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EVALUATION OF PHYSICOCHEMICAL PROPERTIES AND HEAVY METAL LEVELS IN SOILS FROM SELECTED AUTO MECHANIC WORKSHOPS IN IMO STATE, NIGERIA

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration among all authors. Authors JNA and ACU designed the study, performed the statistical analysis, wrote the protocols, managed the literature searches, interpretation and wrote the manuscript. Authors JNA, RIO and CMD managed the analysis of the study and supervised collection of soil samples from the field. All authors read and approved the final manuscript.

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ABSTRACT

Environmental contamination as a result of indiscriminate disposal of spent engine is a serious global issue. The study was carried out to evaluate the physicochemical properties and selected heavy metal levels in soils collected from auto mechanic workshops in Owerri, Okigwe and Orlu zones of Imo State. A total of 27 soil samples (9 from each zone) were randomly collected from a depth of 0 – 20 cm with an improvised soil auger. At each auto mechanic workshop, three sampling points were mapped out for sample collection and homogenized to obtain a composite. Physicochemical properties of soil were analyzed using standard analytical protocols while metal analysis was carried out using AAS. Results showed that all the physicochemical properties of the soil were marginal when compared to the control across the zones. The textural class was sandy loam and moderately acidic. Heavy metal (Pb, Cr, Cd, Zn, Al, Fe, Cu, Ni, Co, and As) were detected in the soil at varying levels but were observed to be below the permissible limits set by the DPR in the studied sites. Pollution index showed that the soil quality was moderately contaminated with moderate potential ecological risk factor in all the sites. The study revealed a gradual buildup of heavy metals in the sampled areas and therefore underscores the need for proper disposal of spent engine oil to avert heavy metals toxicity in the soil as most of these metals are leached down the profile thereby polluting underground waters and posing danger to human health. Continuous monitoring and the use of ecofriendly method (phytoremediation) to remediate the heavy metals are recommended.

Keywords: Physical; chemical; heavy metal; soil; auto-mechanics; Imo State.

1. INTRODUCTION

Soil is an important abiotic component of the ecosystem which serves as the medium for growth of plants and habitat to a large number of micro and macro organisms [1]. According to [2] the state of the soil is very essential as it determines the quantity and quality of produce from it. The economy of Nigeria is largely hinged on revenue from petroleum and its allied products which generate a number of wastes. In Nigeria as in many other countries, spent engine oil obtained after serving and subsequent draining of used oil from automobiles engines is one of the major soil contaminant.

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Spent engine oil is defined as any petroleum-based or synthetic oil that, through contamination, has become unsuitable for its original purpose due to the presence of impurities or loss of original properties [3]. According to [4], spent engine oil is viewed as any lubricating oil that has served its service properties in a vehicle, been drained off from the area of application and considered not fit for its initial purpose because it is contaminated by physical or chemical impurities. It has dark to brown color and has been reported to be harmful to the soil ecosystem [5]. As the engine oil is running while in the vehicle, it picks up a number of additional compounds and dirt from engine wear [6]. Because of the additives and subsequent contamination, spent engine oil has been considered to be more deleterious than crude oil [7]. The highly toxic PAHs found in spent engine oil have been implicated in indirect secondary effects like disruption of plant -water-air relationship [8].

In Nigeria, automobile workshops are sited in government allocated areas known as mechanic villages [9]. Activities carried out in these designated areas include but not limited to panel beating, vulcanizing, charging of car batteries, spray painting, repairs and servicing of motor vehicles [10]. They are equally used for other purposes such as agricultural, recreational, residential purposes [6]. Wastes emanating from these activities include spent engine oil, worn-out parts, packaging materials, used batteries, metal scraps and stripped oily sludge [2]. Unfortunately, these waste products are disposed indiscriminately by the artisans who know little about the resultant environmental harm. High generation/production of spent engine oil in these mechanic villages have been attributed to the increasing number of vehicles been serviced on a daily basis. Spent engine oil is considered as an ordinary waste by majority of the workers who dispose it indiscriminately on soil surface [11]. This practice of disposal into gutters, water drains, open plots and farms is common among the artisans [12]. Indiscriminate disposal of spent engine oil adversely affect plants, microbes and aquatic lives [13] because of the large amount of hydrocarbons and highly toxic polycyclic aromatic hydrocarbons contained in the oil [14]. Heavy metals such as vanadium, lead, aluminum, nickel and iron which are found in large quantities in used engine oil may be retained in soil, in form of oxides, hydroxides, carbonates, exchangeable cation and/or bound to organic matters in the soil [15].

