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Assessment of Heavy Metals and Physiocochemical Quality of Soil around Auto Mechanic Workshops in Mararaba, Nasarawa State

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ABSTRACT

Analysis of soils for the physicochemical properties from 9 selected auto mechanic workshops in Mararaba, Nasarawa State was carried out according to standard methods. Soil samples were analysed for pH, organic matter, salinity and cationic exchange capacity. The level of heavy concentration in the soil samples obtained from the workshops were determined using Atomic Absorption Spectroscopy (AAS). The results obtained for the physicochemical properties and concentration of heavy metals varied according to the sampling locations and the type of metals. The pH of the soil ranged from 7.46 to 8.91, Organic matter; 5.20 to 7.30 %, Soil salinity; 28.80 to 73.03 µS/cm, and Cation exchange capacity of soil ranged from 0.80 to 2.49 meg/100g It was observed that the ranges of concentration of the assessed heavy metals were: Pb: 0.9719-0.2154 mg/kg, Cd: 0.03491 - 0.8991 mg/kg, Ni: 1.2521-1.1762 mg/kg, Cu: 4.6997-0.7291 mg/kg, Cr: 5.6063-1.8736 mg/kg, and Zn: 4.5142-0.6733 mg/kg. The I-geo, Cf and QoC values were also calculated and reported. The results obtained for heavy metals revealed that the soils from some of the sampling locations are impacted negatively as observed in significant concentrations of some heavy metals which are above threshold limit for agricultural soil, indicating potential environmental and health risks. The study highlights the need for regular monitoring and remediation of soils in auto mechanics workshops to prevent environmental pollution and ensure sustainable land used practices.

Keywords: Auto mechanic, workshop, AAS, Heavy Metals, Agricultural soil.

INTRODUCTION

The natural environment provides us with essential ecosystem services, including air and water purification, soil formation, and climate regulation (IPCC, 2022). However, human activities have led to significant environmental degradation, with anthropogenic substances comprising noxious and toxic chemical compounds posing a significant threat to the environment (UNEPA, 2022). The increase in global population has resulted in high levels of industrialization and urbanization, leading to environmental pollution from indiscriminate discharge of industrial effluents (WHO, 2022). These effluents may contain common heavy metals such as Hg, Zn, Cu, Co, Pb, and Cr, which can have devastating effects on human health and the environment (Madu *et al*., 2007). As noted by Olonisakin *et al*. (2005), there is a need for research and public information on these metals to prevent unknown dangers that may create irreparable environmental damage. Soil, a complex mixture of organic and inorganic matter, plays a crucial role in supporting ecosystem services (FAO, 2022). However, soil properties can change due to climate change and anthropogenic impacts, leading to the accumulation of unwanted pollutants (IPCC, 2022). As highlighted by Adesuyi *et al*. (2016), these pollutants can originate from domestic effluents, workshops, industrial and agricultural activities, and have ecological implications with negative effects on human health and well-being. These unwanted pollutants are continuously being released into our soil, water, and air. Some of them originate mostly from domestic effluents, workshops, industrial and agricultural activities and many of them having ecological implications with negative effects on the health and well-being of the populace (Adesuyi *et al*., 2016; Adesuyi *et al*., 2018a; Njoku *et al*., 2018; Anuoluwapo *et al*., 2019; Haodong *et al*., 2022). Auto-mechanic workshops, which offer miscellaneous repair services, are significant contributors to hazardous waste generation (Mohiuddin *et al*., 2011). The operational processes in these workshops involve the use of highly toxic and hazardous materials, including spent oils, greases, lubricants, and paints (Amusan *et al*., 2003). As noted by Maha (2022), the improper disposal of these wastes can contaminate soil, prevent microbial activities, and immobilize soil nutrients. Furthermore, the indiscriminate dumping of used motor oil and other waste constitutes an environmental hazard with global implications (Okonokhua *et al*., 2007). As emphasized by Udousoro *et al*. (2010), there is a need for proper handling and management of used fluids and solvents to prevent environmental pollution.

Auto-mechanic workshops are establishments offering miscellaneous repair services ranging from simple and fast oil change to complex engine rebuilding. They also provide body repair and painting services. The operational processes in auto mechanic workshops often involve the use of highly toxic and hazardous materials (Mohiuddin *et al*., 2011; Kawo *et al*., 2018). It is common knowledge that most of the automobile and mechanical workshops carryout these repair activities with disregard to environmental best practices. During the process reasonable amount of spent engine oil and metal scraps/fillings are deposited on the soil.

The soils which now act as a sink is contaminated with the pollutant which eventually prevent soil microbial activities, immobilization of soil nutrients, lowering of soil pH and soil fertility status (Amos *et al*., 2011). It has been observed that dangerous waste commonly created in auto mechanic shops is from the solvents used to clean parts. These solvents have been reported to be extremely dangerous to humans and the environment. These wastes that are generated daily gradually accumulate and become a burden. Poor handling and management of the used fluids and solvents coupled with the improper disposal of large amounts of waste from different sources into water drains, streams, rivers, farm lands, open vacant plots is a common practice in Nigeria (Okonokhua *et al*., 2007; Udousoro *et al*., 2010). The indiscriminate dumping of used motor oil and other waste constitute environmental hazard with global implications. The waste may contain components such as: Pb, Cd, As, Cr and other potentially toxic metals. The aim of the study is to investigate the physicochemical properties and heavy metal concentrations in soils from auto mechanic workshops in Mararaba, Nasarawa State, with a view to assessing the potential environmental and health risks associated with these contaminants.

