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Assessment of Heavy Metal Pollution in Soil from an Automobile Mechanic Workshop in Abuja

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

Spent oil contaminated soil from a mechanic workshop located in Gwagwalada Area Council of Abuja, FCT of Nigeria, was assessed of heavy metals (Fe, Pb, CD, Cu, Cr, Ni and Zn) concentration. Soil samples were collected from seven points at depth 0- 15 cm, wet digested in duplicates with 2 M HNO_3 in a closed system and concentrations of heavy metals analyzed by Atomic Absorption Spectrophotometer. The order of the mean concentration of heavy metal content in the contaminated sample and control soil were Fe> Zn > Cu >Pb > Cr > Ni > Cd and Fe > Cr > Zn > Pb > Cu > Ni > Cd respectively. The range (mg/kg) of the heavy metals in the contaminated soil were: 158.55 for Fe, 0.01 for Cd, 17.14 for Cu, 3.17 for Cr, 1.96 for Ni, 16.40 for Zn and 60.41 for Pb. There was an indication that Ni had the same source in the contaminated soil with Fe and Zn, having shown a correlations at r= 0.69; p = .043 and r= 0.85; p = .008 respectively while total organic matter and Carbonate content (r = - 0.96; p < 0.001), showed inverse correlation. The degrees of contamination, potential ecological risk factor and potential risk index of the heavy metals in all the points of the mechanic workshop were of low grade. The mean geo-accumulation index, I_{geo}, values for the various metals in the different points were all negative. Therefore, the heavy metals have not caused any harm yet to the mechanic workshop under study. The findings of this study would add to the environmental database of the soil of this mechanic workshop, which in due course, will assist in the monitoring, management and remediation strategies for heavy metal contaminated soil.

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1. INTRODUCTION

The natural soil environment is clean without any pollutant that would affect the existence of plants and animals negatively. Pollution is the introduction of harmful substances into a natural environment, usually by humans [1], These harmful substances originate from agricultural chemicals such as pesticides, fertilizer, insecticides, weedicides, fumigant; industrial waste; radio active pollutants; biological agents; pollutants from automobiles, urban waste, treated timber, lead paints, accidental spills and leakages of chemicals and oil, [2,3]. The pollutants could hamper human health, the quality of life or the natural functioning of the ecosystem by causing instability, disorder, harm or discomfort to the physical systems or living organisms therein [4]. Improper waste disposal and detrimental soil management methods have greatly reduced soil quality, thus resulting to soil pollution.

Oil spillage caused by vandalized oil pipeline, indiscriminate disposal of oil at the mechanic workshops, filling stations, loading and pumping station, accidental spills during drilling from oil wells, spillage during refueling and lubrication of trucks and trains, etc; has been a concerned issue over the years [5] as these incident cause serious pollution of the soil environment.

In cities of developing countries such as Gwagwalada in the Federal Capital territory, Abuja Nigeria, there has been an increase in population with high demand for both new and fairly used cars. The maintenance of these cars has been backed up by the springing up of several auto mechanic workshops to meet up with the repairs and servicing of these cars due to constant use. The servicing of these cars which involves mostly the change of the spent oil in the engine to new oil for effectiveness and efficiency of the car engine, has led to the dumping of the spent motor oil indiscriminately on the soil [6].

This spent motor oil is disposed into gutters, water drain, open vacant plots and farmlands, a common practice by motor mechanics and generator mechanics [7]. Spent motor oil contains heavy metals among other chemical pollutants [4,5,8-9] and include: Lead, Arsenic, Zinc, Barium, Chromium, Copper, Arsenic, Calcium, Aluminum and Cadmium; which result from wear and tear of the engine parts when the oil, which serves as a lubricant, burns inside the engine during use [7,10]. These heavy metals have adverse physiological effects at relatively low concentration and bio-accumulate across the food chain in the ecosystem. They are absorbed into the living tissues without been excreted because they are non-biodegradable. With time, they become toxic: causing serious health problem to plants and animals (man inclusive) such as cardiovascular, kidney and liver problems; anemia, tremor and consequently, resulting in death [4-5,10-13]. Spent oil in the soil results to poor aeration, immobilization of soil nutrients and lowers the pH of the soil [7], which could be an unsatisfactory and detrimental condition to soil organisms; and could reduce growth and productivity of plants.

Therefore, there is a need to check the level of these heavy metals in mechanic workshop soil so as to provide useful environmental information and data for future monitoring to avoid alarming concentrations of these heavy metals in the soil environment.