More so, the engine oil thickness makes it possible to persist in the environment for an extensive period of time, resulting in the disruption of ecological integrity. Reports have illustrated the adverse impacts of spent engine oil that seep into water bodies through run-offs from rainfall as well as the persistence in soil layers [16]. There have also been indications of these compounds subsequently affecting aquatic and soil life forms [17].

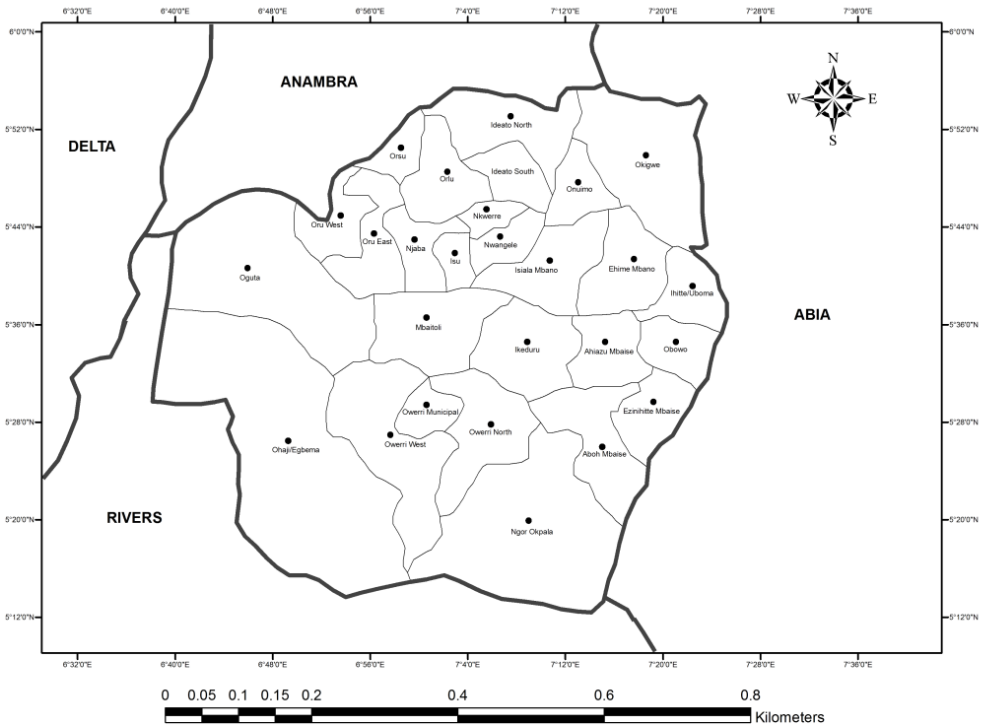
Imo State can be described as a hub for artisans in the business of auto repairs. The siting of these auto workshops in this State is highly unorganized and as a result they are located haphazardly around street corners and sometimes in front of residential areas. Due to the high level of contamination of the soil with used engine oils as a result of indiscriminate disposal by the artisans, there is the need to study the impact of these activities on the terrestrial ecosystem in order to create awareness on the hazards of exposure to these oils and subsequent environmental impacts (on soil). These rampant indiscriminate disposal of spent engine oil in Imo State has necessitated a study on the physicochemical and metal concentration of used motor oil in other to assess its potential impact on the environment to enable stakeholders and policymakers make informed decisions to address the problem which could be harmful to biota and the ecosystem at large.

2. MATERIALS AND METHODS

2.1 Study Area

The study was carried out in Imo State which lies within latitudes $5^0 15^1$ and $7^0 15^1$ North and longitudes $6^0 50^1$ and $7^0 25^1$ East. Imo state is bounded on the East by Abia state, on the West by Enugu State, on the North by Anambra state while Rivers state lies to the South. The state covers an area of 5100km^2. The capital is Owerri which is the largest city in Imo State [18].

Annual rainfall ranges from 1500 to 2200 mm per year. However, variations occur in rainfall amount from year to year. Temperatures are high and similar all over the state. The hottest months are January to March, with the mean annual temperatures above 20^0C. The mean daily maximum air temperatures range from 28^0C to 35^0C, while the mean daily minimum air temperature ranges from 19^0C to 24^0C. Imo State has a high humidity, an average annual relative humidity of 75% and it is highest in the rainy season when it rises to about 90%. Imo State is divided into three Agricultural zones by the Imo state Agricultural Development Program (ADP) based on the agro-ecological and cultural characteristics of the state [19]. The three zones are: Owerri zone, Okigwe zone and Orlu zone.



Map 1. Map of Imo State showing locations of sampled areas

2.2 Collection of Soil Samples

The study was carried out in two (2) stages, *viz*, Field and laboratory studies.

