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Impact of Automobile Repair Activities on Physicochemical and Microbial Properties of Soils in Selected Automobile Repair Sites in Abuja, Central Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author CIE designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author CIN managed the analyses of the study. Author LOO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This research is aimed at evaluating the impact of activities carried out in automobile repair sites on quality of soils in the area. To achieve this target, soil samples were collected from five sampling points in each of the three selected sites (Apo, Kugbo and Zuba) to a depth range of 0 -15 cm using a stainless hand dug auger. Results of analyses of physicochemical properties pH, % porosity, electrical conductivity, particle size distribution, sulphate, chloride, nitrate and microbial contents of the soil samples indicate that most of the values exceeded those of control values. Levels of heavy metals in soils were determined using Automated Atomic Absorption Spectrophotometer (AAS). The results of the analysis revealed a decreasing trend in heavy metal contents (mg/kg) in soil in the three studied automobile repair sites as follows; Apo site: Cu (7668) > Zn (5360) > Cr (1174) > Fe

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(467) > Pb (333) > Ni > (196) > Cd (10.6); Kugbo site: Zn (1587) > Cu (1043) > Cr (783) > Ni (234) > Fe (217) > Pb (170) > Cd (9.47) and Zuba site: Zn (1190) > Cr (767) > Cu (512) > Fe (279) > Pb (250) > Ni (127) > Cd (10.4). Comparative analysis reveals that values of the studied heavy metals have exceeded those of control values and background values of some international regulatory bodies. Pearson's correlation analysis reveals that some of the heavy metals had very strong correlations with one another and with some of the physicochemical properties of the soil. This indicates that the studied heavy metals have the same origin, mutual dependence and identical behaviors.

Keywords: AAS; automobile repair sites; heavy metals; soil; physicochemical properties; statistical analysis.

1. INTRODUCTION

Heavy metal contamination refers to the excessive deposition or discharge of toxic metal(s) in soil, sludge, sediments or water as a result of anthropogenic activities [1]. Soil contamination associated with heavy metal has become a major environmental problem in most developing and developed countries in the world especially the potential health and ecological risk associated with such contamination [2-4]. Heavy metals are one of the most serious pollutants in natural environment because of their toxicity, persistence, wide spread sources, non-biodegradable, bioaccumulation properties and other negative effects they have on soil quality, biota and ecosystem at large [5-7]. Heavy metals are natural components of the earth crust which cannot be degraded nor destroyed completely [8-9]. Examples of heavy metals include: Zinc, Manganese, Cadmium, Lead, Copper, Nickel, Antimony, Arsenic, Cobalt, Tin, Vanadium, Platinum etc. Due to rapid industrialization and economic development, heavy metals have been increasingly introduced in the environment through various pathways which include application of pesticides, herbicides, fertilizers, untreated sludge and sewages on farm lands. Also, irrigation, river run off, atmospheric deposition and industrial activities like: metal mining, smelting of metals, combustion of coal, leaded gasoline, spillage of petroleum products, paints, electroplating, refining refinishing of by-products and automobile repairs [4,10-13].

In Nigeria, "automobile repair sites" are places where various automobile repairs are carried out such as; welding and fabrication, soldering, car battery recharging, scrapping, spraying and painting of vehicle parts, gear box recycling, panel beating of scratched vehicles, discharge of condemned petroleum products (oils, greases, hydraulics fluids) etc [14-15]. These activities tend to release various heavy metal containing wastes into the environment vis-a-viz when discharged indiscriminately in soil. Heavy metal contamination in soil does not only persist in soil but also have wide range of distribution and strong latency [16-17]. It has been reported that absorption and bioaccumulation of heavy metals in humans can lead to the following health issues; liver and kidney damage, neurotoxic effects in children, bone effects and fractures, damages of circulatory and nerve tissues, etc [18-24]. Heavy metal contamination in and around automobile repair sites have been extensively studied [25-32].

In this study the impact of automobile repair activities on the quality of soils in and around some selected automobile repair sites in Abuja were assessed. Physicochemical properties like pH, electrical conductivity, sulphate, chloride, nitrates and microbial properties of soil samples from these sites as well as levels of heavy metal contents were all evaluated. Pearson's correlation coefficient matrix was also conducted to determine the origin of the various heavy metals in soil. The study was conducted in November, 2015.