MATERIALS AND METHODS

Study Area: The study area is located in Mararaba, Nasarawa state, Nigeria. Mararaba is a town located in the north-central part of Nigeria. It is a district of Karu Local Government Area, Nasarawa state and is among the towns that make up the Karu urban area, a conurbation of towns stretching to Nigeria's Federal Capital Territory. It lies on the geographical coordinates of latitude: 9.0266 and longitude: 7.6073. Mararaba is a suburban settlement with a mix of residential and commercial areas. It is known for housing several auto mechanic workshops that cater to the local automotive repair needs.

Nine different automobile workshops were selected for this study. All the stations have typical characteristics of automobile work sites, such as patches of waste engine oil on the ground, scrap metals, discarded engine oil containers and paint cans, among others. The control station is an uncontaminated site with no mechanic activity carried out on the soil of the land before. The location sampling site code, the control site and features around the auto mechanic workshop clusters are shown in **Figure 1**.

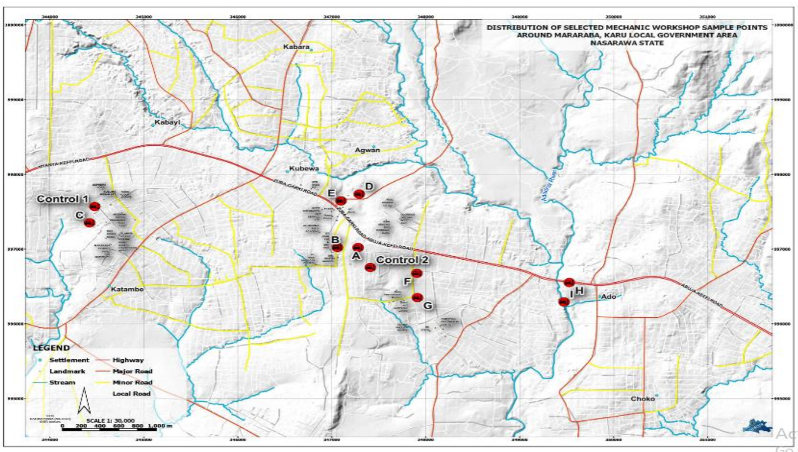

Figure 1: Map of sampling locations in Mararaba Nasarawa state.

Sample collection and sample treatment:

Surface soils are the first locus of input of metals where they tend to accumulate on a relatively long term basis (Abenchi *et al*., 2010). These pollutants normally contaminate the upper layer of the soil at a depth (0 - 40) cm (Krishna and Grovil, 2007). This implies that, high concentration of these pollutants could be present at this depth if assessed. Given the foregoing, 9 surface soil samples were collected randomly from each of the designated auto mechanic workshop clusters at a depth of 0.02m. One control sample was also collected (generally about 100 m away from each cluster) where neither car repairs, industrial nor commercial activities are carried out. The samples were placed in labeled polythene bags and transported to the laboratory. All soil Samples were subsequently air-dried to constant weight to avoid microbial degradation (Kakulu, 1993). They were homogenized, made lump free by gently crushing repeatedly using an acid pre-washed mortar and pestle, and passed through a 2 mm plastic sieve prior to analysis. Thus, a total of 9 surface soil samples were randomly collected from the study areas.

Determination of Physio-chemical Properties of the Soils:

The physiochemical properties of the soil samples were determined using routine methods as described by Allison (1960) and Ibitoye (2006).

pH Analysis: Soil's pH level influences nutrient availability and microbial activity, and assesses whether the soil is acidic, neutral or alkaline. Ground and sieved soil sample (10.00 g) was weighed and transferred into a beaker, 10 cm^3 of deionized water was added and the mixture was stirred to obtain slurry. The mixture was allowed to stand for an hour, stirred at every 10 to 15 minutes. A calibrated pH meter with glass-calomel electrode was used for the pH measurement. Prior to the pH determination, the prepared standard buffer solutions were used for the pH calibration. The pH meter electrode was thoroughly rinsed with deionised water after immersing into each of the soil solution (Reddy, 2015). The result obtained is in **Table 1**.

