

Original Research Article

ASSESSMENT OF HEAVY METAL POLLUTION LEVEL OF AN AUTOMOBILE MECHANIC WORKSHOP IN NORTH CENTRAL REGION OF NIGERIA.

ABSTRACT

Following the reports in the literatures of the harmful components of spent motor oil, this study was geared towards determining the concentration of some heavy metals: Fe, Cd, Cu, Cr, Ni, Zn and Pb, from the soil of a mechanic workshop located in lorry (tipper) garage opposite AY filling station at Gwagwalada Area Council of the Federal Capital Territory Abuja and levels pollution of this site using pollution indices. The determined heavy metals were compared with the guideline stated by Nigerian regulatory agency, international standards and studies from other literatures.

Seven spots were sampled at 0 – 15 cm depth at the mechanic workshop while a control sample was obtained from a SHESTCO environment in Sheda, Abuja. The concentrations of the heavy metals were determined using AAS after closed system digestion of the soil samples using 2M HNO₃. Other parameter of the soil characterized include: pH in water and KCl, electro-conductivity, carbonate content and total organic matter content. Statistical data analysis of the results was carried and the single indices of the heavy metals calculated.

The order of the mean concentration of heavy metal content in the sampled soil was found to be Fe > Zn > Cu > Pb > Cr > Ni > Cd while the order of the mean concentration of the heavy metals in the control soil was found to be Fe > Cr > Zn > Pb > Cu > Ni > Cd. There was an indication that Ni has the same source in the sample soil with Fe and Zn with correlations at $r = 0.69$; $p = .043$ and $r = 0.85$; $p = .008$ respectively. The findings of this study would add to the environmental database of the soil of this mechanic workshop, which in due course, will assist the management and remediation strategies for heavy metal contaminated soil.

Keywords: Soil pollution, auto mechanic workshop; heavy metals; pollution indices, Gwagwalada

1. INTRODUCTION

The natural soil environment is clean and remains enjoyable for both plants and animals in the absence of pollution. Pollution is the introduction of harmful substances into a natural environment, usually by humans [1]. These harmful substances originates 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 issued issue over the years [5] as these incident cause serious pollution of the soil environment.

In developing cities of Nigeria, such as Gwagwalada in the Federal Capital territory, Abuja, there has been an increase in population with high demand for both new and fairly used cars. The maintenance of these cars has been back up by the springing up of several auto mechanic workshops to meet up with the repairs and servicing of these cars due to constant

usage. The servicing of these cars which involves mostly the change of the spent oil in the engine to new oil for effective and efficient use, has lead to the dumping of the spent motor oil indiscriminately on the soil [6].

This spent motor oil are 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, Aluminium and cadmium and result from wear and tear from engine parts when the oil burns inside the engine during use as an engine lubricant [7,10]. The heavy metal from spent oil have adverse physiological effects at relatively low concentration and bio-accumulate across the food chain in the ecosystem as they are absorbed and into the living tissues without been excreted as they non-biodegradable, thus 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. MATERIAL 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 trowel that was washed with soap and distilled water prior to sampling. The soil samples were stored in a black polyethylene bag and labelled accordingly before taken them to the laboratory. At the laboratory, the samples were air dried for 1 week and passed through a of 2mm sieve. The physicochemical properties of the soil were determined as follows: total Calcium trioxocarbonate (IV) according [14] method; wet Digestion of Soil Samples for metal analysis of- Fe, Cd, Cr, Cu, Ni, Zn and Pb, as the soil from each spot was digested in duplicates using 2M HNO₃ [15-17]; pH in water and KCl was carried out 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 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 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 the each heavy metal in the contaminated soil. These indicators include contamination factor, degree of contamination, ecological risk factor, enrichment factor, and index of geo-accumulation etc.

Contamination factor:

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

Mathematically, it is expressed as

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

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 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)

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:

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

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]

Potential Ecological risk factor

Hakanson [21] stated that initially, potential ecological risk factor was 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.

$$E_f^i = T_f^i \times C_f^i \quad (3)$$

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

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 the 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

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
$40 \leq E_f^i < 80$	Moderate	$150 \leq RI < 300$	Moderate
$80 \leq E_f^i < 160$	Higher	$300 \leq RI < 600$	Sever
$160 \leq E_f^i < 320$	High	$600 \leq RI$	Serious
$320 \leq E_f^i$	serious		

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 :

$$I_{geo} = \log_2 \frac{C_D^i}{1.5C_R^i} \quad (6)$$

Where:

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]

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

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 1). The pH of the soil was found to be slightly alkaline as 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 was found to range from 1151 to 1182 with a mean value of 1161.86 ± 10.84 . However, it was found to be much higher than the reported by Ekeocha and Anunuso[30].

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.