2. MATERIALS AND METHODS

2.1 Description of Study Area

The study area Abuja is situated in the North Central part of Nigeria. The City was made the Federal Capital Territory in 1991. Geographically, Abuja lies on the coordinates of latitude 9°40'N and 9°29'E and falls within the Guinea forest – Savannah mosaic zone in the West Africa sub-region. The automobile repair sites chosen for the study were each drawn from three major districts in Abuja Municipal Area Council namely: Apo in Gudu district, Kugbo in Kugo district and Zuba in Madalla district. The geological map of the study area is presented in Fig. 1.

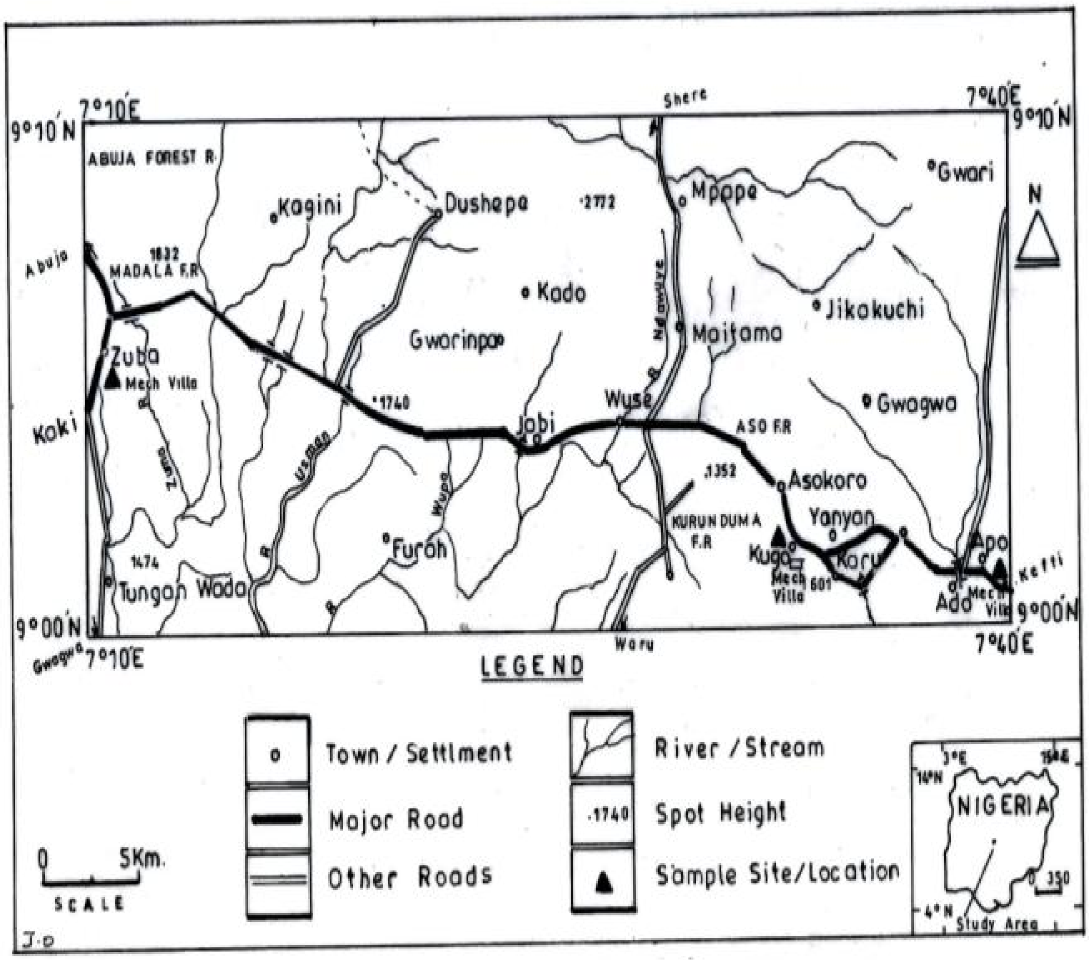

Fig. 1. Geological Map of Study Sites

2.2 Soil Sampling

Soil samples were randomly collected with a stainless hand dug auger up to a debt range of 0 -15 cm with five sampling points in each of the three automobile repair sites investigated. A controlled sample was also collected from a distance approximately 100 km where neither industrial nor commercial activities take place. The sampled soils were enclosed in separate dry new polyethylene nylon bags and taken to the laboratory for analysis.

2.3 Quality Control

All laboratory glass wares used during the analysis were of high quality and Pyrex. Also, they were thoroughly washed and air dried prior to their various uses. The reagents used were all of analytical grade. Working standard solutions for the heavy metals were prepared from their stock solutions of 100 ppm. The respective absorbencies of all the standard solutions of each investigated heavy metal were determined using Automated Atomic Absorption Spectrophotometer (AAS) with model Unicam 969 Solar according to the method described by (AOAC 1990). The standard calibration curves were obtained for concentration against absorbance for each sample. Triplicate samples were also run to ensure high precision of results.