2. MATERIALS AND METHODS

2.1 Sample Preparation and Analysis

Soil samples were collected from seven different spots of the mechanic workshop at the 0 -15 cm. The sampling was carried out with a shovel that was washed with soap and distilled water prior to sampling. The soil samples were stored in a black polyethylene bag and labelled accordingly. At the laboratory, the samples were air dried for 1 week and passed through a 2 mm sieve. The physicochemical properties of the soil were determined as follows: total Calcium trioxocarbonate (IV) [14]; wet Digestion of Soil samples for metal analysis of: Fe, Cd, Cr, Cu, Ni, Zn and Pb; carried out in duplicates using 2 M HNO_3 [15-17]; pH in water and KCl was done using the ph meter [18]; organic matter of the soil samples were determined based on Walkey-Black method according to the procedure of Estefan et al. [14].

The data obtained were subjected to statistical analysis. One-way ANOVA analysis was use to test the significant difference of the mean of the heavy metals. Descriptive analysis was to reveal the minimum, maximum, mean and standard deviation of the concentrations of the heavy metals obtained after AAS analysis. Correlation analysis was used to ascertain the probable common source of the heavy metal pollutants in the contaminated soil [19,20].

2.2 Pollution Indices

Some indicators were used to assess and interpret the contamination status of each heavy metal in the contaminated soil. These indicators include contamination factor, degree of contamination, ecological risk factor, and index of geo-accumulation etc.

2.2.1 Contamination factor

Contamination factor is used to express the contamination of a given toxic substance [21].

Mathematically, it is expressed as

$$C_f^i = \frac{C_r^i}{C_R^i} \qquad (1)$$

Where:

C_f^i = the contamination factor of a single metal;
C_r^i = the measured concentration of the metal in the sample;
C_R^i = the background concentration of the soil according to DPR [22].

Contamination factor is defined according to four categories [23]:

Contamination factor values < 1 = low contamination factor,
1 ≤ Contamination factor value ≤ 3 = moderate contamination,
3 < Contamination factor value ≤ 6 = considerable contamination) and
Contamination factor value > 6 = very high contaminated)

2.2.2 Degree of contamination

The sum of the contamination factors of all the elements in the sample is referred to as the degree of contamination, which is mathematically expressed as:

$$C_D = \sum_{i=1}^{n} C_f^i \qquad (2)$$

Where:

C_D = Degree of contamination
C_f^i = Contamination factor of a single element i
n = Count of the heavy metal

According to Hakanson, the degree of contamination in soil and sediments may be termed the sum of pollution [21]. Four categories has been defined for the degree of contamination as follows; (< 8 indicates low degree of contamination), (8-16 indicates moderate degree of contamination), (16-32 indicates considerable degree of contamination) and (>32 indicates very high degree of contamination) [23].

2.2.3 Potential ecological risk factor

Hakanson [21] stated that potential ecological risk factor was initially only applicable to water pollution control but have in recent times been effectively applied to determine the extent of pollution in soils and sediments. Therefore, this factor evaluates the potential harm of a given heavy metals in the studied soil. The categories of potential ecological risk factor and Index are as shown on (Table 1).

The proposal by [21] as shown in equation (3) was followed in determining the potential ecological risk index of the heavy metals studied in the contaminated soil.

$$E_f^i = T_f^i \; x \; C_f^i \qquad (3)$$

Where:

E_f^i = the potential ecological risk factor of single metal;
T_f^i = the toxicity response factor of a given metal; and
C_f^i = Contamination factor of a single element, i

Table 1. Categories of E_f^i and RI [20]

Ranges of Potential Ecological risk	Categories of Potential Ecological risk	Ranges of Potential risk index	Categories of potential risk index
< 40	Low	RI < 150	Low grade
40 ≤ E_f^i < 80	Moderate	150 ≤ RI < 300	Moderate
80 ≤ E_f^i < 160	Higher	300 ≤ RI <600	Sever
160 ≤ E_f^i < 320	High	600 ≤ RI	Serious
320 ≤ E_f^i	serious		

Table 2. Classification of geo-accumulation index

I_{geo} Value	Class	Soil Quality
≤ 0	0	Uncontaminated
0 – 1	1	From Uncontaminated to moderately contaminated
1 – 2	2	Moderately contaminated
2 – 3	3	From moderately contaminated to strongly contaminated
3 – 4	4	Strongly contaminated
4 – 5	5	From strongly contaminated to extremely contaminated
> 6	6	Extremely contaminated

The toxicity response factors of metals [21] are:

Cd = 30; Cr = 2; Cu = Pb = Ni = 5; Zn = 1

The Potential Ecological risk index was calculated based on equation (4), which is a sum of the potential ecological risk of the single heavy metal in the sample from each spot. The format of calculating degree of contamination applies to potential risk index.

$$RI = \sum_{(i=1)}^{n} E_f^i \quad (4)$$

Where:

E_f^i = the potential ecological risk factor of single metal;
RI = the potential ecological risk index of many metals
n = Count of the heavy metal

2.2.4 Index of Geo-accumulation

Index geo-accumulation is used to assess the effects of heavy metal contamination on agriculture and man [24]. Therefore, it is used to determine the extent of metal pollution as proposed by Muller [25].

Mathematically, it is stated as:

$$I_{geo} = log_2 \frac{C_D^i}{1.5C_R^i} \quad (5)$$

Where:

C_r^i = the measured concentration of the metal in the sample;
C_R^i = the background concentration of the soil according to [22]
I_{geo} = Index of geo-accumulation

1.5 is the correction factor for compensating the background data as a result of lithogenic effects. The classification of geo-accumulation index is presented in (Table 2) as reported by [26].

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of the Soil

The results of some physicochemical properties of the soil from the mechanic workshop are as presented in (Table 3). The pH of the soil was found to be slightly alkaline. The pH of the contaminated soil sample determined in water ranged from 7.33 to 7.51 with a mean value of 7.41±0.06 while the pH of the soil in KCl ranged from 7.26 to 7.58 with a mean value of 7.43±0.011. It was also found that there was no significant difference in all the values of pH obtained from the various soil samples, whether in water or in KCl. The pH values obtained were in line with those reported in the literatures, [27-28]. Though other authors [4,29], reported pH that were slightly acidic.

The Electro-conductivity of the soil ranged from 1151 to 1182 µS/cm, with a mean value of 1161.86±10.84 µS/cm. However, it was found to be much higher than that reported by Ekeocha and Anunuso [30]. This high electro-conductivity could be due to the high ionic concentration of the heavy metals in the contaminated soil which would, in due course, leach into the underground water, thus, making the water unfit for animal and human consumption. The Carbonate content ranged from 1.48 to 1.86% with a mean concentration of 1.64 ± 0.13%, which was lower than that reported by [27]. The mean value of the total Organic matter of the soil was found to be 3.20±0.25% as it ranged from 2.73 to 3.49.

3.2 Heavy Metal Concentrations

The heavy metals of interest were detected in the soil analyzed, though Cadmium concentrations for some spots were below the detection limit of the instrument, AAS, used for the analysis. The concentrations of the heavy metals in the contaminated soil are shown in (Table 4) while the descriptive analyses of the heavy metal concentration are presented in (Table 5).

3.2.1 Iron concentration

Among the heavy metals determined, Iron had the highest concentration as predicted and was detected in all the spots of the mechanic workshop, with concentration ranging from 331.56±3.42 to 490.11±0.004 mg/kg which was lower than the range, 748 - 70,606 ±10114.3 mg/kg, reported in the literature by Nwachukwu et al [31-32]. Iwegbue et al. [29] also reported higher iron concentration which ranged from 1746.4 to 2839.6mg/kg. The mean concentration of Fe was 419.64±60.74 mg/kg, lower than, 11,776mg/kg reported by some authors [33] and the background value of the Department of Petroleum resources [22]. There was an extreme significant difference between this mean concentration of Fe in the sample and the concentration of Fe in the control soil 11.14±0.04 mg/kg, at $p < 0.05$, showing the impact of the spent motor oil on the mechanic workshop soil. Also, the mean concentration of Fe was found to be extremely higher than the concentrations of Cd, Cu, Cr, Ni, Zn and Pb ($p < 0.001$) in this study. However, since Iron is present in the red blood cells and helps in the transportation of oxygen in the blood from lungs to the tissues, it is not considered dangerous to health [32,34].

3.2.2 Cadmium concentration

The concentration of cadmium in some spots was below the detection limits of the instrument used. It ranged from ND to 0.011±0.01mg/kg while the mean concentration of the cadmium in the contaminated soil was 0.01±0.01mg/kg. There was no significant different between the cadmium concentration of the sample (0.01±0.01mg/kg) and that of the control soil (0.01±0.01 mg/kg). However, the mean concentration of Cd was significantly lower than those of Cu ($p = 0.006$), Zn ($p = 0.001$) and Pb ($p = 0.007$) and Fe ($p = 0.001$). Also, the cadmium concentration was found to be lower than those of: DPR background value and intervention values; Dutch target; UK allowable limits and other international standards. The cadmium concentration from this contaminated soil was lower than that reported in some literatures [31, 35-36] while Iwegbue et al. [29] reported higher concentration of cadmium.