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 $\pm$ SD	7.41 $\pm$ 0.06	7.43 $\pm$ 0.011	1161.86 $\pm$ 10.84	1.64 $\pm$ 0.13	3.20 $\pm$ 0.25

3.2 Heavy metal Concentrations

The AAS analysis results of the contaminated soil indicating the concentrations of the heavy metals are shown (table 2). All the heavy metals of interest were detected, though in some spots, the concentration of Cadmium was below the detection limit. More so, the descriptive analysis of the heavy metal concentration are presented (table 3). The heavy metal concentrations of the contaminated soil were compared with the allowable concentration of some countries is as shown in table 4.

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

Value = mean $\pm$ SD, n = 2.

172 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

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174

175 Iron Concentration

176 Iron was detected in all the spots of the mechanic workshop. The soil Fe concentration ranged from 331.56±3.42 to
 177 490.11±0.004 mg/kg. The mean concentrations of the Iron in the contaminated soil were found to be 419.64±60.74 mg/kg.
 178 There was an extreme significant difference between the mean concentration of Fe in the sample, 419.64±60.74 mg/kg,
 179 and the control soil, 11.14±0.04 mg/kg, at $p < 0.05$. The mean concentrations of Fe was found to be extremely higher than
 180 those of Cd, Cu, Cr, Ni, Zn and Pb ($p < 0.001$). The iron concentration in this study was found to be lower than the
 181 background value stated by DPR [22]. Some authors, [31-32] reported 748-70,606 ±10114.3 mg/kg and 11,776mg/kg of
 182 Fe concentration that were much higher.

183

184 Cadmium Concentration

185 The concentration of cadmium was found to be below detection limits for some of the spots analyzed as the results
 186 ranged from ND to 0.011±0.01mg/kg. The mean concentration of the cadmium in the contaminated soil was found to be
 187 0.01±0.01mg/kg. There was no significant different between the Cadmium concentration of the sample (0.01±0.01mg/kg)
 188 and that of the control soil (0.01±0.01 mg/kg). However, the mean concentration of Cd was found to be significantly lower
 189 than those of Cu ($p = 0.006$), Zn ($p < 0.001$) and Pb ($p = 0.007$) and Fe ($p < 0.001$). The cadmium concentration was found
 190 to be lower than those of: DPR background value and intervention values; Dutch target; UK allowable limits and other
 191 international standards. The cadmium concentration from this contaminated soil was lower than that reported in some
 192 literatures [31, 33-34]

193

194 Copper Concentration

195 The concentration of copper in the contaminated soil ranged from 41.96±3.44 to 59.095±0.02 mg/kg. The mean
 196 concentration of the copper in the contaminated soil was found to be 51.26±5.90 mg/kg. The Copper concentration of the
 197 sample, 51.26±5.90 mg/kg, was found to be significantly higher than that of the control soil, 0.91±1.28 mg/kg. Though in
 198 the sample from the mechanic workshop, the concentration of Cu was found to be statistically difference from the
 199 concentrations of Fe ($p = 0.000$), Cd ($p=0.006$); Cr ($p=0.036$); Ni ($p=0.012$) Zn ($p=0.000$) but did not differ significantly with
 200 that of Pb ($p = 1.000$). The Copper concentration was lower than the intervention value of DPR, EEC guideline, UK
 201 allowable limits Austria allowable limits and France but higher than the background value of DPR Dutch target value,
 202 Germany threshold values, Canadian criteria and Sweden allowable limits. The Cu concentration reported by [31,33-34]
 203 were all lower than the concentration found in this study..

204

205 Chromium Concentration

206 Chromium was present in all the samples of the contaminated soil analyzed, with a ranging concentration of 6.98±2.66 to
 207 10.15±0.006 mg/kg. The mean concentration of the chromium in the contaminated soil was found to be 9.03±1.07 mg/kg.
 208 There was no significant difference between the concentration of Chromium in the sample soil, 9.03±1.07 mg/kg and that
 209 of the control soil, 10.43±4.01 mg/kg. More so, the mean concentration of Cr differed significantly with the concentrations
 210 of Fe ($p < 0.001$); Cu ($p = 0.036$); Zn ($p < 0.001$) and Pb ($p = 0.046$). The concentration of Chromium was found to be
 211 lower than the allowable concentrations presented by most countries: France, Canada, Sweden, Austria, Germany, UK,
 212 Europe, Dutch and that of DPR. A Cr concentration of 12.9 mg/kg, which was higher was reported [32]

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216 Nickel Concentration

217 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
 218 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
 219 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
 220 significantly lower than the concentrations of those of Fe ($p = 0.001$); Cu ($p = 0.012$); Zn ($p = 0.001$) and Pb ($p = 0.016$).

The mean concentration of Nickel was found to be lower than the concentration limits stated by DPR, Austria, Germany, UK, France, Canada, Europe, Dutch and Sweden.

Zinc Concentration

The concentration of Zinc ranged from 107.92 ± 6.56 to 124.32 ± 0.127 mg/kg, though the mean concentration was found to be 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 found to be within the allowable concentration of some countries as shown on table 4 but exceeded that of Canada. The Zinc concentration reported by Abdullah et al [33] was higher than that in this study while Karim et al [32] reported a concentration of 123.03 mg/kg similar to 124.32 mg/kg in this study.