2.3 Field Studies

Soil samples were collected from the pre-selected auto mechanic workshops that were constantly receiving spent engine oil. Each zone was subdivided into three groups for sample collection. Each auto mechanic workshop was further divided into three quadrants from which soil samples were collected in a randomized method along a transect at 30m interval and labelled accordingly. The samples were collected with an improvised soil augur of approximately 7.5cm at a depth of 0 – 20 cm after the removal of the exposed surface and plant debris according to [20]. This depth was chosen because organic matter which is the major sorptive material of pollutants is found in significant quantities in surface soils hence the accumulation of pollutants at that region. Control soil samples were collected 5km away from auto mechanic workshops and labeled accordingly (Fig. 1.). The samples from each workshop were homogenized in a clean plastic bucket and a composite sample drawn from each. Auger soil samples were subsequently sieved with 2 mm sieve and used for soil physicochemical properties and metal determination. A total of twenty seven (27) batch soil samples were collected in all, 9 per zone.

2.4 Laboratory Analysis

Soil sample analysis was carried out at the soil laboratory of the International Institute of Tropical Agriculture (IITA), Ibadan following the method of [21].

For heavy metals determination, the prepared soil samples was digested with perchloric and nitric acid and Cd, Pb, Cu, Cr, Co, Mn, Fe, As, Ni and Zn was read using Atomic Absorption Spectrophotometer (AAS).

2.5 Method of Heavy Metal Determination

Heavy metals like lead, cadmium, nickel, arsenic and chromium were determined using double acid method of extraction and extraction acid read out with AAS.

The samples were mixed gently and homogenized and sieved through 2 mm mesh - sieve. The samples were first dried, and then placed in electric oven at a temperature of 40 °C approximately for 30 minutes. The resulting fine powder was kept at a room temperature for digestion.

Fig. 1. Composited Soil Samples Collected from the Study Area

2.6 Digestion of Soil Samples

1g of the oven dried sample was weighed using a top loading balance and placed in 250ml beakers separately to which 15ml of aqueous solutions (35% HC1, and 70% high purity HNOs in 3:1 ratio) was added. The mixture was then digested at 70% till the solution became transparent The resulting solution was filtered through whatman filter paper no 42 and into a 50ml dilute 50ml volumetric flask and diluted to mark volume using deionized water and the sample solution was analysed for concentration of selected metals using an atomic absorption spectrophotometer (Perkin-Elmer A Analyst 400).

2.7 Analysis of Soil Samples for Heavy Metals

AAS A Analyst 400 model was used in determining the content of metals in the previously digested soil samples. The nitrous oxide, acetylene gas and compressor were fixed and compressor turned on and the liquids trap blown to rid of any liquid trapped. The extractor and AAS control were turned on. The slender tube and nebulizer piece were cleaned with purifying wire and opening of the burner was cleaned with an arrangement card. The worksheet of AAS programming on the joined PC was opened and the empty cathode light embedded in the light holder. The light was turned on, beam from cathode adjusted to hit target zone of the arrangement card for ideal light throughput, at that point the machine was touched off. The fine was set in a 10ml graduated chamber containing deionizer water and yearning rate was estimated. The analytical blank was prepared and a series of calibration solutions of known amounts of analyte element (standard) were made. The blank and standards were atomized in turn and their responses were measured. A calibrator graph was plotted for each of the solutions after which the sample solutions were atomized and measured. The various metals concentration from the solution were determined from the calibration based on the absorbance obtained for the unknown samples.

2.8 Statistical Analysis

Descriptive statistics were conducted to determine the mean and standard deviations of investigated heavy metals in soil samples using IBM SPSS 25.0 software.

2.9 Evaluation of Ecological Risk of Heavy Metals in the Sampled Soils

Pollution indices are tools widely used to quantify the extent of environmental contamination by heavy metals and the likely risks organisms (microbes, plants, animals and humans) are prone to as a result of heavy metals contamination of polluted soil. In this study, the following indices were applied to estimate the extent of contamination as a result of indiscriminate disposal of SEO in the sampled areas: Geo-accumulation index, contamination factor and degree of contamination, pollution load index, ecological risk factor and potential ecological index.