Organic Matter Content (OM): This analyses the percentage of organic matter present in the soil, which affects soil structure, water retention, nutrient content, and overall soil health. Organic Matter was determined using Walkley-Black Method. Dry soil sample (1.00g) was weighed and transferred into a 500cm^3 Erlenmeyer flask, 10cm^3 of 0.167 moles dm^{-3} potassium dichromate ($K_2Cr_2O_7$) solution was added using pipette followed by the addition of 20cm^3 of concentrated H_2SO_4 using a dispenser and the mixture was swirled gently to mix. The mixture was allowed to stand for 30 minutes and diluted with 200cm^3 of deionised water. Phosphoric acid (10cm^3) was added followed by 0.2g sodium fluoride (NaF). (The H_3PO_4 and NaF were added to complex Fe^{3+} which would interfere with the titration end point). This was followed by the addition of 10 drops ferroin indicator. The mixture was titrated with 0.5 moles dm^{-3} Fe^{2+} solution, the colour of the solution at the beginning was yellow-orange to dark green, while the colour changed to wine red at the end point. A blank was prepared and titrated in the same manner but without the soil (Schulte, 2012).

$$\% \text{ Organic Matter} = 10\,[1- (S \div B)] \times 0.67 \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where S is sample titration, B is blank titration, 10 is conversion factor for units. 0.67 is a factor derived from the conversion of % organic carbon to % organic matter. The result obtained is in **Table 2**.

Cationic Exchange Capacity (CEC): This assesses the soil's ability to retain and exchange positively charged ion (cations), which are crucial for nutrient availability and plant uptake. Soil sample (25.0g) was weighed into a 500cm^3 Erlenmeyer flask and 125cm^3 of 1 mole dm^{-3} NH_4OAc was added and mixed thoroughly, then allowed to stand overnight. A 5.5cm^3 Buchner funnel was fitted with retentive filter paper which was moisten and light suctioned, and the soil transferred. The soil was gently washed four times with 25cm^3 additions of the NH_4OAc, allowing each addition to filter through but not allowing the soil to crack or dry. Suction was applied only to ensure slow filtering. The leachate was discarded. The soil was further washed with eight separate additions of 95% ethanol to remove excess saturating solution. The adsorbed NH_4 was extracted by leaching the soil with eight separate 25cm^3 additions of 1 mole dm^{-3} KCl. The soil was discarded, and the leachate transferred to a 250cm^3 volumetric flask. Then the volume was diluted with additional KCl. The concentration of NH_4-N in the KCl extract was determined by colorimetry. Also NH_4-N was determined in the original KCl extracting solution

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(blank) to adjust for possible NH_4-N contamination in this reagent (Chapman, 1965). The result obtained is in Table 1.

Calculations

$$CEC\left(\frac{cmol}{kg}\right) = \left[\left(NN_4 - N_{(in\ extract)}\right) - \left(NH_4 - N_{(in\ blank)}\right)\right] \div 14 \ldots\ldots\ldots\ldots\ldots (2)$$

Where NH_4-N is reported in mg N/L CEC

$$CEC\left(\frac{cmol}{kg}\right) = \left[\left(NN_4 - N_{(in\ extract)}\right) - \left(NH_4 - N_{(in\ blank)}\right)\right] \div 18 \ldots\ldots\ldots\ldots\ldots (3)$$

Where NH_4-N is reported in mg NH_4/L Organic.

Soil Salinity: Soil's electrical conductivity indicates its salinity level and potential impact on plant growth and nutrient uptake. Soil salinity was determined weighing soil sample (20g) into a 250cm^3 beaker. 20cm^3 of deionized water was added to the beaker and stirred thoroughly with glass rod for about 1 hour until well mixed; the suspension was allowed to settle. The EC of the supernatant was measured at 25°Cwith a conductivity meter. The conductivity meter probe was properly rinsed with deionized water before and after reading (Wang *et al*., 2014). The result obtained is in **Table 1.**

Measurement of Heavy Metal Content in the Samples:

Sample Digestion: Soil sample (1.00g) was weighed into a 250cm^3 beaker for digestion and 10cm^3 of concentrated HNO_3 added, then heated at 95°C. This was refluxed after cooling, with repeated addition of HNO_3 until no brown fumes were given off by the sample. The volume of the solution was allowed to reduce to 5cm^3 by evaporation. 10cm^3 H_2O_2 was added slowly without allowing any losses after cooling the mixture. 10 cm3 of HCl was added to the mixture and refluxed at 95°C for 15 minutes. The digest obtained was filtered using Whatman No. 41 filter paper. The filtrate was diluted, made up to 100cm^3 volume in a volumetric flask and stored for analyses (USEPA 3050B) (1996), Awofulu, 2005). This was done in three replicate for each soil.

Heavy Metal Analysis

One gram of the dried fine soil sample was weighed and transferred into an acid washed, round bottom flask containing 10cm^{3}concentrated nitric acid. The mixture was slowly evaporated over a period of 1hr on a hot plate. Each of the solid residues obtained was digested with a 3:1 concentrated HNO_3 and $HClO_4$ mixture for 10mins at room temperature before heating on a hot plate. The digested mixture was placed on a hot plate and heated intermittently to ensure a steady temperature of 150°C over 5hrs until the fumes of $HClO_4$ were completely evaporated (Jacob *et al*., 2009).

The mixture was allowed to cool to room temperature and then filtered using Whatman No.1 filter paper into a 50cm^3 volumetric flask and made up to the standard mark with deionized water after rinsing the reacting vessels, to recover any residual metal. The filtrate was then stored in pre-cleaned polyethylene storage bottles ready for analysis. Heavy metal concentrations were determined using an Atomic Absorption Spectrophotometer (AAS) at the Chemistry Advanced Research Centre, Sheda Science and Technology Complex (SHESTCO), Abuja. The instrument settings and operational conditions were in accordance with the manufacturer's specifications. The instrument was calibrated with analytical grade standard metal solutions (1 mg/dm^3) in replicates. The result obtained is in Table 5.