2.4 Sample Preparation and Digestion

Soil samples were first dried in an open air after which stones and debris present were removed through handpicking. The respective samples were further crushed in an acid pre washed mortar and pestle, sieved to an aperture size of 338 µm with a stainless laboratory sieve with make Endecott's Limited London England serial number 489494. Soil digestions were done in accordance with the methods by [25,33].

Table 1. Physicochemical parameters and methods of analyses

Parameter	Method	Reference
Heavy metal	Atomic Absorption Spectrophotometer (AAS)	[34]
pH		[35]
% Porosity		[36]
Particle size distribution	Hydrometer method	[37]
Total coliform count		[38]
Electrical conductivity		[35]
Chloride		[39]
Sulphate	Precipitation method	[39]
Nitrate		[39]

2.5 Statistical Analyses

Statistical analysis was done using IBM SPSS statistics 16.0software. Descriptive statistics was carried to determine the mean, range and standard deviation while Karl Person correlation coefficient was used in determination of correlation between metals and with the physicochemical properties of the soil.

3. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Physicochemical Contents of Studied Soil

The accumulation of certain heavy metals in sediments had been reported to be directly or indirectly controlled by redox conditions either through a change in the redox state or speciation [40]. The result of the study revealed that highest pH value of 7.88 was recorded in a point in Kugbo automobile repair site while the least value of 7.10 was also recorded in Zuba automobile repair site. A decreasing trend in the mean values of pH in the investigated automobile repair site were observed to follow the sequence of Kugbo site (7.548) > Apo site (7.26) > Zuba site (7.20). This depicts that soil samples from all the sites are slightly basic which could also be attributed to anthropogenic activities like indiscriminate discharge of used electrolytes on the soil. The results of the pH as recorded were also found to be higher than those reported by [10,41]. Importantly, pH plays significant role in solute concentration and in sorption and desorption of contaminants in soil [42].

Results of percentage porosity of soil as shown in Table 2 reveal that all the values of percentage porosity in the investigated soils were above average with least and highest values of 59.8% and 66.4% recorded in Zuba and Kugbo automobile repair sites respectively. A decreasing order of mean values of % porosity in all the sites can be written as Zuba site (61.9%) > Apo site (60.5%) > Kugbo site (59.4%). High % porosity in soil could be traceable to some automobile repair activities like welding and fabrication, panel beating of automobile parts, indiscriminate discharge of metal scraps, lubricants, hydraulics, battery electrolytes and petroleum products. Electrical conductivity recorded mean values of 281 µs/cm, 383 µs/cm and 384 µs/cm in Kugbo, Zuba and Apo automobile repair sites respectively. These mean values also exceeded that of control site (206 µs/cm) which possibly indicates anthropogenic influence on the quality of the soil. High values of electrical conductivity could be traced to deposit of heavy metals which are also good electrical conductors. In addition, results of the study showed that values of particle size distribution in all the sites ranges from (349 - 596) µm as shown in Table 2. Mean values of particle size distribution in the investigated sites were observed to follow a decreasing order of Zuba site (576 µm) > Apo site (563 µm) > Kugbo site (428 µm) respectively which also exceeded that of control value and thus depicts anthropogenic influence. High particle size distribution could also be linked to some automobile repair activities like scrapping and refurbishment of vehicles, spraying and painting etc.

3.2 Results of Anionic Contents in Studied Soils

Results of anionic contents in investigated soil as shown in Table 2 reveal that values of sulphate fluctuated between 0.51 – 0.68 mg/g, 0.18 – 0.57 mg/g and 0.45 – 0.65 mg/g in Apo, Kugbo and Zuba automobile repair sites respectively. High sulphate content is soil could be attributed to automobile repair sites activities like indiscriminate discharge of lubricants, electrolytes, oil sludge and used petroleum products. Chloride contents in investigated soils recorded a decreasing mean values in the order of Apo site (0.110 mg/g) > Zuba site (0.097 mg/g) > Kugbo site (0.033 mg/g). Some automobile repair activities that could have added to chloride content in soil include: Changing and repair of automobile air condition gases, radiator coolants etc. Nitrates contents in investigated soil fluctuated between 0.09 – 0.25 mg/g in Apo site, 0.09 – 0.35 mg/g in Kugbo site and 0.02 – 0.11 mg/g in Zuba site. Total coliform count unit (cfu/g) as shown in Table 2 recorded some values that exceeded those of control 160 cfu/g and standard acceptable count of 100 cfu/g. comparatively the values of total coliform count unit in all the sites fluctuate between 110 – 230 cfu/g in Apo site, 90 – 590 cfu/g in Kugbo site and 90 – 250 cfu/g in Zuba site respectively. These values also indicate various levels of microbial contamination in the investigated automobile repair sites.