2.10 Geo-accumulation Index

Geo-accumulation Index as put forward by [22]; [23]; is a commonly used for the assessment of soil pollution by heavy metals. This index formulates as the ratio of the concentrations of heavy metals in soils to background metal levels in soils or in corresponding soils. It was calculated using the following formulae:

I-geo = $\log_2[(Cn /1.5Bn)]$

$$I_{-geo} = Log_2\frac{Cn}{1.5Bn} = \frac{Log10(\frac{Cn}{1.5Bn})}{Log10(2)} \quad (1)$$

Where C_n metal is the measured concentration of the examined heavy metal in the soil sample and Bn is the geochemical background concentration or reference value of the metal n. The factor 1.5 is introduced to minimize the effect of possible variations in the background or control values which may be attributed to lithogenic variation in the soil. The background value is reference value of metals by the Department of Petroleum Resources DPR, [24] were use, for maximum allowable concentration of metals in Nigeria soil. Seven contamination classes are used to define the degree of metal pollutants in soils as follows: Igeo< 0 means unpolluted; 0 ≤ Igeo< 1 means unpolluted to moderately polluted; 1 ≤ Igeo< 2 means moderately polluted; 2 ≤ Igeo< 3 means moderately to strongly polluted; 3 ≤ Igeo< 4 means strongly polluted; 4 ≤ Igeo< 5 means strongly to very strongly polluted; Igeo> 5 means very strongly polluted.

2.11 Contamination Factor (CF) and Degree of Contamination (C_{deg}.)

Contamination factor (CF) is used to determine the contamination status of soil; it is the ratio of measured mean concentration value of heavy metals in samples and the background values of the metals calculated with the following equation:

$$CF = \frac{CMetal}{Cbackground} \quad (2)$$

$$C_{deg}. \quad \sum_{i=1}^{n} CF \quad (3)$$

Where C_{Metal} is the heavy metal content in samples, CF is contamination factor, C_{deg}. is the degree of contamination and $C_{Background}$ is the pre-industrial concentration of individual metals which is the background value of metals. Four contamination categories of contamination factor are recognized as thus: CF < 1 Low contamination factor; 1 ≤ CF ≤ 3 Moderate contamination factor; 3 ≤ CF ≤ 6 Considerable contamination factor; 6 ≤ CF Very high contamination factor. High Contamination values imply strong anthropogenic influence. Degree of contamination is the sum of all contamination factors with the following categories**:** C_{deg} < 8 Low degree of contamination; 8 ≤ Cdeg ≤ 16 Moderate degree of contamination; 16 ≤ Cdeg ≤ 32 Considerable degree of contamination; 32 ≤ Cdeg Very high degree of contamination [25].

2.12 Pollution Load Index (PLI)

The pollution load index (PLI) is defined as the nth root of the multiplication of the concentration factors (CFmetal) of the individual heavy metals in the samples. It is estimated using the following equation as proposed by Gu [26]:

$$PLI \ \sqrt[n]{CF1XCF2XCF3\ldots..CFn} \quad (4)$$

where CF_1 is the mean contamination factor of the first heavy metal, CF_2 the second metal, CF_3 the third and CF_n the nth metal. The values of PLI > 1 Polluted; PLI = 1 Baseline levels of pollution; PLI < 1 Not polluted.

2.13 Potential Ecological Risk Index (RI)

The Potential Ecological Risk Index (RI) model of assessing risk of heavy metals is proposed by Hakanson (1980) and Gong et al. (2008) to estimate the synergistic, likelihood effects, concentration, toxic level and ecological sensitivity of the heavy metals. Potential ecological risk index (RI) was calculated as follows using the following equations.

$$RI = \sum_{i=1}^{n} (E_r^i) \quad (5)$$

$$E_r^i = T_r^i \ X \ C_f^i \quad (6)$$

$$C_f^i = \frac{C_D^i}{C_R^i} \quad (7)$$

Where E_r^i is the single potential ecological risk factor, T_r^i is the heavy metal toxic response factor, C_f^i is the single heavy metals pollution index, C_D^i is the concentration of individuals heavy metals in samples and C_R^i is the reference value for heavy metals. The following terminology are used to described the potential ecological risk factor, Ei< 40 indicate low potential ecological risk, 40 <Ei< 80 moderate potential ecological risk, 80 <Ei< 160 considerable potential ecological risk, 160 <Ei< 320 high potential ecological risk and Ei> 320 very high potential ecological risk.

The following terminology were used to described the potential ecological risk index; Ri< 150 low ecological risk, 150 ≤ Ri> 300 moderate ecological risk, 300 ≤ Ri> 600 considerable ecological risk, and Ri> 600 very high ecological risk.