RESULTS AND DISCUSSION

Determination of physiochemical properties of the soils

The physiochemical properties of the soil samples were determined using routine methods as described by Allison (1960) and Ibitoye (2006). Physicochemical characteristics of soil such as pH, organic matter (OM), cation exchange capacity (CEC), moisture content and particle size distribution are known to influence the interactions and dynamics of metals within the soil matrix. The results of the physicochemical characteristics of the soils investigated are summarized below:

pH: The pH of soils surrounding auto mechanic workshop clusters in Mararaba, Karu LGA of Nasarawa State, Central Nigeria is shown in **Table 1**.

Soil pH is a major factor influencing metal chemistry (Gambrell, 1994). The mean values of the pH of soils in the vicinity of auto mechanic workshop clusters ranged from 7.46 to 8.91 in deionized water

Table 1: The Physicochemical properties of soils surrounding auto mechanic workshop clusters in Mararaba, Karu LGA of Nasarawa State, Central Nigeria.

Soil sample	*pH*	Organic matter (%)	Soil salinity	
			EC(µS/cm)	CEC(meg/100g)
A	7.83±0.4	5.60	67.83±0.06	1.27±0.06
B	7.89±0.2	2.61	73.03±0.04	1.16±0.04
C	7.99±0.2	3.67	28.80±0.05	0.80±0.05
D	7.95±0.6	6.77	37.83±0.04	1.28±0.04
E	8.19±0.6	1.82	68.25±0.06	1.16±0.06
F	7.75±0.4	1.26	73.25±0.08	1.13±0.08
G	7.83±0.4	1.38	45.76±0.07	1.09±0.07
H	7.98±0.6	1.53	72.15±0.06	1.03±0.06
I	7.46±0.3	3.81	62.13±0.08	2.49±0.08
J	8.24±0.6	4.56	61.85±0.05	2.11±0.05
Control Soil 1	6.50±0.6	0.94	46±0.06	1.13±0.06
Control Soil 2	7.20±0.3	1.25	35±0.04	2.49±0.04

Organic Matter: The organic matter content of soil sample is shown in **Table 1**. The organic matter was in the range of 5.20 to 7.30 %. It plays an important role in metal binding (Akans *et al.* 2010). From the results, sample H was observed to have the highest organic matter (7.30%) while soil from site E had the least (5.20%). This amount of organic matter has been reported by Akoto *et al.*, (2008) to have the potential to bind toxic ions. Organic matter of soils immobilizes heavy metals at strongly acidic conditions and mobilizes metals at weakly acidic to alkaline reactions by forming insoluble or soluble organic metal complexes, respectively (Brümmer and Herms, 1982). Organic matter contents were higher in the study areas than that of the control which may be due to the presence of more waste from the activities carried out around the sites (Eluyera & Tukura 2020).

Soil Salinity: The electrical conductivity (EC) of the soil ranged from auto mechanic workshop clusters in Mararaba, Karu LGA of Nasarawa State, Central Nigeria is shown in **Table 1**.

EC measures the electrical conductivities of the water-extracted from soils which is an indication of the relative water-soluble salt contents of the soil. It depends on the amount of dissolved minerals and gives the ability of a substance to conduct an electric current at a specific temperature, usually (25 ^{0}C) (Yisa *et al.*, 2012). The range of EC values obtained in this study were lower than 108 to 201 µS/cm values reported for soil samples around metal scrap dump in some parts of Delta State (Akpoveta *et al.*, 2010).

Heavy metal concentrations: Many studies have shown that urban soils receive loads of contaminants that are usually greater than the nearby contiguous sub-urban or rural areas, due to the higher tempo of anthropogenic activities of urban settlements (Adelekan and Alawode, 2011). This is largely confirmed by this study judging from the concentrations of the metals investigated in the control and cluster soils **Figure 2**.