3.3 Heavy Metal Contents in Studied Soils

Results of heavy metal distribution in soil in the investigated automobile repair sites are shown in Table 3. From the results, copper is the most abundant heavy metal with its values ranging from (217-22000) mg/kg. Copper recorded mean values of 7668 mg/kg, 1043 mg/kg and 512 mg/kg in Apo, Kugbo and Zuba automobile repair sites respectively. These values were found to be higher than those reported by [43-46]. These values also exceeded that of control 37.3 mg/kg, background value of 36 mg/kg by (DPR, 2002) and background values of some international regulatory bodies listed in Table 4. Although copper is an essential mineral, high content of it could lead to serious health problem. Values of zinc were in the range of (410-8421) mg/kg in all the sites. Mean values of zinc in the investigated automobile repair sites decreases in the order of Apo site (5360 mg/kg) > Kugbo site (1587 mg/kg) > Zuba site (1190 mg/kg). These values were observed to be very high especially when compared with values from control, DPR and those of some international regulatory bodies (Table 4). Also the recorded values were also seen to have exceeded those reported by [15,47-48].This possibly suggest anthropogenic influence which could be from activities of auto mechanics like scrapping and painting of vehicles, attrition of vehicle tires, indiscriminate discharge of lubricating oil containing zinc additives like zinc dithiophosphates etc.

More so, nickel recorded a decreasing mean values in the order of Kugbo site (234 mg/kg) > Apo site (196 mg/kg) > Zuba site (127 mg/kg). These values are higher than those from control (108 mg/kg), background values of DPR (35 mg/kg), South Africa (91 mg/kg), France (50 mg/kg), China (50 mg/kg), EU guidelines (75 mg/kg) and FAO/WHO guidelines (50 mg/kg). They are also higher than those reported by some researchers [15,49-52]. Nickels entering the natural environment are mainly through human activities like discharge of used batteries, diesel, grease, lubricating oils, tanks storing petroleum products etc. High concentration of nickel in the body can displace vital elements from the enzymes in humans system which could result in the breakage of metabolism route and subsequently result to heart and liver disease [53] Cadmium contents in all the investigated sites were also observed to be in the range of (1.23 - 19.2) mg/kg. Cadmium also recorded mean values of 10.5 mg/kg, 10.4 mg/kg and 9.47 mg/kg in Apo, Zuba and Kugbo automobile repair sites respectively. Comparatively, these values were higher than DPR background values of 0.80 mg/kg, international regulatory bodies (Table 4) and those reported by [54-56]. Cadmium in soil could be from condemned batteries, pigments, paints, etc. Some health problems associated with cadmium poising include: chronic renal, anemia, cancer, lung infection, cardiovascular diseases, respiratory system disorders, skin and tooth decay among others [22].

Furthermore, lead was observed to have mean concentrations of 333 mg/kg, 250 mg/kg and 170 mg/kg in Apo, Zuba and Kugbo automobile repair sites. When compared with values established by some regulatory bodies (Table 4) the recorded values were observed to higher than those reported by [57-60]. Lead enters the soil through some processes like; welding and soldering, gases from vehicle exhaust, car paints, dry cell batteries, leaded gasoline etc. Lead in human blood can replace calcium in the bones and is capable to create blood, bone, enzyme and nerve disorders. It can lead to general weakness, muscle relaxation, neurotic disorders, anemia, insomnia and skin discoloration [22]. Chromium fluctuated between (288 – 1174) mg/kg in all the sites. A decreasing trend in mean concentration of chromium in the three automobile repair sites is seen to follow the order of Apo site (1174 mg/kg) > Kugbo site (788.6 mg/kg) > Zuba site (766.8 mg/kg). These values were also higher than the acceptable values of some regulatory bodies as shown in Table 4 and those reported by [52,59,61]. Chromium can enter the soil through any of the following processes: Discharge of oils and greases, scrapping of vehicle parts, spraying of paints, pigments containing chromium, air conditioning coolants, brake emission, petroleum products, etc. Although chromium is essential to the body, high content of it especially in form of chromium (VI) is toxic to human system. Mean values of iron were seen to follow a decreasing order of Apo site (467 mg/kg) > Zuba site (279 mg/kg) > Kugbo site (217 mg/kg) with a general value range of (145 – 561) mg/kg. These values were observed to be lower than those reported by [33,62-63].