Table 3. Physicochemical properties of the experimental soil (0-15 cm)

Sample size	pH in water	pH in KCl	Electro-conductivity	Carbonate content %	Total Organic Matter (%)
7	7.39	7.4	1161	1.65	3.1978
7	7.45	7.43	1157	1.59	3.25
7	7.40	7.53	1163	1.48	3.42
7	7.51	7.58	1182	1.66	3.20
7	7.33	7.26	1151	1.74	3.11
7	7.38	7.37	1168	1.86	2.73
7	7.42	7.45	1151	1.53	3.49
Min	7.33	7.26	1151	1.48	2.73
Max	7.51	7.58	1182	1.86	3.49
Mean ±SD	7.41±0.06	7.43±0.011	1161.86±10.84	1.64±0.13	3.20±0.25

Table 4. Heavy metal concentration of the soil samples

Sampling spots	Heavy metals (mg/kg)						
	Fe	**Cd**	**Cu**	**Cr**	**Ni**	**Zn**	**Pb**
1	490.11±0.01	ND	59.10±0.021	10.15±0.01	4.18±0.05	115.44±1.48	60.57±1.42
2	331.56±3.42	0.011±0.01	55.55±1.91	9.44±1.25	3.36±0.94	121.62±2.63	19.14±1.55
3	387.24±2.22	ND	48.71±3.16	6.98±2.66	3.07±0.55	124.32±0.13	28.92±4.17
4	461.19±1.81	ND	50.42±2.28	8.51±1.49	4.02±0.03	119.75±0.87	44.68±3.82
5	373.17±2.59	0.002±0.12	47.33±4.25	9.22±0.79	2.22±1.47	107.92±6.56	79.55±4.97
6	408.57±0.43	ND	41.96±3.44	10.05±0.02	4.00±0.11	122.38±1.42	51.13±5.30
7	485.62±4.11	ND	55.74±2.22	8.88±1.83	3.92±0.09	120.54±3.81	65.78±1.66
Control	11.14±0.04	0.01±0.01	0.91±1.28	10.43±4.01	0.78±0.21	5.83±2.98	3.99±1.18

Value = mean ±SD, n = 2

Table 5. Some descriptive analysis of the contaminated soil

Sample size	Metals	Range	Min	Max	Mean±SD
7	Fe	158.55	331.56	490.11	419.64±60.74
7	Cd	0.01	ND	0.011	0.01±0.01
7	Cu	17.14	41.96	59.10	51.26±5.90
7	Cr	3.17	6.98	10.15	9.03±1.07
7	Ni	1.96	2.22	4.18	3.54±0.71
7	Zn	16.40	107.92	124.32	118.85±5.55
7	Pb	60.41	19.14	79.55	49.97±21.06

3.2.3 Copper concentration

The concentration of copper in the contaminated soil ranged from 41.96±3.44 to 59.095±0.02 mg/kg. The mean concentration of the copper in the contaminated soil was 51.26±5.90 mg/kg, which was significantly higher than that of the control soil, 0.91±1.28 mg/kg, signifying the impact of the activities at the mechanic workshop. The concentration of Cu was statistically difference from the concentrations of Fe ($p = 0.000$), Cd ($p=0.006$); Cr ($p=0.036$); Ni ($p=0.012$) and Zn ($p=0.000$) but did not differ significantly with that of Pb ($p = 1.000$). The Copper concentration was lower than the intervention value of DPR, EEC guideline, UK allowable limits, Astria allowable limits and France but higher than the background value of DPR and Dutch target value, Germany threshold values, Canadian criteria [37] and Sweden allowable limits. The Cu concentration reported by [29,31,35,36] were all lower that the concentration found in this study.

3.2.4 Chromium concentration

Chromium was present in all the samples of the contaminated soil analyzed, with concentration ranging from 6.98±2.66 to 10.15±0.006 mg/kg. The mean concentration of the chromium in the contaminated soil was 9.03±1.07 mg/kg. There was no significant difference between the concentration of Chromium in the contaminated soil, 9.03±1.07 mg/kg and that of the control soil, 10.43±4.01 mg/kg. More so, the mean concentration of Cr differed significantly with the concentrations of Fe ($p < 0.001$); Cu ($p = 0.036$); Zn ($p < 0.001$) and Pb ($p = 0.046$). The concentration of Chromium was lower than the allowable concentrations presented by most countries: France, Canada, Sweden, Austria, Germany, UK, Europe, Dutch and that of DRP. A Chromium concentration of 12.9 mg/kg reported by Karim et al. [33] was higher than that from this study while Iwegbue et al. [29] reported lower concentration.

