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Determination of Heavy Metal Concentration in Soils and Settled Dust of Automobile Workshops at Afikpo in Ebonyi State, Nigeria

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ABSTRACT

Soil and settled dust contaminated with heavy metals pose a major threat to human health. The objective of this study was to determine the concentration of heavy metals in soil and settled dust from automobile workshops in Afikpo, Ebonyi State, Nigeria. Sixteen soil samples were collected at depths (0-5, 5-10, 10-15, and 15-20 cm) from four randomly selected automobile workshops. Control samples were collected 4 kilometers away from any automotive repair activity. Four dust samples were also collected from parked vehicles at each of the four automobile workshops. Soil and settled dust samples were analyzed for heavy metal concentration, pH, and electrical conductivity. Soil pH differed significantly ($P \leq 0.05$), ranging from 4.29 to 5.78 in the workshops and 4.39 to 5.88 in the control. Electrical conductivity differed significantly ($P \leq 0.05$) among soil samples from different locations. EC ranged from 46.33 $\mu\text{S}/\text{cm}$ to 312.33 $\mu\text{S}/\text{cm}$ in the workshops, and 50.33 $\mu\text{S}/\text{cm}$ to 80.67 $\mu\text{S}/\text{cm}$ in the control. Arsenic and Mercury were not detected in soil and dust samples from both the workshops and the control. Cd concentration differed significantly ($P \leq 0.05$), ranging from 20.7 mg/kg to 708.5 mg/kg in the workshops. The concentration of lead (Pb) was higher in all the workshops than in the control, the highest concentration of Pb was 2769.6 mg/kg at location D. The concentration of Cd in the dust samples ranged from 48.8 mg/kg to 439.9 mg/kg, while Pb ranged from 1200.8 mg/kg to 2500.6 mg/kg. Heavy metals detected in soil and dust samples from the workshops indicate contamination from anthropogenic waste.

INTRODUCTION

Urbanization has rapidly increased environmental pollution, requiring immediate attention (Wang *et al.*, 2024). The rise in automobile, industrial, and factory emissions has increased the release and accumulation of harmful, toxic chemicals in the environment, posing a great threat to the environment and human health (Liu *et al.*, 2021). Heavy metals are chemical elements characterized by densities exceeding 4mg/kg (Mitra *et al.*, 2022). These elements naturally occur in the environment such as soils, rocks, and water bodies in both terrestrial and freshwater ecosystems. Although natural background levels exist in these ecosystems, urban environments often show elevated concentrations due to anthropogenic activities. Primary urban sources include vehicle emissions, industrial discharges, and manufacturing, among other activities (Asamoah-Boateng, 2009; Adetunji & Odetokun, 2011).

The activities of humans are contributing to high levels of heavy metal contamination in the soil and the environment. Waste and oil from automobile workshops are among the leading sources of heavy metals in the soil. Soil, especially those at automobile workshops and motor parks, contain various heavy metals with varying concentrations (Duru *et al.*, 2024; Eludoyin, & Ogbe, 2017). These soils are potentially contaminated due to activities such as overhauling vehicle engines, metal fabrication, panel beating, and the deposition of large quantities of spent engine oil, metal fillings, and other

waste (Adewole & Uchegbu, 2010). Direct contact with contaminated or polluted soil and settled dust poses significant health risks leading to anemia, renal failure and impairment of the central nervous system (Ishola *et al.*, 2017).

The infiltration of soil contaminants into groundwater aquifers for human consumption poses potentially more significant threats. Unfortunately, this sometimes happens in areas with no significant source of above-ground contamination (Adelekan & Abegunde, 2011). Soil characteristics as well as metal solubility, aid the movement of heavy metals within the soil while interacting with the soil components. Soil pH, type, organic matter, temperature, texture and structure are some of the major factors influencing heavy metal mobility (Sherene, 2010; Caporale & Violante, 2015). Neutral to slightly alkaline soil generally limits the desorption of heavy metals, while acidic conditions enhance their mobility (Sherene, 2010; Caporale & Violante, 2015). Since most chemical reactions are temperature-sensitive, higher soil temperatures accelerate the dissolution of metals in soil solutions (Sherene, 2010). This can enhance root activity, leading to accelerated metal uptake by plants (Sherene, 2010). Researchers have examined several methods to assess potential heavy metal contamination in soils (Schwartz *et al.*, 2011; Jiang *et al.*, 2013; Jiao *et al.*, 2015; Haghighizadeh *et al.*, 2024). Analyzing heavy metal concentrations at different soil depths and mobility involves pre-treatment methods such as wet digestion, microwave-assisted

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dissolution, or extraction to break down organic matter before determining metal concentrations; this has been an effective method in heavy metal detection (Simone *et al.*, 2012).