3.4 Karl Pearson's Correlation Analysis

Correlation analysis which is statistical tool that help to measure and analyze the degree of relationship between two of more variables. This enables us to have an idea about the degree and direction of the relationship between the variables. Correlation coefficient data is also a vital which can be used to deduce the possible source(s) of heavy metals in soil. Mathematically, Karl Pearson's correlation coefficient can be stated as:

$$r = \frac{N\sum XY - \sum X \sum Y}{\sqrt{N\sum X^2 - \left(\sum X\right)^2}\sqrt{N\sum Y^2 - \left(\sum Y\right)^2}} \quad - \quad - \quad - \quad - \qquad (1)$$

where N = number of samples; X,Y are the single samples indexed;

The correlation coefficient matrix for heavy metals present in soil samples from the various automobile repair sites investigated are shown in Tables 5, 6 and 7. Pearson correlation coefficients were implored for all the sites. The results shown in Table 5 indicate that strong positive correlation exist between the following metals like Pb/Cr (r = 0.94) evidencing that in 94% of cases, the correlation of both heavy metals increases simultaneously. Other strong positive correlation were seen among Zn/Ni (r = 0.88), Cr/Ni (r = 0.96), Cr/Zn (r = 0.75), Cd/Zn (r = 0.76), Ni/Cd (r =0.60) and Cu/Pb (r = 0.55) respectively. This indicates that the studied heavy metals have identical behavior, are mutually dependence and are also from the same source(s). Strong negative correlations also exist between some physicochemical properties of the soil samples and some heavy metals as follows:

> Cd/pH (r = -0.88), SO_4^{2-}/NO_3^- (r = -0.96), Zn/pH (r = -0.87), Cd/PSD (r = -0.86), Cu/SO_4^{2-} (r = -0.82), Cd/SO_4^{2-} (r = -0.77), Ni/pH (r = -0.76), Fe/%P (r = -0.69), Cu/pH (r = -0.65) and Cr/pH (r = -0.59). This strong negative correlation indicates that the sources of the metal were from different origin.

Results of correlation coefficient matrix of Kugbo site shown in Table 6 reveals that strong positive correlations exist between heavy metals in the sampled soils as Pb/Cd (r = 0.87), Zn/Cu (r = 0.81) and Pb/Zn (r = 0.53). Also among metals and physiochemical properties like Fe/pH (r = 0.93), Pb/%P (r = 0.80), Fe/%P (r = 0.73), Zn/ SO_4^{2-} (r = 0.79), PSD/ Zn (r = 0.74), Cu/ SO_4^{2-} (r = 0.70) and Zn/Cl^- (r = 0.61). Strong negative correlation also occurred between heavy metals like Fe/Cr (r = -0.93), Ni/Zn (r = -0.72), Cd/Cu (r = -0.74) and Pb/Cu (r = -0.58) and with physiochemical properties of soil like Cr/pH (r = -0.91), Ni/PSD (r = -0.87), PSD/Cd (r = -0.69), Ni/NO_3^- (r = -0.65) and Cu/EC (r = -0.63). Strong positive correlations were also seen among some heavy metals in Zuba site as follows: Cu/Cr (r = 0.95), Pb/Zn (r = 0.65), Cr/Ni (r = 0.53) and with some physiochemical properties like Fe/EC (r = 0.96), Zn/pH (r = 0.94), Zn/PSD (r = 0.94), Pb/%P (r = 0.69), Pb/PSD (0.65), Zn/ SO_4^{2-} (r = 0.66). Major strong negative correlation among heavy metals like Ni/Zn (r = -0.87), Cd/Pb (r = -0.84), Cr/Zn (r = -0.65), Cu/Zn (r = -0.64) and Cu/Fe (r = -0.63). Also between heavy metals and some physiochemical properties like Ni/pH (r = -0.94), Pb/Cl^- (r = -0.89), Ni/PSD (r = -0.88), Fe/%P (r = -0.80), Cr/pH (r = -0.75), Cu/pH (r = -0.75), Cd/%P (r = -0.74), Cu/NO_3^- (r = -0.65) and Cu/EC (r = -0.61) respectively. The correlation coefficients between concentrations of various heavy metals and those of physiochemical properties of the soil samples shows strong linear relationship between the variables, which probably indicate their common origin or their common sink in the soils. Presence of heavy metals in these soils could also be attributed to indiscriminate discharge of heavy metal containing wastes generated from various automobile activities in soils in and around the investigated automobile repair sites.