3. RESULTS AND DISCUSSION

Table 1 below shows the physicochemical properties of soils in selected auto mechanic workshops in three zones of Imo state. Particle size distribution is known to influence the interactions and dynamics of metals within the soil matrix. In this study, particle size distribution at Owerri, Okigwe, Orlu zones with their control showed 75 ± 5.34 %, 85 ± 6.21 %, 75 ± 5.34 %, 97 ± 7.15 % sand, 61 ± 4.26 %, 62 ± 4.28 %, 66 ± 5.11 %, 135 ± 27.63 % silt and 0.84 ± 0.07 %, 0.72 ± 0.04 %, 0.76 ± 0.06 %, 0.44 ± 0.02 % clay respectively. There was a significant difference ($p < 0.05$) between particle distributions in all the sampled zones relative to the control.

The result further showed that the textural class is sandy loam and did not affect the textural class of the SEO contaminated soil while clay was very low. This corroborates the works of [27], and [28]. The sand content obtained in this study were in the same range with that reported by Loska [28], while clay content were lower than that reported by Onianwa [29] at auto mobile mechanic villages in Imo state. Muller [27] reported similar observation of low % of clay in soil samples. There was no significant difference ($p > 0.05$) among the moisture content of the soil across the zones. Percentage moisture content were 35 ± 3.24 % in Owerri Zone, 34 ± 3.22 % in in Okigwe Zone, 35 ± 3.24 % in Orlu Zone with 34 ± 3.22 % in control site. This is lower than the values reported by Muller [27]; but in the range with [30]. Bulk density of values showed that there was a significant ($p < 0.05$) among the sampled zones with the control. The values of bulk density were below value of 1.81gcm^{-3} reported by James and Ducan [31]. High bulk density (> 1.5gcm^{-3}) retards water infiltration and plant root penetration resulting in increased surface water pollution [32]. pH value is as important factor influencing the availability and mobility of elements in soil. Many metal cations are more soluble and available in the soil solution at low pH (below 5.5) including Cd, Cu, Hg, Ni, Pb, and Zn**.** pH value ranged from 5.43 to 5.91 indicating that the soil is moderately acidic *in situ*. The pH values obtained in the soils of the study area were in the same range with the pH range of 5.02 to 5.70 obtained from spent engine oil contaminated soil in auto mechanic workshops clusters in Gboko and Makurdi Benue State. Toppi and Gabbrielli [33] also reported a similar range of pH values at automobile mechanic villages in Imo state. The mean values for organic carbon and organic matter were significantly ($p < 0.05$) different across the zones. The result further revealed that organic matter and organic carbon contents were lower than the control. This contradicts the observation of [33] who opined that polluted sites had higher significant organic matter and organic carbon compared to the control, but corroborates with the findings of [34] in automobile workshops in Calabar, Cross Rivers State. According to the rating of [35] the soil organic carbon can be rated as extremely low. There was no significant difference in the total nitrogen content of the soil in all the zones. However, the control had higher values of TN than the sampled sites. This agrees with findings of [27]. There was no significant ($p<0.05$) difference in EC of the soil samples across the zones. The available phosphorus in all the zones ranged from 0.19 ± 0.03 to 0.22 ± 0.02 with the control having 1.24 ± 0.12. There was no significant difference ($p<0.05$) between Ca, Mg, K, and Na with their control counterparts. Total exchangeable bases in the study sites were generally high (more than 12 cmol/kg) when compared with the values obtained by Toppi and Gabbrielli [33]. The values obtained for EC in this study is higher than that reported by previous researchers [27]. The implication of the EC content in this study is an indication of the presence of trace metals ions or ionisable materials in the soil [33]. Soil samples of this nature with EC exceeding 8 Ds m^{-1} will affect the growth of many cash crops (Estefa et al., 2013). Also, there was no significant ($p<0.05$) difference in the ECEC of samples in all the sites. However, the control sample had higher ECEC values than the sites.

Assessment of heavy metals levels in areas of heavy anthropogenic pressure is essential to determine the potential risks organisms (microbes, plants, animals and humans) livings in such areas are prone to. Although previous studies had established that there are no soil quality guidelines for heavy metals in soils in Nigeria [36] in this study, we use the permissible limits set by the Department of Petroleum Resources (DPR) as benchmark for the heavy metal assessment. Thus, in this study, levels of heavy metals in SEO polluted soils were determined and results presented in Table 2. Mean values for Pb ranged from 1.045 ± 0.1 to 1.534 ± 0.2 while Orlu zone had 1.475 ± 0.2. There was a significant ($p<0.05$) difference in the mean Pb values across the zones. Pb was not detected in the control site. Though the concentration of Pb obtained in this study was lower than the limit of background values set by Nigerian DPR, the fact that lead was detected in the soil samples is a source of concern. Lead concentration greater than 1.0 mgkg^{-1} is generally indicated a local source of pollution [32]. Low concentration of Lead from SEO polluted soil can be attributed to gradual decrease in metal concentration which could arise from leaching [27]. As concentration ranged from 1.761 ± 0.3 to 1.805 ± 0.3. No significant ($p<0.05$) difference was found among the As in all the zones. No As was detected at the control site. Mean values for Cr in Owerri , Okigwe, and Orlu Zone were 0.273 ± 0.01, 0.272 ± 0.01, and 0.273 ± 0.01 respectively. Concentration of