While numerous studies have examined heavy metal concentrations in different environmental matrices, majority have focused on soil (Duru *et al.*, 2024; Kicińska *et al.*, 2022) and overlooked settled dust particles in automobile workshops. Since soil and dust contamination with heavy metals poses health risks to humans, reducing their concentrations in soil and settled dust would improve staff health at automobile workshops. Therefore, this study underscores the crucial need to determine the concentration of heavy metals in soil and settled dust at selected automobile workshops in Afikpo, Ebonyi State, Nigeria where different automobile work is carried out.

MATERIALS AND METHODS

Study area description

The study site was in Afikpo, Afikpo Local Government Area of Ebonyi State, Nigeria. The study site is indicated on the map as shown in Figure 1.

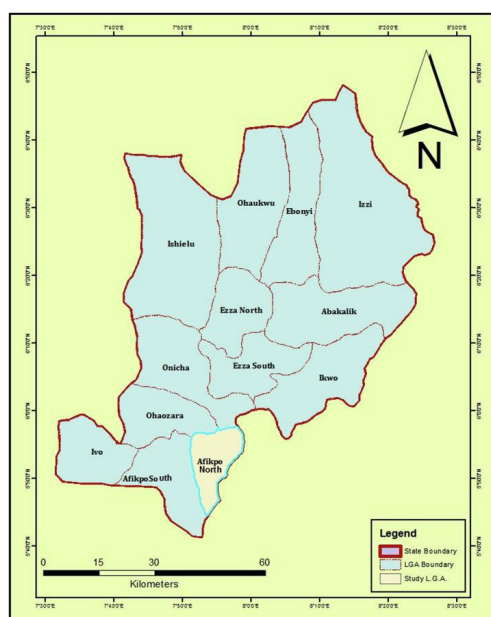


Figure 1: Map of Ebonyi State showing Afikpo L.G.A. (Adapted from Okonkwo & Ikegwu, 2020)

Field sampling

For this study, four automobile workshops (A, B, C, D) and a control site (E) were selected as sampling sites as shown in Figure 2. The locations are automobile repair facilities within the study site. It is important to note that this research did not consider the age or type of vehicles serviced at each workshop, focusing instead on the overall environmental impact of these facilities.

Soil samples were collected from the study area using a soil auger. At each automobile workshop, three sampling points were randomly selected. At each point, four soil samples were collected at depths of 0–5 cm, 5–10 cm, 10–15 cm, and 15–20 cm to represent both the surface and subsurface layers. Control soil samples were obtained from Ohabuike

Primary School in Afikpo, located approximately 4 km away from any automobile workshop activity. In addition, dust samples were randomly collected from five locations within each workshop and pulled to form a composite sample. The dust samples were collected using a clean plastic brush from the windscreens and outer surfaces of parked or abandoned vehicles. All soil and dust samples were placed in clean, labeled Ziploc plastic bags and transported to the laboratory for further analysis.

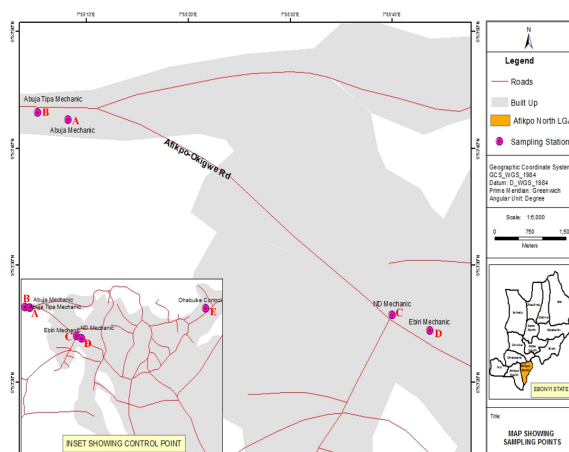


Figure 2: Map of Afikpo showing sampling locations (Source: BGI Gis Lab Port-Harcourt)

Sample preparation and digestion

The soil samples were air-dried for a week, ground and sieved with a 2 mm plastic sieve before analysis; likewise, dust samples were dried in an oven for 72 hours at 105 °C. The analysis was performed using analytical-grade chemicals. Soil and dust samples were digested with aqua regia prepared at a 1:3 ratio of HNO₃ to HCl. Two grams of dried sample (either soil or dust) were placed in a flat-bottom flask, followed by the addition of 20 mL of aqua regia. The flask was gently shaken and then heated on an electrothermal heater in a fume hood until the solution was nearly dry. After cooling, 20–30 mL of distilled water was added to the flask, and the mixture was vigorously shaken to ensure thorough homogenization. The resulting solution was filtered through Whatman filter paper into a volumetric flask, and distilled water was used to dilute it to the required volume. The final filtrate was quantitatively transferred into a 120 mL plastic bottle. Calibration standards were prepared by serial dilution from stock solutions of the target elements and were matrix-matched to the acid concentration of the digested samples. Heavy metal concentrations of lead (Pb), cadmium (Cd), mercury (Hg) and arsenic (As) were subsequently measured using an atomic absorption spectrophotometer. The pH and electrical conductivity were determined in the soil samples using a multiparameter pH meter (Hanna HI 19829) using a soil-water ratio of 1:5.