3.2.5 Nickel concentration

The range of the Nickel concentration in the contaminated soil was 2.22±1.47 to 4.18±0.049 mg/kg, with a mean concentration of 3.54±0.71 mg/kg. The Nickel concentration in the sample soil, 3.54±0.71 mg/kg, did not differ significantly with that of the control soil 0.78±0.21 mg/kg at $p < 0.05$. However, in the contaminated soil, the concentration of Ni was significantly lower than the concentrations of those of Fe ($p = 0.001$); Cu ($p = 0.012$); Zn ($p = 0.001$) and Pb ($p = 0.016$). Iwegbue et al. [29] reported higher concentration of nickel.The mean concentration of Nickel was lower than the concentration limits stated by DPR, Austria, Germany, UK, France, Canada, Europe, Dutch and Sweden.

3.2.6 Zinc concentration

The concentration of Zinc ranged from 107.92±6.56 to 124.32±0.127 mg/kg, though the mean concentration was 118.85±5.55 mg/kg. The Zinc concentration of the sample soil, 118.85±5.55 mg/kg, was significantly higher than that found in the control soil, 5.83±2.98 mg/kg. An extreme significant difference was observed between the mean concentration of Zn and all the other heavy metals at $p = 0.001$. The concentration of Zinc in the contaminated soil was within the allowable concentration of some countries as shown on (Table 6) but exceeded that of Canada. The Zinc concentration reported by Abdullah et al. [35] was higher than that in this study while Iwegbue et al. [29] reported lower concentration. However, Karim et al. [33] reported a concentration of 123.03 mg/kg similar to 124.32 mg/kg in this study.

3.2.7 Lead concentration

Lead was present in all the samples obtained from the different spots of the mechanic workshop and range from 19.14±1.55 to 79.55±4.97 mg/kg. The mean concentration of Pb in the control soil was 3.99±1.18 mg/kg. The concentration of Pb in the contaminated soil, 49.97±21.06 mg/kg, was significantly higher than that of the control soil, 3.99±1.18 mg/kg, at $p < 0.05$. However, the mean concentration of Pb was statistically different from the mean concentration of Fe ($p = 0.001$); Cd ($p = 0.007$); Cr ($p = 0.046$); Ni ($p = 0.016$) and Zn ($p = 0.001$). However, the concentration of Lead was lower than the permissible limits stated by DPR, France, Austria, Germany, UK EEC and Dutch, it surpassed the allowable concentrations in Canada and Sweden. Karim et al. [33] reported higher concentration of Pb while Iwegbue et al. [29] reported lower concentration of lead.

The order of the mean concentration of heavy metal content in the sampled soil was Fe > Zn > Cu > Pb > Cr > Ni > Cd whereas, the concentration profiles of the metals in the soil of Iwegbue et al. [38] followed the order Fe > Pb > Cr > Zn > Ni > Cu > Cd. In both study, Iron had the highest concentration while Cd had the least

Table 6. Comparisons with some international guidelines

	Heavy metals (mg/kg)						
	Fe	**Cd**	**Cu**	**Cr**	**Ni**	**Zn**	**Pb**
Present study	419.64	0.01	51.26	9.03	3.54	118.85	49.97
Background value, DPR	4700	0.8	36	100	35	140	85
Intervention value DPR		17	190	380	210	720	530
Dutch target value		0.8	36	100	35	140	85
EEC guideline values (1993)		1-3	140-300			150 -300	50- 300
UK allowable limits		3	135	400	75		300
Germany allowable limits		1	40	60	50	150	70
Germany threshold values		0.4 -1.5	20 - 60	30 -100	15 -70	60-200	40-100
Austria allowable limits		1-2	60 -100	100	50 -70		100
Sweden allowable limits		0.4	40	60	30		40
Canadian Criteria (CCME)		0.5	30	20	20	60	25
France allowable limits		2	100	150	50		100

ECDGE [36], DPR [22], CCME [37], Iwegbue et al. [29]

concentration. More so, the order of the mean concentration of the heavy metals in the control soil was Fe > Cr > Zn > Pb > Cu > Ni > Cd. The concentration order of Fe, Pb, Ni and Cd in the contaminated site and control of this study were the same.