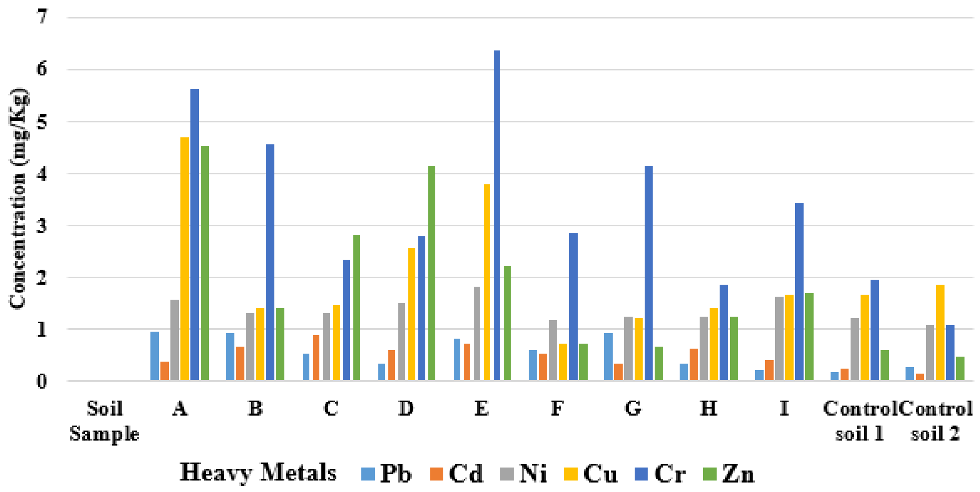

Figure 2: Heavy Metal Concentrations in Soil Sample

It is important to note that there are no soil quality guidelines for heavy metals in soils in Nigeria (Iwegbue *et al*., 2006; Ipeaiyeda *et al*., 2007). Therefore the results obtained in this study is in **(Figure 2)**, can only be discussed in the context of the control values and standards set elsewhere.

Lead (Pb): The mean values of Pb in soils obtained in this study ranges from 0.9719 mg/kg to 0.2154 mg/kg for soil samples A and I Clusters, respectively. The values obtained in soil sample studied are higher than the control soil 1 with levels of (0.1972 mg/kg), while values obtained in site I is lower than for control soil 2 (0.2782mg/kg). The values of Pb obtained in this study were lower than the 1162 mg/kg reported by Nwachukwu *et al*. (2011) for auto mechanic workshop area in Owerri, South-East Nigeria. However, the levels are in line with those reported by Udousoro *et al*. (2010) in South-South Nigeria and those in industrial areas in North-West Nigeria, but above that reported by Pam *et al*. (2013) in central Nigeria. Allowable limits of Pb concentrations vary widely with countries (Lacatusu, 2000).

Virtually all the levels of Pb obtained in this study are below the acceptable limits for soils in several countries. The slight high mean values in the study areas than the control attested to the overall high level of contamination of the environment with this metal and could easily be attributed largely to the activities in the auto mechanic Pam *et al*. 303 clusters. It is reported that Pb has the highest composition of heavy metals in waste oils (Oguntimehin *et al*., 2008). It is possible that these levels of Pb is elevated by the amount of waste oil, presence of automobile emissions, and expired motor batteries indiscriminately dumped by battery chargers and auto mechanics in the surrounding areas.

Cadmium (Cd): The mean concentrations of Cd examined at the various areas of study ranged from 0.03491 - 0.8991 mg/kg. These concentrations in control soil 1 and 2 are lower than the study site 0.2631 and 0.1542 mg/kg respectively, and all these have values that are still lower than the relatively relaxed criteria acceptable in Germany (Lacatusu, 2000). This finding of some level Cd concentration in the study site is consistent with that of Luter *et al*. (2011) who investigated heavy metals in soils of auto-mechanic shops and refuse dump sites in other parts of Makurdi, Central Nigeria, as well and reported a range of 0.6 - 3.5 mg/kg. The results are also in the same range as those reported by other workers in other parts of Nigeria (Abenchi *et al*., 2010; Adelekan and Alawode, 2011). The mean soil Cd levels in the studied cluster areas confirm that the auto mechanic work shop environment is generally Cd enriched. The main source of environmental Cd pollution is the ferrous-steel industry (Onder *et al*., 2007); the accumulation of Cd in the areas studied in here is likely to come from lubricating oils, vehicle wheels and metal alloys used for hardening of engine parts (Dabkowska - Naskret, 2004).

Nickel (Ni): The concentration of Ni in the soils investigated shows a distribution mean of 1.2521 mg/kg and 1.1762 mg/kg for the Mararaba mechanic-clusters, and a mean content of 1.2067 mg/kg and 1.0852 mg/kg for the respective control sites 1 and 2. The results are relatively lower than values of 11.5 mg/kg in Ipeaiyeda *et al*. (2007) and 17.38 - 16.52 mg/kg recorded by Iwegbue *et al*. (2006). The results are in lower compare to the range of 4.20 to 48.6 mg/kg reported by Luter *et al*. (2011) and in the same study area; they are below that in India as reported by Krishna and Govil (2007). Like the other metals the distribution of Ni in this location could be attributed to the disposal of spent automobile batteries from the nearby auto-battery chargers and various paint wastes which have contributed to the contamination of the soils samples (Udousoro *et al.*, 2010). In all cases, however, the concentration of Ni was below the maximum allowable limits for heavy metals in soils regulated by various countries, which suggests that, for now, there is little anthropogenic contribution.

Copper (Cu): Copper was present in all the soil samples investigated. These values are higher than those at the various control sites. There is wide range of distribution of Cu in the control soil with mean values of 1.6672 and 1.8532 mg/kg for the 1 and 2, in that order. These values did not exceed the maximum allowable limit (100 mg/kg) in Australia, Canada, Poland, Great Britain, Japan (125 mg/kg), and Germany (50 mg/kg) (Lacatusu, 2000). This is ascribed to automobile wastes containing electrical and electronic parts, such as copper wires, electrodes and copper pipes and alloys from corroding vehicle scraps which have littered the vicinity of these clusters for a long time, with metals released from the corrosion gradually leaching into the soil (Nwachukwu *et al.*, 2011).