Table 2. Physiochemical properties of soil samples from investigated automobile repair sites

Sample points	pH	Percentage porosity (%)	Electrical conductivity (µs/cm)	Particle Size distribution (µm)	Sulphate (mg/g)	Chloride (mg/g)	Nitrate (mg/g)	Total coliform count (cfu/g)
A_1	7.20	59.6	388	511	0.60	0.05	0.15	230
A_2	7.19	62.1	391	568	0.51	0.11	0.25	210
A_3	7.22	60.1	386	561	0.63	0.13	0.15	140
A_4	7.39	60.9	369	576	0.68	0.12	0.09	110
A_5	7.31	59.7	388	596	0.68	0.08	0.12	120
$\bar{X} \pm SD$	7.26±0.09	60.5±1.04	384±8.79	562±31.7	0.51±0.26	0.10 ±0.34	0.15±0.58	162±54.5
Range	7.19-7.39	59.6-60.9	369-391	511-596	0.51-0.68	0.05-0.11	0.09-0.25	110-230
K_1	7.49	59.8	219	459	0.57	0.06	n.d	360
K_2	7.88	63.4	230	349	0.29	n.d	n.d	590
K_3	7.77	66.4	310	458	0.40	0.11	0.07	450
K_4	7.41	59.8	289	474	0.18	0.09	0.11	180
K_5	7.19	60.2	355	400	0.34	n.d	n.d	90
$\bar{X} \pm SD$	7.55±0.28	61.9±2.92	281±56.6	428±525	0.35±0.14	0.87±0.25	0.09±0.35	334±202
Range	7.19 -7.88	59.8-66.4	219-355	349-474	0.18-0.57	0.06-0.11	0.07-0.11	90-590
Z_1	7.10	59.3	389	527	0.45	0.11	0.02	140
Z_2	7.19	56.8	388	556	0.58	0.15	0.09	250
Z_3	7.19	60.8	367	587	0.65	0.13	n.d	80
Z_4	7.24	59.7	391	600	0.62	0.09	n.d	80
Z_5	7.33	60.4	380	610	0.59	0.11	0.11	90
$\bar{X} \pm SD$	7.20±0.09	159±1.57	383±9.87	576±34.2	0.58±0.77	0.12 ±0.23	0.07 ±0.49	128±72.6
Range	7.19-7.33	56.8-60.8	367-291	527-610	0.45-0.65	0.09-0.15	0.02-0.11	80-250
Control	7.29	56.6	206	366	0.16	n.d	n.d	160

A: Apo automobile repair sites; K: Kugbo automobile repair sites; Z: Zuba automobile repair sites; n.d: not determined

Table 3. Heavy metal contents (mg/kg) of sampled soils from the three automobile repair sites

Sample points	Fe	Zn	Cu	Ni	Pb	Cr	Cd
A_1	561	8200	1677	238	96.4	1117	12.5
A_2	426	5288	22000	212	357	1173	11.5
A_3	423	8421	12830	402	967	1916	10.6
A_4	411	847	219	48.6	194	814	8.90
A_5	512	4045	1616	80.5	51.7	848	8.90
$\bar{X}$±SD	467±66.4	5360±3144	7668±9488	196±141	333±373	1174±444	10.5±1.59
Range	411-561	847-8421	219-22000	48.6±402	51.7-967	813- 915	8.94±12.5
K_1	203	2869	3144	195	89.6	911	1.20
K_2	320	719	407	370	201	288	10.2
K_3	259	2016	340	110	316	726	15.2
K_4	145	1441	1017	178	15.7	915	1.50
K_5	157	890	306	318	225	1074	19.2
$\bar{X}$±SD	217±73.3	1587±879	1043±1210	234±107	170±118	783±303	9.47±8.07
Range	145-320	719-2869	340-3144	110-370	15.7-316	288-1074	1.23-19.2
Z_1	302	410	686	187	199	830	10.2
Z_2	331	976	351	148	58.3	764	12.5
Z_3	195	1010	956	127	249	1120	9.50
Z_4	306	1710	352	126	443	630	8.80
Z_5	260	1845	217	48.0	298	491	11.1
$\bar{X}$±SD	279±53.4	1190±589	512±303	127±50.7	250±140	767±236	10.4±1.41
Range	195-331	410-1845	217-956	48.0-187	58.3-443	491-1120	8.84-12.5
C_T	2.45	73.4	37.3	108	102	1108	n.d
B_T	5000	140	36.0	35.0	85.0	100	0.800
I_V	n.l	720	190	210	530	380	17.0