From the control site of Iwegbue et al. [29], concentrations higher than that from this study were reported: 17.5 mg/kg for Zn; 4.0 mg/kg for Cu; 2.5 mg/kg for Ni and 1490.4 mg/kg for Fe concentration. While their result showed lower concentrations of 0.88 mg/kg for Cr; < 0.01 mg/kg for Pb than that in the present study. The heavy metals concentrations of control soil of this study were lower than that reported by Ozulu et al. [28], with Pb, Fe, Cu, Zn, and Cd concentration as 0.95 mg/kg, 999.88 mg/kg 13.11 mg/kg 23.11 mg/kg and 2.06 mg/kg respectively. Higher concentrations of Pb, Fe, Cu, Ni were reported from the control sites of Iwegbue et al. [38]: 0.93 mg/kg for Cr, 1.8 $mgkg^{-1}$ for Cu, 4.8 mg/kg for Zn, 2.6 mg/kg for Pb, 1893 mg/kg for Fe, and 4.1 mg/kg for Ni, Cd was below their dictation limit as was also found in this study. Whereas, Ilemobayo and Kolade [6] reported heavy metal concentrations (Fe, 611.24 mg/kg; Cd 0.00 mg/kg; Cu 124 mg/kg; Cr 115 mg/kg; Ni 43.57 mg/kg; Zn 693 mg/kg Pb 218 mg/kg) which were higher than the concentrations in this study.

3.3 Data Analysis

Correlation analysis of soil Heavy metal and other parameters of the contaminated soil are presented in (Table 7). The correlation analysis is used to explore the inter-metal relationships of the heavy metals and ascertain the probable common sources of the heavy metal pollutants in the contaminated soil [19-20]. The linear relationship between two variables are ascertained on a scale of between -1 (negative or inverse relationship) to +1 (positive or sympathetic relationship). IBM SPSS Statistics 21 software package was used to analyze the correlation analysis between the heavy metal concentrations, pH in water, pH in KCl, Carbonate content, and Total organic matter content of the contaminated soil.

The mean concentration of Fe was significantly correlated with Cd ($r = -.711$; $p = .037$) and Ni ($r = 0.69$; $p = .043$). Therefore, the strong negative correlation between Fe and Cd, implies that they were from different sources while Fe and Ni, with strong positive correlation, are from the same origin. More so, Zn and Ni were found to be significantly correlated at $r = 0.85$; $p = .008$. There is an indication that Ni has the same source in the contaminated soil with Fe and Zn. Other parameters that correlated significantly to each other include: pH in KCl and pH in water, with strong positive correlation ($r = 0.84$; $p = .009$), showing that either water or KCl electrolytes can be used for the determination of the pH of the soil; Carbonate content and Cr ($r = 0.68$, $p = .048$), indicating that the availability of Chromium is influenced by the carbonate content of the soil [39] total organic matter and Carbonate content ($r = -0.96$; $p < 0.001$), showed inverse correlation which agreed with the findings of Shetye et al. [40]. Fe, Cd, Cu, Ni, Zn and Pb did not have any significant correlation with any of the physicochemical properties of the soil whether at 0.05 or 0.01 level of significance. This implies that these six heavy metals were of anthropogenic origin. However, only Chromium was significantly correlated with the carbonate content of the soil.

In addition, significant correlation were found between Fe, Cd, Ni, Zn, Cr, Carbonate, pH water, pH KCl and organic matter. However, Cu and Pb were found not to have any significant correlation with any of the other parameters at all.

The calculated contamination factors, which represent the impact of the individual heavy metal element on the soil from the different spots analyzed, are presented on (Table 8). The highest contamination factor of Fe, 0.10, was from spot 1 and 7 while the mean contamination factor was 0.09. The maximum and mean values of the contamination factor of Cd were 0.01 each, whereas, those of Cu were: 1.64 and 1.42 respectively. The maximum and mean contamination factor of Cr, Ni, Zn and Pb were: 0.1 and 0.09, 0.12 and 0.1, 0.89 and 0.85, 0.94 and 0.59 respectively. The categories of the contamination factor of the single heavy metals were of low contamination for Fe, Cd, Cr, Ni, Zn and Pb while Copper was of moderate contamination. The moderate contamination of copper in the mechanic workshop could have originated from some mechanical parts of the cars that are plated with copper, a content of the gasket sealant and anti-seize compound, a component of bronze which is used in making crankshaft and camshaft bearings [41-42]. Stratson [42] also mentioned that other sources of copper could be: Leaching from oil coolers, leaks from cooling systems, external contaminates and from excessive wear. Copper was also reported to have originated from additives, such as anti-wear and corrosion inhibitors additives, that were added to engine oil used in the crankershaft of the car [43-45]. From (Table 8), the degrees of contamination of the heavy metals in all the soils of the spots in the mechanic workshop were low. This could imply that the mechanic workshop has low contamination.