Data analysis

Data for the soil were analyzed using mixed model in SAS 9.4 (SAS Institute Inc., Cary, NC, USA) as a two-way ANOVA with location as the first factor and depth as

the second factor. The model included the location, depth, and any possible interactions. Data for dust was analyzed as one-way ANOVA using generalized linear model (GLM) in SAS 9.4. The data was tested for normality prior to analysis. Means were separated with Tukey test at the 5% alpha level.

RESULTS AND DISCUSSION

Physicochemical properties of soil and settled dust of selected automobile workshop

The lowest pH value was obtained in location C at a depth of 0-5 cm, and the highest in location E at a depth of 15-20 cm (Table 1). The pH values of the soil samples in the automobile workshops and the control were acidic.

Electrical conductivity (EC) or soil salinity measures the amount of salt in the soil. The EC values for the automobile workshop are 46.33 μScm^{-1} at location B, depth 5-10 cm, as the lowest and 312.33 μScm^{-1} at location C, depth 10-15 cm was the highest (Table 1).

Table 1: Physicochemical Properties of Soil in different Automobile Workshop at different depths

Parameters	Depth (cm)	Location					SEM	Pvalue		
		A	B	C	D	E		L	D	L*D
pH	0-5	4.75b	4.59c	4.29e	5.07a	4.39d	0.01	<.0001	<.0001	<.0001
	5-10	4.79b	4.67c	4.70c	5.56a	4.81b	0.01			
	10-15	4.88e	5.01d	5.09c	5.62b	5.72a	0.01			
	15-20	5.36c	5.01d	5.39c	5.78b	5.88a	0.02			
EC	0-5	71.67b	65.33c	63.67c	88.00a	50.33d	0.14	<.0001	<.0001	<.0001
	5-10	52.67c	46.33d	54.33c	78.00a	75.33b	0.47			
	10-15	91.00b	66.00d	312.33a	76.33c	64.33d	0.70			
	15-20	150.67b	107.33c	174.67a	99.67d	80.67e	0.47			

EC: electrical conductivity; L: location; D: depth; L*D: location $\times$ depth interaction; Location A: Abuja Automobile Workshop; Location B: Abuja Tipa Automobile Workshop; Location C: Ndubuisi Automobile Workshop; Location D: Ebiri Automobile Workshop; Location E: Control (Ohabuike Primary School). abMeans in the same row with different superscripts denote significant differences ($P \leq 0.05$)

Distribution of heavy metals in the soil and settled dust of automobile workshop

Table 2 shows the standard threshold levels of heavy metals in soil in Nigeria. The concentrations of heavy metals in soil samples from the automobile workshops at different depths are presented in Table 3. Generally, heavy metal concentrations in soil samples from automobile workshops were higher than those in control samples. The concentration of Pb ranged from 16.4 to 2769 mg/kg in the automobile workshops and from 61.5 to 184.5 mg/kg in control. The highest concentration (2769 mg/kg) of Pb was observed in location D at a depth of 5 – 10 cm, and the lowest concentration (16.4 mg/kg) was obtained in location A at a depth of 5-10 cm. Locations A, B, and C had higher Pb concentration in the topsoil than their subsoil; conversely, location E had lower Pb accumulation in the topsoil.

The concentration of Cd ranged from 20.7 to 976.7 mg/kg in the automobile workshop and from 21.2 to 449.5 mg/kg in the control. In general, Cd concentration varied across locations, with the control having a high concentration (449.5 mg/kg) at a depth of 5-10cm. Location C had the highest concentration of Cd at the topsoil (683.8mg/kg) and depth of 5-10cm (976.7mg/kg) while location D had the highest (708.5mg/kg) concentration at depth of 10-15cm and 15-20cm (81.7mg/kg). Arsenic and Hg were below the limit of detection in all the soil samples from the automobile workshops and the control.

The concentrations of heavy metals in the settled dust

from automobile workshops are presented in Figures 3 and 4. The settled dust from location A had the highest concentration of Cd (436.3 mg/kg) with location B having the lowest concentration (34.5 mg/kg) of all the automobile workshops. Location C was 56.8 mg/kg and location D was 53.3 mg/kg. The mean concentration of Pb (Figure 4) shows that location B has the highest concentration (2522.1 mg/kg), followed by location D (1826.9 mg/kg), location A (1343 mg/kg) and the lowest concentration was recorded in location C with 1058.8 mg/kg. Arsenic and Hg were below the limit of detection in the settled dust samples from the four automobile workshops.