A: Apo automobile repair sites; K: Kugbo automobile repair sites; Z: Zuba automobile repair sites; C_T: control sample; n.d: not determined; n.l: no limit; B_T: background values of DPR (2002); I_V: Intervention value of DPR (2002)

Table 4. Background values of heavy metals of some international regulatory bodies

Countries	Zn	Cu	Ni	Pb	Cr	Cd	References
Tanzania	150	200	100	200	100	1	[64]
South Africa	240	16	91	20	6.5	7.5	[65]
France	n.a	100	50	100	n.a	2	[66]
China	250	100	50	80	200	0.5	[67]
Sweden	n.a	40	30	40	60	0.4	[15]
EU Guidelines	300	140	75	300	150	3	[68]
FAO/WHO Guidelines	300	100	50	100	100	3	[69]

n.a: not available

Table 5. Pearson's correlation coefficient matrix of heavy metals in apo automobile repair sites (n = 5)

	Fe	Zn	Cu	Ni	Pb	Cr	Cd	pH	EC	%P	PSD	SO_4^{2-}	Cl^-	NO_3^-
Fe	1.00													
Zn	0.40	1.00												
Cu	-0.49	0.33	1.00											
Ni	-0.07	0.88*	0.53	1.00										
Pb	-0.57	0.48	0.55	0.83	1.00									
Cr	-0.28	0.75	0.52	0.96**	0.94*	1.00								
Cd	0.38	0.76	0.41	0.60	0.12	0.37	1.00							
pH	-0.27	-0.87	-0.65	-0.76	-0.35	-0.59	-0.88*	1.00						
EC	0.44	0.72	0.52	0.49	0.11	0.34	0.59	-0.85	1.00					
%P	-0.69	-0.36	0.71	-0.10	0.11	-0.07	0.06	-0.08	-0.07	1.00				
PSD	-0.51	-0.64	0.07	-0.46	0.01	-0.24	-0.86	0.56	-0.21	0.26	1.00			
SO_4^{2-}	0.08	-0.41	-0.82	-0.41	-0.16	-0.26	-0.77	0.80	-0.59	-0.64	0.38	1.00		
Cl^-	-0.61	0.30	0.69	0.62	0.68	0.63	0.48	-0.44	-0.03	0.59	-0.33	-0.62	1.00	
NO_3^-	-0.14	0.41	0.91*	0.43	0.24	0.31	0.64	-0.80	0.70	0.64	-0.16	-0.96**	0.53	1.00

EC: Electrical Conductivity; %P: Percentage Porosity; PSD: Particle Size Distribution; Significant /r/(p < 0.05); ** (p < 0.01)*

Table 6. Pearson's correlation coefficient matrix of heavy metals in Kugbo automobile repair sites (n=5)

	Fe	Zn	Cu	Ni	Pb	Cr	Cd	pH	EC	%P	PSD	SO_4^{2-}	Cl^-	NO_3^-
Fe	1.00													
Zn	-0.14	1.00												
Cu	-0.22	0.81	1.00											
Ni	-0.27	-0.72	-0.28	1.00										
Pb	-0.53	-0.20	-0.58	0.05	1.00									
Cr	-0.93*	0.33	0.28	-0.37	-0.27	1.00								
Cd	0.18	-0.51	-0.74	0.28	0.87	0.00	1.00							
pH	0.93	0.00	-0.17	-0.02	-0.38	-0.91*	-0.04	1.00						
EC	-0.50	-0.38	-0.63	-0.10	0.39	0.56	0.71	-0.55	1.00					
%P	0.73	-0.06	-0.51	-0.24	0.80	-0.58	0.47	0.77	0.06	1.00				
PSD	-0.13	0.74	0.49	-0.87	-0.40	-0.11	-0.69	0.21	-0.35	0.08	1.00			
SO_4^{2-}	0.08	0.79	0.70	-0.27	0.17	0.23	-0.09	-0.02	-0.31	-0.01	0.18	1.00		
Cl^-	-0.20	0.61	0.19	-0.97**	-0.14	0.23	-0.38	0.13	0.03	0.27	0.92*	0.06	1.00	
NO_3^-	-0.36	0.06	-0.19*	-0.65	-0.33	0.18	-0.32	-0.02	0.24	0.08	0.66	-0.54**	0.79	1.00

EC: Electrical Conductivity; %P: Percentage Porosity; PSD: Particle Size Distribution; Significant /r/(p < 0.05);** (p < 0.01)*

Table 7. Pearson's correlation coefficient matrix of heavy metals in Zuba automobile repair sites (n=5)