Cd were 0.606 ± 0.03, 0.302 ± 0.02, and 0.596 ± 0.03. Cd was not found at the control site. The concentration of Ni in control, Owerri, Okigwe and Orlu zones were 0.235 ± 0.01, 0.932 ± 0.03, 0.918 ± 0.03, and 0.931 ± 0.03. The concentration of Ni in the control was lower than the sampled sites. The mean values of Co, Fe, Cu, Zn, and Al in Owerri, Okigwe and Orlu zones are: 1.324 ± 0.2, 1.278 ± 0.11.312 ± 0.2; 63.927 ± 3.34, 69.563 ± 3.53, and 65.487 ± 3.42; 12.964 ± 2.42, 12.446 ± 2.14, 12.653 ± 2.31; 156.137 ± 28.12, 156.125 ± 28.04, 156.121 ± 28.01; and 1.353 ± 0.2, 1.352 ± 0.2, 1.353 ± 0.2 respectively. In all the sampled sites, metal concentration was higher than control sites except Fe that was observed to be slightly higher in the control.

The result of geo-accumulation index of the analysed soil samples across the zones is displayed in Fig. 2. The result showed that all the heavy metals fall under Uncontaminated to moderately contaminated (0 ≤ Igeo < 1) except Fe and Zn that fall under moderately to strongly contaminated suggesting that urgent environmental attention. The contamination values of the heavy metals are an indication of anthropogenic pressure due to the activities of automobile mechanics in the sampled zones. The Igeo results obtained in this study were similar to the results reported by Oliveira and Pampulh [37].

Table 1. Physicochemical properties of soils in selected auto mechanic workshops in three zones of Imo state

Parameters	Owerri zone	Okigwe zone	Orlu zone	Control
SAND	75 ± 5.34^{c}	85 ± 6.21^{b}	75 ± 5.34^{c}	97 ± 7.15^{a}
SILT	61 ± 4.26^{c}	62 ± 4.28^{c}	66 ± 5.11^{b}	135 ± 27.63^{a}
CLAY	0.84 ± 0.07^{a}	0.72 ± 0.04^{b}	0.76 ± 0.06^{b}	0.44 ± 0.02^{c}
MC	35 ± 3.24^{a}	34 ± 3.22^{a}	35 ± 3.24^{a}	34 ± 3.22^{a}
BD	67 ± 4.78^{a}	66 ± 4.75^{a}	66 ± 4.75^{a}	60 ± 4.21^{b}
p^{H}	5.43± 1.03^{b}	5.91 ± 1.11^{b}	5.48 ± 1.05^{b}	6.42 ± 1.47^{a}
OC	0.74 ± 0.06^{b}	0.82 ± 0.09^{a}	0.76 ± 0.07^{b}	0.82 ± 0.09^{a}
OM	0.27 ± 0.02^{b}	0.30 ± 0.03^{b}	0.29 ± 0.02^{b}	0.99 ± 0.11^{a}
TN	0.10 ± 0.01^{b}	0.11 ± 0.01^{b}	0.10 ± 0.01^{b}	0.41 ± 0.04^{a}
Av. P	0.19 ± 0.03^{b}	0.23 ± 0.02^{b}	0.22 ± 0.02^{b}	1.24 ± 0.12^{a}
Ca	0.31 ± 0.03^{b}	0.35 ± 0.03^{b}	0.32 ± 0.03^{b}	2.43 ± 0.23^{a}
Mg	0.24 ± 0.04^{b}	0.27 ±0.05^{b}	0.25 ± 0.04^{b}	8.20 ± 1.32^{a}
K	0.41 ± 0.02^{b}	0.43 ± 0.02^{b}	0.41 ± 0.02^{b}	7.01 ± 1.25^{a}
Na	2.69 ± 0.25^{b}	2.88 ± 0.28^{b}	2.72 ± 0.26^{b}	8.03 ± 1.19^{a}
TEA	29.1 ± 2.26^{b}	28.2 ± 2.25^{b}	29.0 ± 2.27^{b}	0.85 ± 0.10^{a}
TEB	22.2 ± 2.14^{b}	22.5 ± 2.16^{b}	22.3 ± 2.15^{b}	73.97 ± 5.31^{a}
EC	87.3 ± 6.54^{a}	88.2 ± 6.70^{a}	87.6 ± 6.55^{a}	89.6 ± 6.74^{a}
ECEC	85.9 ± 6.33^{b}	86.3 ± 6.35^{b}	86.0 ± 6.31^{b}	95.6 ± 7.02^{a}