The values of the potential ecological risk factor of the different points in the mechanical workshop under study are shown in (Table 9), ranged from: 0.00 to 0.41 for Cd; 5.83 to 8.21 for Cu; 0.14 to 0.20 for Cr; 0.32 to 0.60 for Ni; 0.77 to 0.89 for Zn; and 1.13 to 4.68 for Pb. The mean values of the potential ecological risk factor of the heavy metals are: 0.10, 7.10, 0.18, 0.50, 0.84, and 2.93 for Cd, Cu, Cr, Ni, Zn and Pb respectively. According to the categories of the potential ecological risk factor by Hu et al. [20] presented on (Table 1), the potential ecological risk factor of all the heavy metals studied were found to have low potential ecological risk factor.

The potential risk index of the heavy metals in the soil from all the studied spot were of low grade as shown in (Table 9). Therefore, the heavy metals have not caused any harm to the mechanic workshop under study.

Table 7. Correlation coefficient matrix for soil parameters

	Fe	Cd	Cu	Cr	Ni	Zn	Pb	pHH_2O	pH KCl	Cond.	Carbonate	O.M
Fe	1											
Cd	-.711*	1										
Cu	.373	.271	1									
Cr	.146	.183	.138	1								
Ni	.690*	-.265	.306	.332	1							
Zn	.600	-.435	.194	-.004	.848**	1						
Pb	.467	-.540	-.063	.363	-.144	-.274	1					
pHH_2O	.205	.186	.295	-.230	.531	.317	-.557	1				
pHKCl	.281	-.139	.188	-.607	.472	.551	-.602	.840**	1			
Conductivity	.225	-.282	-.288	-.142	.490	.430	-.347	.648	.647	1		
Carbonate	-.076	-.125	-.597	.676*	.045	-.171	.390	-.324	-.563	.230	1	
O. M	.188	.062	.649	-.610	-.097	.029	-.155	.286	.459	-.315	-.959**	1

**. Correlation is significant at the 0.05 level (1-tailed).*
***. Correlation is significant at the 0.01 level (1-tailed).*
O.M= Organic matter

Table 8. Values of contamination factor and degree of contamination of contaminated soil

Sampling spots	Contamination factor							Degree of contamination
	Fe	Cd	Cu	Cr	Ni	Zn	Pb	C_d
1	0.10	0.00	1.64	0.10	0.12	0.89	0.71	3.56
2	0.07	0.01	1.54	0.09	0.10	0.82	0.23	2.86
3	0.08	0.00	1.35	0.07	0.09	0.87	0.34	2.80
4	0.10	0.00	1.40	0.09	0.11	0.86	0.53	3.09
5	0.08	0.00	1.31	0.09	0.06	0.77	0.94	3.25
6	0.09	0.00	1.17	0.10	0.11	0.87	0.60	2.94
7	0.10	0.00	1.55	0.09	0.11	0.86	0.77	3.48
Min	0.07	0	1.17	0.07	0.06	0.77	0.23	2.37
Max	0.1	0.01	1.64	0.1	0.12	0.89	0.94	3.80
Mean	0.09	0.01	1.42	0.09	0.1	0.85	0.59	3.15
C_f^i category	Low cont.	low cont.	Moderate cont.	low cont.	low cont.	low cont.	low cont.	

Table 9. Values of potential ecological risk factor and Potential risk index

Sampling spot	E_f^i						RI
	Cd	Cu	Cr	Ni	Zn	Pb	
Spot 1	0	8.21	0.2	0.6	0.89	3.56	13.46
Spot 2	0.41	7.72	0.19	0.48	0.82	1.13	10.75
Sot 3	0	6.77	0.14	0.44	0.87	1.7	9.92
Spot 4	0	7	0.17	0.57	0.86	2.63	11.23
Spot 5	0.08	6.57	0.18	0.32	0.77	4.68	12.6
Spot 6	0	5.83	0.2	0.57	0.87	3.01	10.48
Spot 7	0	7.74	0.18	0.56	0.86	3.87	13.21
Min	0	5.83	0.14	0.32	0.77	1.13	9.92
Max	0.41	8.21	0.2	0.6	0.89	4.68	13.46
Mean	0.10	7.10	0.18	0.50	0.84	2.93	11.67
E_f^i	Low	Low	Low	Low	Low	Low	

