Cu, considerably contaminated with Zn, moderately contaminated with Pb, Mn, Cd and Ni, and low contaminated with Se, Cr, Co and Fe. A similar pattern of heavy metals contamination in soil samples of auto repair workshops in Oghara, Delta State was reported by Anegbe *et al.* (2018). Heavy contamination of the workshops with copper and zinc might have resulted from inappropriate dumping of automobile wastes containing electrical and electronic parts and scraps, such as copper wires, pipes, electrodes and alloys as well as use of zinc in brake linings of vehicles which may be released during mechanical abrasion of vehicles, combustion of engine oil and vehicle tyres respectively.

Pollution Load Index Assessment

Table 11 also shows the pollution Load Index (PLI) of the workshops. The results revealed that GIM workshop have the highest pollution severity on the soil by having the highest PLI value of 2891.8 while GDH workshop recorded the lowest with PLI value of 13.1. The order of pollution severity posed on the soil by the workshops is GIM > GAS > GOA > NWC > GDH. However, all the workshops have PLI values greater than 1 (>1) denoting deterioration of the soil due to accompanying anthropogenic activities of the workshops such as indiscriminate disposal of metal containing compounds such as used engine oil, vehicle spare parts, welding activities among others. Consequently, soils from the workshops are considered to be polluted with heavy metals and this calls for urgent concern and monitoring. Various studies have reported deterioration of soil samples in various workshops sampling sites (Ololade, 2014; Sam *et al.,* 2015; Rabe *et al.,* 2018; Anegbe *et al.,* 2018; Ibrahim *et al.,* 2019; Jimoh *et al.,* 2020).

Table 11: DC and PLI of the Workshops

Heavy Metals	CF of the Workshops					DC of Metal per Workshops
	GAS	GDH	GIM	GOA	NWC	
Cd	1.7	1.4	3.9	1.5	1.3	9.7
Co	1.4	1.2	1.4	1.0	1.0	6.1
Cr	2.0	1.4	1.2	1.5	1.0	7.0
Cu	179.0	1.0	20.3	9.8	8.3	218.5
Fe	1.1	1.0	1.0	1.0	1.0	5.1
Mn	1.3	1.1	4.4	1.1	2.0	9.8
Ni	1.9	1.6	2.2	1.4	1.4	8.6
Pb	2.3	2.0	5.3	0.6	3.1	13.4
Se	1.9	1.4	1.6	1.3	1.0	7.2
Zn	4.5	0.9	7.9	6.0	1.3	20.7
DC of Workshop	197.2	13.1	49.2	25.2	21.4	
PLI of Workshop	2150.0	33.4	2891.8	124.1	111.9	

CONCLUSION

The study revealed gradual dispersion of heavy metals from the workshops to the nearest surroundings by observing a decreases in heavy metal levels from workshop points to the nearest surroundings with increased sampling distance and by statistically evaluating the relationship between heavy metals levels in the soil samples and distance of sampling from the workshops using Pearson correlation coefficient at 0.05 and 0.01 significant levels, the matrix of which revealed a negative correlation which indicates inverse linear relationship. Thus, concluded that the heavy metals contamination in the workshop soils are gradually dispersing to the nearest surroundings. The study revealed that significant percentage of heavy metals in the soil samples are caused by anthropogenic activities (QoC) of the workshop. Therefore, concluded that the workshops are the major sources of heavy metal contaminations in the soil samples. The study also revealed various ranges of heavy metals contamination factors in the workshop soils ranging between moderate to very high contamination status. Degree of contamination of the workshop with heavy metals revealed that the workshops are very highly contaminated with Cu, considerably contaminated with Zn, moderately contaminated with Pb, Mn, Cd and Ni, and low contaminated with Se, Cr, Co and Fe in an order Cu>Zn>Pb>Mn>Cd>Ni>Se> Cr>Co>Fe. The study concluded that the pollution load index assessment of the workshops denotes deterioration which implies that the workshop soils are polluted with heavy metals with pollution severity decreasing order of GIM > GAS > GOA > NWC > GDH.

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