Values are mean of triplicate; means having different superscript of letters along the row differ significantly at P < 0.05 using least significant difference

Table 2. Heavy metal levels in soils of auto mechanic workshops in Imo state

Heavy metals	DPR limit	Control	Owerri zone	Okigwe zone	Orlu zone
Pb (mg/kg)	85.0	ND	1.534 ± 0.2^{a}	1.045 ± 0.1^{b}	1.475 ± 0.2^{a}
As (mg/kg)	29.0	ND	1.805 ± 0.3^{a}	1.761 ± 0.3^{a}	1.792 ± 0.3^{a}
Cr (mg/kg)	100	ND	0.273 ± 0.01^{a}	0.272 ± 0.01^{a}	0.273 ± 0.01^{a}
Cd (mg/kg)	0.80	ND	0.606 ± 0.03^{a}	0.302 ± 0.02^{b}	0.596 ± 0.03^{a}
Ni (mg/kg)	35.0	0.235 ± 0.01^{b}	0.932 ± 0.03^{a}	0.918 ± 0.03^{a}	0.931 ± 0.03^{a}
Co (mg/kg)	20	ND	1.324 ± 0.2^{a}	1.278 ± 0.1^{b}	1.312 ± 0.2^{a}
Fe (mg/kg)	5000	76.784 ± 4.25^{a}	63.927 ± 3.34^{d}	69.563 ± 3.53^{b}	65.487 ± 3.42^{c}
Cu (mg/kg)	36.0	2.453 ± 0.65^{d}	12.964 ± 2.42^{a}	12.446 ± 2.14^{c}	12.653 ± 2.31^{b}
Zn (mg/kg)	140	146.642 ± 2.67^{b}	156.137 ± 28.12^{a}	156.125 ± 28.04^{a}	156.121 ± 28.01^{a}
Al (mg/kg)	-	0.426 ± 0.02^{b}	1.353 ± 0.2^{a}	1.352 ± 0.2^{a}	1.353 ± 0.2^{a}

Values are mean triplicate; means having different superscript of letters along the row differ significantly at P < 0.05 using least significant difference

The contamination factor and corresponding degree of contamination is presented in Table 3. The values of contamination factor in all the zones were observed to be < 1 indicating uncontaminated to low contamination with respect to the metals studied except Fe and Zn with values > 1 in Owerri and Okigwe zones respectively. This indicates that the soil is contaminated with respect to Fe and Zn. Degree of contamination indicate low degree of contamination with values of 3.7, 3.9 and 2.4. The studied sites are therefore classified as having low degree of contamination indicating low anthropogenic pressure at these sites. This is in line with the findings of [38] in Gombe, Northern Nigeria.

The pollution load index in all zones were observed to be less than 1 indicating no serious pollution (PLI < 1 = not polluted) at the sites (Fig. 3).

The potential ecological risk and potential ecological risk index is presented in Table 4. The ecological risk factor across the zones were observed to be low (< 40) indicating low ecological risk factor. The ecological risk index on the other hand showed values less than 150 indicating low ecological risk.