Chromium (Cr): Chromium concentrations are in the range of 1.8736 - 6.3664 mg/kg for the study sites and were found to be 1.9645 - 1.0923 mg/kg in the control soil 1 and 2 respectively. All the values were found to be higher except for site F which was lower. In a study of automobile workshops in Federal Capital Territory Abuja, Nigeria, the contents of Fe, Cu, Zn, Cd, Pb, and Cr varied from 651.44±0.01 to 682.61±0.02, 0.76±0.00 to 2.96±0.00, 11.93±0.00 to 35.36±0.00, 0.29±0.00 to 0.58±0.00, 2.81±0.00 to 10.94±0.00, and 1.45±0.00 to 4.81±0.02 in dry season while the concentrations of Fe, Cu, Zn, Cd, Pb, and Cr ranged from 534.41±0.00 to 549.28±0.01, 0.35±0.00 to 1.68±0.00, 6.19±0.01 to 32.06±0.00, 0.07±0.00 to 0.29±0.01, 2.34±0.00 to 5.00± 0.00 and 1.06±0.00 to 1.45±0.00 in wet season (Eluyera & Tukura 2020). Eluyera & Tukura (2020) found chromium (Cr) concentrations obtained from the soil samples studied were below 100 mg/kg. The major source of chromium is from chromium containing wastes, especially industrial effluents. Chromium is commonly found at contaminated sites in form of chromium (VI) and it is the dominant form of chromium in shallow aquifers where aerobic conditions exist (Osakwe *et al.*, 2014).

Zinc (Zn): The Zinc content in all the soils had a mean range of 0.6733 mg/kg to 4.5142 mg/kg in the studied aera. These values are higher than those at the control (0.46523 - 0.6056 mg/kg) and suggest that, there is anthropogenic contribution. Since no industry exists in the vicinities of these areas, we assume the elevation of Zn levels to be from the auto mechanic clusters, since this element is found as part of many additives to lubricating oils (Abenchi *et al.*, 2010). However, the concentration of Zn in this investigation is small compared with many other studies (Nwachukwu *et al.*, 2010; Nwachukwu *et al.*, 2011 and Shinggu *et al.*, 2007), although it is comparable to that of soils in Cameroon, South East Korea and that of Yauri, North West Nigeria (Yahaya *et al.*, 2010). The values of Zn obtained in the cluster conform to the acceptable limits, for now, while that of the AP- and GBK-clusters are above the maximum allowable limits (Lacatusu, 2000). Therefore the results obtained in this study as seen in **Figure 2**, can only be discussed in the context of the control values and standards set elsewhere.

Assessment of the impact of the auto mechanic workshop clusters on the surrounding soil environment

To have an idea about the levels of contamination of the soils surrounding the auto mechanic workshops clusters (Pam *et al.*, 2013), data obtained were compared with those from the control sample points, taken to be the unpolluted or background values. 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 with the element (Puyate *et al.*, 2007). The average levels of these metals in the soil, around the auto-mechanic clusters indicate that they are not derived from the natural geology of the area as evident from the low level of metals in control samples. The heavy metals in this study showed a distribution pattern of Cr > Zn > Cu > Ni > Pb > Cd as presented in **Figure 3**, as compared a distribution pattern of Cu > Pb > Zn > Mn > Ni > Cd as obtained by Pam *et al.*, 2013.

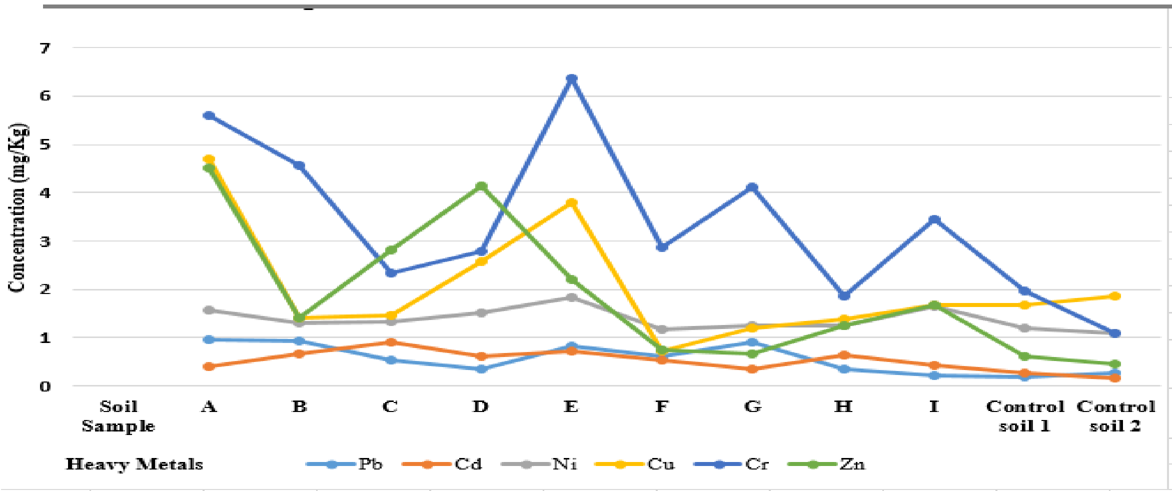

Figure 3: Pattern of metal fluctuations in the mechanic clusters and soil control.