	Fe	Zn	Cu	Ni	Pb	Cr	Cd	pH	EC	%P	PSD	SO_4^{2-}	Cl^-	NO_3^-
Fe	1.00													
Zn	-0.10	1.00												
Cu	-0.63	-0.64	1.00											
Ni	0.37	-0.87	0.59	1.00										
Pb	-0.22	0.65	-0.14	-0.39	1.00									
Cr	-0.53	-0.65	0.95*	0.53	-0.32	1.00								
Cd	0.41	-0.18	-0.40	-0.05	-0.84	-0.21	1.00							
pH	-0.04	0.94*	-0.75	-0.94*	0.43	-0.75	0.10	1.00						
EC	0.96*	-0.03	-0.61	0.35	0.03	-0.60	0.16	-0.02	1.00					
%P	-0.80	0.34	0.36	-0.44	0.69	0.12	-0.73	0.22	-0.59	1.00				
PSD	-0.42	0.94*	-0.35	-0.88*	0.65	-0.37	-0.30	0.85	-0.36	0.53	1.00			
SO_4^{2-}	-0.48	0.66	-0.03	-0.58	0.34	0.09	-0.20	0.52	-0.53	0.66	0.82	1.00		
Cl^-	-0.02	-0.45	0.24	0.24	-0.89*	0.49	0.72	-0.32	-0.29	-0.59	-0.36	0.11	1.00	
NO_3^-	0.26	0.32	-0.69	-0.55	-0.43	-0.59	0.83	0.60	0.10	-0.38	0.17	0.00	0.33	1.00

EC: Electrical Conductivity; %P: Percentage Porosity; PSD: Particle Size Distribution; Significant /r/(p < 0.05);** (p < 0.01)*

3.5 Variation in Level of Heavy Metal in the Study Area

In order to have a comparative knowledge about the level of heavy metal contamination in soil in and around the studied mechanic villages, data obtained from these sites were compared with background values established by DPR 2002 and other standard regulatory bodies as shown in Table 4. The background value of an element is the maximum level of the element in an environment beyond which the environment is said to be polluted by the element [70]. All the investigated heavy metals but iron had values greater than the maximum acceptable limit of these bodies. This implies that the auto mechanic sites had various degrees of contamination which could be traceable to anthropogenic activities. A trend of variation of heavy metal contents in soils in three automobile repair sites can be summarized as: Apo site: Cu > Zn > Cr > Fe > Pb > Ni > Cd; Kugbo site: Zn > Cu > Cr > Ni > Fe > Pb > Cd; Zuba: Zn > Cr > Cu > Fe > Pb > Ni > Cd. The result of the study also reveals that Cu, Zn and Cr had very high variation and standard deviation. Pb, Ni and Fe showed moderate variation while Cd showed the least variation. Large variations imply great heterogeneity of metals in soil while low variations show more or less homogeneous distribution of heavy metals in soil. This could be traced to different levels of contamination caused by varying degrees of automobile wastes discharge in soils [71].

4. CONCLUSION

The results obtained from the study supply valuable information on various levels of heavy metal contents in soils in and around the three major automobile repair sites in Abuja, Nigeria. The results also showed the distribution pattern of the studied heavy metals whose values in all the sites with the exception of iron were found to have exceeded the background or pre-industrial reference value(s) provided by some world regulatory bodies. The high values recorded could be attributed to anthropogenic activities like indiscriminate discharge of heavy metal containing wastes generated from various auto-mechanic practices. A trend of variation of heavy metal contents in soils in three automobile repair sites can be summarized as: Apo site: Cu > Zn > Cr > Fe > Pb > Ni > Cd; Kugbo site: Zn > Cu > Cr > Ni > Fe > Pb > Cd and Zuba: Zn > Cr > Cu > Fe > Pb > Ni > Cd. Statistical analysis conducted using Pearson's correlation coefficient on the variables revealed that these heavy metals had strong correlation with each other and with some of the physicochemical properties of the soil. They also showed a high approximation to perfect correlation indicating a strong linear relationship between the measured variables.

5. RECOMMENDATION

Based on the findings of this research work, it is therefore suggested that systematic investigation should be conducted in order to check the rate of heavy metal loading and change in the quality of soil in and around these automobile repair sites. Indiscriminate discharge of heavy metal containing wastes generated from auto mechanic repairs on soil in particular and environment at large should be totally stopped. Better still, these wastes should be collected, recycled and properly disposed in order to save our environment from harmful pollutants. Also, adequate sensitization on the damages of indiscriminate discharge of waste in the environment should be made by relevant authorities and a more environment friendly automobile mechanic village concept and proper waste management encouraged.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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