Table 10. Geo- accumulation index of the heavy metals of the contaminated soil

Sampling spots	Fe	Cd	Cu	Cr	Ni	Zn	Pb
Spot 1	-3.85	ND	0.13	-3.88	-3.65	-0.75	-1.07
Spot 2	-4.41	-6.77	0.04	-3.99	-3.97	-0.86	-2.74
spot 3	-4.19	ND	-0.15	-4.42	-4.10	-0.78	-2.14
Spot 4	-3.93	ND	-0.10	-4.14	-3.71	-0.81	-1.51
Spot 5	-4.24	-9.23	-0.19	-4.02	-4.56	-0.96	-0.68
spot 6	-4.11	ND	-0.36	-3.90	-3.71	-0.77	-1.32
Spot 7	-3.86	ND	0.05	-4.07	-3.74	-0.80	-0.96
Min	-4.41	ND	-0.36	-4.42	-4.56	-0.96	-2.74
Max	-3.85	-6.77	0.13	-3.88	-3.65	-0.75	-0.68
Mean	-4.07	-8.81	-0.08	-4.05	-3.89	-0.82	-1.35
I_{geo} Value(min)	0.00	0	0.00	0.00	0.00	0.00	0.00
I_{geo} Value(max)	0.00	0.00	1.00	0.00	0.00	0.00	0.00
I_{geo} Value(mean)	0.00	0.00	0.00	0.00	0.00	0.00	0.00
I_{geo} Class	0	0	0	0	0	0	0
Category of I_{geo}	Uncont.	Uncont.	Uncont.	Uncont.	Uncont.	Uncont.	Uncont.

The aim of geo-accumulation index was to compare the concentration of the heavy metal content of the mechanic workshop with that of the background concentration as stated by DRP in Nigeria [22]. The calculated geo-accumulation index is presented in (Table 10).

Table 11. Levels of the pollution indices studied

Pollution indices	Spot 1	Spot 2	Spot 3	Spot 4	Spot 5	Spot 6	Spot 7
C_d	Low	Low	Low	Low	Low	low	Low
RI	Low grade	Low grade	Low grade	Low grade	Low grade	Low grade	Low grade

C_d = degree of contamination
RI = Potential risk index

The minimum, maximum and mean values of the I_{geo} of the metals in each spot analyzed are for Fe: -4.41, -3.85 and -4.07; Cd, ND, -.6.77 and -8.81; Cu: -0.36, 0.13, -0.08; Cr: -4.42, -3.88 and -4.05; Ni: -4.56, -3.65 and -3.89; Zn: -0.96, -0.75 and -0.82; and Pb: -2.74, -0.68 and -1.35 respectively. The minimum values of the all the I_{geo} of the metals were negative, except Cadmium whose concentration was below detection limit. The maximum I_{geo} of the metals under consideration were negative though that of copper concentration was positive, 0.13. The mean I_{geo} values for the various metals in the spots were all negative. Following the classification of the I_{geo} on (Table 2), there is an indication that the spots analyzed are uncontaminated as revealed on (Table 10).

4. CONCLUSION

The heavy metals (Fe, Cd, Cu, Cr, Ni, Zn and Pb) determined in the soil from different spots of the mechanic workshop were compared with the heavy metals from the control soil samples and some international guideline. The order of the mean concentration of heavy metal content in the contaminated soil was Fe> Zn > Cu >Pb > Cr > Ni > Cd while the order of the mean concentration of the heavy metals in the control soil was Fe > Cr > Zn > Pb > Cu > Ni > Cd. The concentration order of Fe, Pb, Ni and Cd in the contaminated site and control of this study were the same. The results showed that the concentrations of the heavy metal in the soil samples were below the intervention concentration stated by DPR. The degrees of contamination of the heavy metals in all the points of the mechanic workshop were low. Also, all the heavy metals studied were found to have low potential ecological risk factor. The potential risk index of the heavy metals in the soil from all the studied spot were of low grade. Therefore, the heavy metals have not caused any harm to the mechanic workshop under study. The mean I_{geo} values for the various metals in the spots were all negative. Based on the classification of the I_{geo}, there was an indication that the spots analyzed were uncontaminated. Therefore, soil pollution assessment using C_d, RI and I_{geo} indices confirmed that the soil in the mechanic workshop was uncontaminated. Thus, this study could be used to monitor the progressive pollution of this particular mechanic workshop.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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