From the mean soil heavy metal concentrations, the mechanic cluster has the highest concentration of heavy metals except for Cd, which was below value for mechanic clusters. The general order of concentration of heavy metals in the cluster is mechanic cluster > control soil. Various quantitative indices were employed to assess the impact of human activities on the concentration toxic trace metals in soil namely: (i) Index of geo-accumulation (I-geo) (ii) Contamination factor (CF) and (iii) Quantification of anthropogenic concentration of metal (QoC) as in the study by Pam *et al*., 2013.

Geo-accumulation index (I-geo): The Index of Geo-accumulation (I-geo) is a numerical value used to assess the contamination levels of heavy metals in sediments or soils. It provides information about the degree of pollution based on the accumulation of a specific heavy metal in comparison to its background concentration. The I-geo value is calculated using the formula (1) (Muller, 1969; Dasaram *et al*., 2011; Adepoju and Adekoya, 2012).

$$\text{I-geo} = \log_2 (C_n/1.5B_n) \;\ldots\ldots\;\; (4)$$

Where Cn is the concentration of the heavy metal in the enriched sample and Bn is the concentration of the metal in the unpolluted (control) samples.

The factor 1.5 is introduced to minimize the effect of the possible variations in the background or control values which may be attributed to lithogenic variations in the soil (Fagbote and Olanipekun, 2010).

Interpretation of I-geo values:

- I-geo < 0: No pollution or background levels of the heavy metal.
- 0 ≤ I-geo < 1: Uncontaminated to moderately contaminated.
- 1 ≤ I-geo < 2: Moderately contaminated.
- 2 ≤ I-geo < 3: Moderately to strongly contaminated.
- 3 ≤ I-geo < 4: Strongly contaminated.
- I-geo ≥ 4: Extremely contaminated.

The geo-accumulation index (I-geo) for the soils shows as follows:

Lead: Samples A, B, E, F and G showed moderate to strong contamination. While samples C, D, H, I showed minimum to no contamination.

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Cadmium: Cd values are generally low across all sites indicating minimal to no contamination. **Nickel:** For Ni, samples B and C showed moderate contamination, while A, D, E, F, G, H and I showed minimal contamination.

Copper: All samples except F and G showed minimal contamination. Sample F showed strong contamination, while G showed moderate to strong contamination.

Chromium: All samples, except which showed moderate contamination, showed minimum contamination.

Zinc: Samples A and D showed a contamination of Zn, samples B, F, G, H and I showed minimal contamination, while samples C and E showed moderate contamination.

Overall, the interpretation suggests varying levels of contamination for each heavy metal at the different sample sites. Some metals like Cd show minimal contamination across all sites, while others like Pb and Zn indicate stronger contamination at certain locations. This information can be used to identify potential areas of concern and guide environmental management strategies.

Contamination factor (Cf): The Contamination Factor (Cf) is a measure used to assess the degree of contamination of heavy metals in soils or sediments. It compares the concentration of a specific heavy metal in the sample to a reference or background concentration. The Contamination Factor is calculated using the formula suggested by Hakanson (1980) and Dasaram *et al*. (2011).

$$Cf = C\ Metal/C\ Background \quad \ldots\ldots.. \quad (5)$$

Where C Metal is the concentration of the heavy metal in the sample

C Background is the background concentration of the same heavy metal

Interpretation of Cf values:

Table 2: Categories of contamination factors (Hakanson, 1980; Dasaram *et al.,* (2011)

Contamination factor	**Category**
Cf < 1	Low contamination factor
1 < Cf < 3	Moderate contamination factor
3 < Cf <6	Considerate contamination factor
6 < Cf	Very high contamination factor

Contamination factor (Cf)

The contamination factor values for the soils are

Table 3: Classification of Cf results

Heavy Metal/ Sample Site	**Pb**	**Cd**	**Ni**	**Cu**	**Cr**	**Zn**
A	Moderate	No Contamination	No Contamination	Low to Moderate	Low to Moderate	Considerable
B	Moderate	Low to Moderate	No Contamination	No Contamination	Low to Moderate	Low to Moderate

C	Low to Moderate	Moderate	No Contamination	No Contamination	No Contamination	Moderate
D	No Contamination	Low to Moderate	No Contamination	Low to Moderate	Low to Moderate	Considerable
E	Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Moderate	Low to Moderate
F	Low to Moderate	Low to Moderate	No Contamination	No Contamination	No Contamination	No Contamination
G	Moderate	No Contamination	No Contamination	No Contamination	Low to Moderate	No Contamination
H	No Contamination	Low to Moderate	No Contamination	No Contamination	No Contamination	Low to Moderate
I	No Contamination	No Contamination	Low to Moderate	No Contamination	Low to Moderate	Low to Moderate

Quantification of anthropogenic concentration (QoC):

The third approach using the quantification of anthropogenic concentration of metal employs the concentration in the control samples to represent the lithogenic metal. This is calculated in accordance with Equation (6):

Quantification of anthropogenic metal Anthropogenic metal = $\frac{x - x_c}{x}$ = × 100 ………. (6)

Where x = average concentration of the metal in the soil under investigation, and x_c = average concentration of the metal in the control samples (Victor *et al*., 2006).