Lead Concentration

Lead was found present in all the samples obtained from the different spots of the mechanic workshop and was found to range from 19.14 ± 1.55 to 79.55 ± 4.97 mg/kg. The mean concentration of Pb, 49.97 ± 21.06 mg/kg, in the contaminated soil was found to be 3.99 ± 1.18 mg/kg for Pb. The concentration of Pb in the sample soil, 49.97 ± 21.06 mg/kg, was found to differ significantly from that of the control soil, 3.99 ± 1.18 mg/kg, at $p < 0.05$. However, the mean concentration of Pb was found to be 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 ($p < 0.001$). Though the concentration of Lead was lower than permissible limits stated by DPR, France, Austria, Germany, UK EEC and Dutch, it surpassed the allowable concentrations in Canada and Sweden. Karim et al [32] reported higher concentration of Pb.

The order of the mean concentration of heavy metal content in the sampled soil was found to be $Fe > Zn > Cu > Pb > Cr > Ni > Cd$ whereas, the concentration profiles of the metals in the soil of Iwegbue et al [41] follow the order $Fe > Pb > Cr > Zn > Ni > Cu > Cd$. In both study, Iron had the highest concentration while Cd had the least concentration. . More so, the order of the mean concentration of the heavy metals in the control soil was found to be $Fe > Cr > Zn > Pb > Cu > Ni > Cd$. The concentration order of Fe, Pb, Ni and Cd in the contaminated site and control of this study were found to be the same.

Iwegbue et al [29] reported lower concentrations of heavy metals from their control site as follows: 0.93 mg/kg for Cr; 1.8 mg/kg for Cu; 4.8 mg/kg Zn; 2.6 mg/kg for Pb; 1893 mg/kg for Fe, 4.1 mg/kg for Ni as Cd found was below their detection limit. While Ilemobayo and Kolade [6] reported heavy metal concentrations (Fe, 611.24mg/kg; Cd 0.00mg/kg; Cu 124 mg/kg; Cr 115 mg/kg; Ni 43.57mg/kg; Zn 693 mg/kg Pb 218 mg/kg) which were higher than the concentration in this study. The control concentration 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 [41]: 0.93 mg/kg for Cr, 1.8 mg kg⁻¹ for Cu, 4.8 mg kg⁻¹ for Zn, 2.6 mg kg⁻¹ for Pb, 1893 mg kg⁻¹ for Fe, and 4.1 mg kg⁻¹ for Ni, while Cd = BD: while Cr, Ni and Cd concentrations reported herein were higher than the concentration reported by Iwegbue et al [41].

282 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

283 ECDGE [34], DPR [22], CCME [35], Iwegbue et al [29].

285 3.3 Data analysis

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

294 The mean concentration of Fe was found to be significantly correlated with Cd ($r = -.711$; $p = .037$) and Ni ($r = 0.69$; $p =$
 295 $.043$). More so, Zn and Ni were found to be significantly correlated at $r = 0.85$; $p = .008$. There is an indication that Ni has
 296 the same source in the sample soil with Fe and Zn. Other parameters that correlate significantly to each other include: pH
 297 in KCl and pH in water ($r = 0.84$; $p = .009$), Carbonate content and Cr ($r = 0.68$, $p = .048$), Total organic matter and
 298 Carbonate content ($r = - 0.96$; $p < 0.001$).

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

301 Table 7: Correlation coefficient matrix for soil parameters

	Fe	Cd	Cu	Cr	Ni	Zn	Pb	pH		Cond	Carbonate	O.M
								pHH ₂ O	KCl			
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 ₂ O	.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.

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 found to be 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 found to be 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 [36-37]. Stratson [37] also mentioned that other sources of copper could be from: Leaching from oil coolers, leaks from cooling systems, external contaminates and from excessive wear. Copper is reported to have originated from additives, such as anti-wear and corrosion inhibitors additives, that were added to engine oil used in the crankshaft of the car [38-40]. 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

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 category	Low cont.	low cont.	Moderate cont.	low cont.	low cont.	low cont.	low cont.	

The values of the potential ecological risk factor of the different in the mechanical workshop under study, 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 (2017) present on (table 1), the potential ecological risk factor of each heavy metal on (table 1), all the heavy metals studied were found to have low potential ecological risk factor.

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

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	

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 found to be negative except for Cadmium that the metal concentration was below detection limit. The maximum I_{geo} of the metals under consideration were as well 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).

Geo- accumulation index of the heavy metals of the contaminated soil

[illegible]

352
353
354
355

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

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 found to be Fe > Zn > Cu > Pb > Cr > Ni > Cd while the order of the mean concentration of the heavy metals in the control soil was found to be 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 found to be the same. The results showed that the concentrations of the heavy metal in the soil samples were below the intervention concentration stated by DPR. Soil pollution assessment using C_d , RI and I_{geo} indices confirmed the soil in the mechanic workshop is uncontaminated. Thus, this particular mechanic workshop can be considered uncontaminated.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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