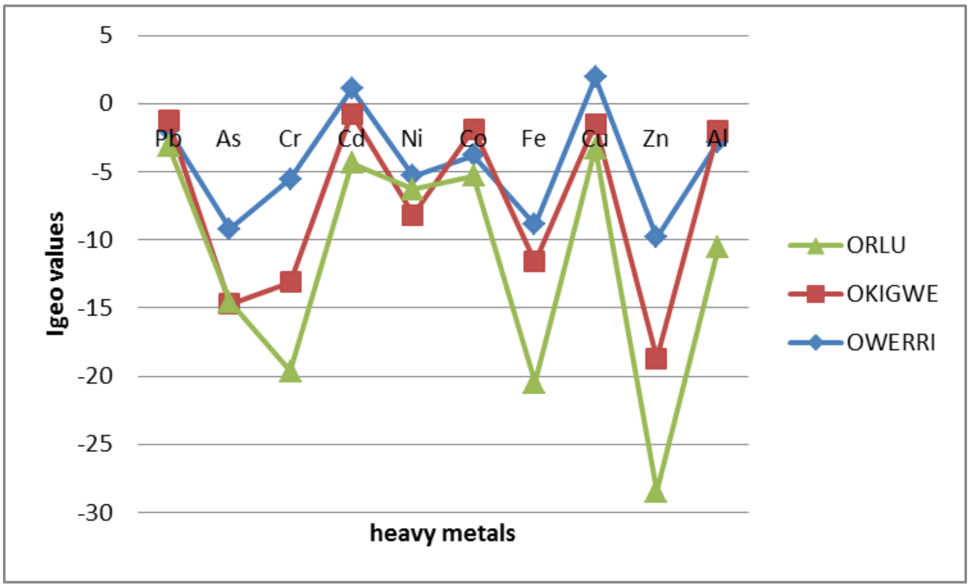


Fig. 2. Geo-accumulation index of the soil

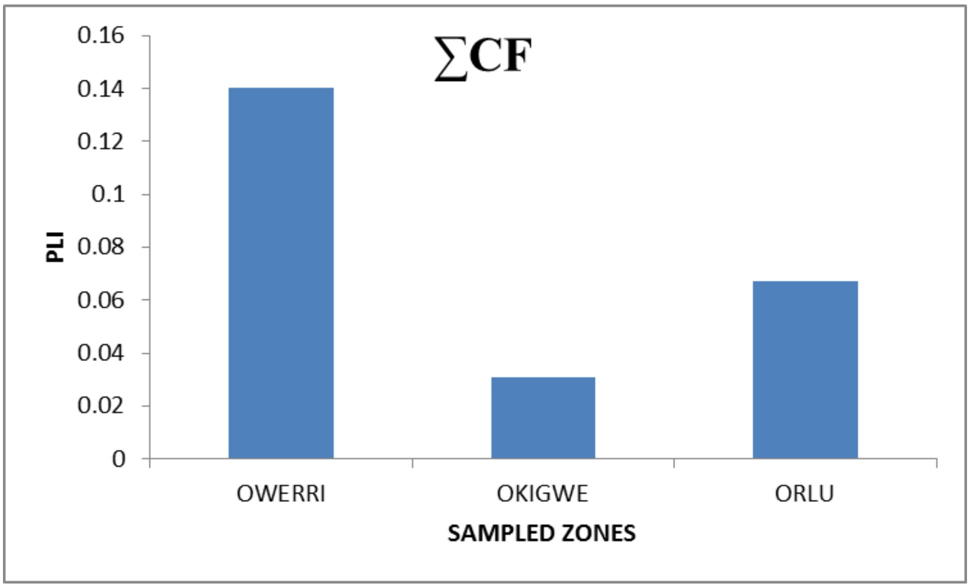


Fig. 3. Pollution load index across the zones

Table 3. Contamination Factor (CF) and Degree of Contamination ($C_{deg.}$)

Zones	Metals

	Pb	As	Cr	Cd	Ni	Co	Fe	Cu	Zn	Al	C_d
Owerri	0.081	0.07	0.14	0.68	0.09	0.066	1.012	0.36	1.15	0.09	**3.7**
Okigwe	0.030	0.05	0.16	0.37	0.07	0.063	1.901	0.19	1.03	0.07	**3.9**
Orlu	0.010	0.03	0.12	0.45	0.04	0.065	0.091	0.25	1.33	0.02	**2.4**

Table 4. Potential ecological risk factor (E_i) and ecological risk index (RI)

Sample	E_i										
	Pb	**As**	**Cr**	**Cd**	**Ni**	**Co**	**Fe**	**Cu**	**Zn**	**Al**	***RI***
Owerri	0.040	0.56	0.13	0.05	0.07	0.063	1.41	0.04	1.75	0.06	**4.1**
Okigwe	0.031	0.04	0.17	0.78	0.09	0.081	1.80	0.10	1.43	0.09	**4.6**
Orlu	0.042	0.04	0.11	0.69	0.03	0.056	1.67	0.03	1.71	0.05	**4.4**

4. CONCLUSION

The present study were undertaken to assess the physicochemical and heavy metal concentration in the soil from selected auto mechanic workshops in Imo State. The study showed that the soil pH was acidic. Particle size distributions of the soil were mostly sandy. The soil in sampled zones had low concentration of N, P and K indicating low fertility of the soil. Varying levels of metals were observed in the soils. The results showed a gradual buildup of heavy metals in all the zones with obvious health implications. The indices of pollution estimated ranged from moderately contaminated across the zones, thus indicating that soils from the auto mechanic shops need urgent remediation to forestall further accrual into the ecosystem. Based on the result of this study it is recommended that strict environmental laws be put in place in order to control indiscriminate disposal of spent engine oil by the artisans. Our research is currently underway to see the possibility of using plants in the remediation of these polluted sites (phytoremediation).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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