If the QoC value is very low (close to 0), it suggests minimal contamination.

If the QoC value is between 0.1 and 0.5, it may indicate low to moderate contamination.

If the QoC value is between 0.5 and 1, it could suggest moderate contamination.

If the QoC value is greater than 1, it may indicate considerable contamination.

All three indices were employed to assess the impact of the auto mechanic works on the surrounding soils. Contamination factor (CF) Cf was calculated from the mean concentrations of the heavy metals in the study areas with the control sampling sites taken to represent the background values **(Table 3).** According to Akoto *et al*. (2008), Cf values between 0.5 and 1.5 indicate that the metal is entirely from crust materials or natural processes; whereas Cf values greater than 1.5 suggest that the sources are more likely to be anthropogenic. The Cf revealed that soils show highest Contamination factors for Pb and Cu ranging from considerable contamination to very high contamination, while Zn, Mn and Cd had minimal to moderate contamination. Ni on the other hand demonstrated moderate to considerable contamination. High (>1.5) Cf values of a metal indicate significant contribution from anthropogenic origins. Therefore, the high values of Cf in **Table 3**, especially for Pb and Cu, is a clear indication that the contamination in the soils in the vicinity of the auto mechanic clusters originates from human activities, most probably in the auto mechanic workshops, and that the pollution is relatively recent on a time scale of years. The order of anthropogenic inputs in investigated soils is Cr > Cu > Ni > Zn > Pb and Cd.

Quantification of soil contamination (QoC)

On the basis of the quantification of anthropogenic input of the heavy metals in the soils

Here's a qualitative classification of the QoC results based on the ranges mentioned above:

Table 4: Classification of the QoC results

Heavy metals/ Sample site	**Pb**	**Cd**	**Ni**	**Cu**	**Cr**	**Zn**
A	Low to Moderate	Low to Moderate	Minimal	Low to Moderate	Low to Moderate	Low to Moderate
B	Low to Moderate	Low to Moderate	Minimal	Minimal	Low to Moderate	Low to Moderate
C	Low to Moderate	Low to Moderate	Minimal	Minimal	Low to Moderate	Low to Moderate
D	Minimal	Low to Moderate	Low to Moderate	Low to Moderate	Minimal	Low to Moderate
E	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate
F	Low to Moderate	Low to Moderate	Minimal	Considerable	Minimal	Minimal
G	Low to Moderate	Minimal	Minimal	Low to Moderate	Low to Moderate	Minimal
H	Minimal	Low to Moderate	Minimal	Minimal	Minimal	Low to Moderate
I	Minimal	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate	Low to Moderate

Conclusion: The findings from this study shows that the mechanic workshop clusters are indeed polluted with heavy metals particularly Pb, Cd, Ni, Cu, Cr, and Zn, six of the nine metals as shown by all the indices of contamination considered indicate significant to considerable degree of contamination. The concentrations of these heavy metals exceed the threshold limits for agricultural soil, indicating a potential risk to human health and the environment. The study highlights the need for proper waste management and environmental monitoring in auto mechanic workshops to prevent soil pollution.

Suggestions: Regular monitoring of soil and water quality should be conducted in and around auto mechanic workshops regularly to detect any potential pollution. These workshops should adopt proper waste management practices, including segregation, storage and proper disposal of hazardous waste and adopt the use of personal protective equipment (PPE) including gloves and masks, to prevent exposure to heavy metals as while as creating public awareness campaigns to educate people about the risks associated with heavy metal pollution and the importance of proper waste management.

Recommendations: Guidelines should be developed for auto mechanic workshops on proper waste management and environmental monitoring and the regulatory agencies should enforce existing regulations and laws related to environmental pollution and waste management. Training and capacity-building programs should be conducted for workers in auto mechanic workshops on proper waste management and environmental monitoring. Contaminated soil should be remediated through appropriate technologies, such as phytoremediation or chemical remediation. By implementing these suggestions and recommendations, the risk of heavy metal pollution from auto mechanic workshops can be minimized, and the environment and human health can be protected.

Limitation to the Study: Several limitations were encountered during the course of the study: Sample size and representativeness which affects the representativeness of the findings and the ability to generalize the results to the entire area. The study focused on specific set of heavy metals due to resource limitations. Other potentially hazardous metals could have been present in the soil but were not analysed. The study did not account for potential variations in heavy metal concentrations over time. Contamination levels could change seasonally or due to fluctuations in the workshop's activities. Communication challenges influenced engagement with workshop owners, community understanding of the study's objectives, and sample collection. The study might not have accounted for external factors that could influence heavy metal contamination, such as nearby industrial activities, weather conditions, or natural geological processes. Addressing these limitations in future research and risk assessments will contribute to a more comprehensive understanding of the ecological and health risks associated with heavy metal contamination in soil from auto mechanic workshop.

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