Table 2: National Standards and Regulatory Enforcement Agency (NESREA) Threshold Limits for Heavy Metals in Soil

Heavy Metal	Limit Mg/Kg
Lead (Pb)	40.00
Cadmium (Cd)	3.00
Copper (Cu)	100.00
Iron (Fe)	0.30
Manganese (Mn)	0.00
Nickel (Ni)	0.05

NESREA (2022)

Table 3: Concentration of heavy metals in soil of automobile workshops in Afikpo at different depths

Heavy Metal	Depth (cm)	Location					SEM	Pvalue		
		A	B	C	D	E		L	D	L*D
Lead (mg/kg)	0-5	104.3c	187.7b	181.8b	2164.1a	61.5c	10.63	<.0001	<.0001	<.0001
	5-10	16.4c	30.9c	174.9b	2769.6a	170.8b	13.71			
	10-15	23.0c	30.7c	118.3b	1746.6a	184.8b	13.71			
	15-20	22.4d	21.2d	99.1b	2089.3a	173.7b	11.10			
Cadium (mg/kg)	0-5	33.6d	51.9c	683.8a	96.7b	35.1d	1.57	<.0001	<.0001	<.0001
	5-10	27.3e	71.1d	976.7a	180.3c	449.5b	2.50			
	10-15	27.5d	81.9b	40.6c	708.5a	44.1c	1.71			
	15-20	21.8c	33.5b	20.7c	81.7a	21.2c	1.57			

L: location; D: depth; L*D: location×depth interaction; Location A: Abuja Automobile Workshop; Location B: Abuja Tipa Automobile Workshop; Location C: Ndubuisi Automobile Workshop; Location D: Ebiri Automobile Workshop; Location E: Control (Ohabuike Primary School). abMeans in the same row with different superscripts denote significant differences ($P \leq 0.05$)

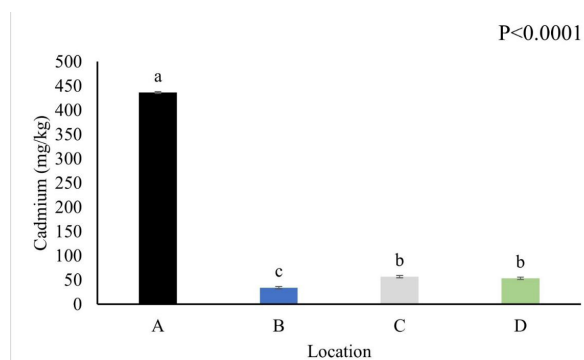


Figure 3: Cadmium concentration in settled dust samples in different automobile workshops. Location A: Abuja Automobile Workshop; Location B: Abuja Tipa Automobile Workshop; Location C: Ndubuisi Automobile Workshop; Location D: Ebiri Automobile Workshop Location E: Control (Ohabuike Primary School), abdenotes significant ($P < 0.05$) difference

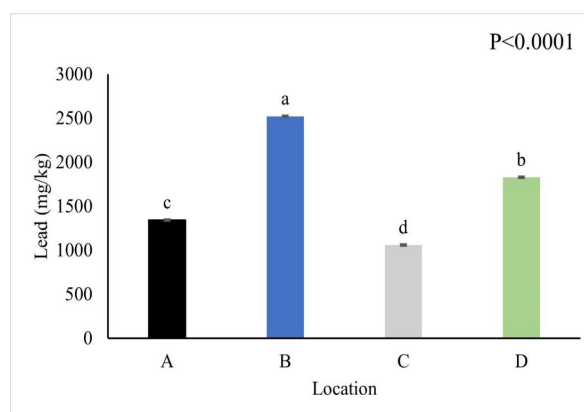


Figure 4: Lead concentration in settled dust samples in different automobile workshops. Location A: Abuja Automobile Workshop; Location B: Abuja Tipa Automobile Workshop; Location C: Ndubuisi Automobile Workshop; Location D: Ebiri Automobile Workshop Location E: Control (Ohabuike Primary School), ab denotes significant ($P < 0.05$) difference

DISCUSSION

Physiochemical properties and heavy metal concentration in the soil of automobile workshop

This study evaluated the concentration of heavy metals in soil and settled dust in automobile workshops at Afikpo, Ebonyi State, Nigeria. The distribution of heavy metals in soil is a major factor in evaluating the environmental impact of long-term land applications of heavy metals (Bai *et al.*, 2010). Soil pH is an important soil property that contributes to soil contamination due to its impact on solute sorption and desorption (Kadem, *et al.*, 2004). Majorly high pH reduces the mobility of some metal species down the soil profile while low pH usually enhances metal distribution and transportation in soil. (He *et al.*, 2004). The pH from the automobile workshops and the control were found to increase with depth. This implies that the acidity of the soil in the study sites decreased with depth which leads to a decrease in the rate of adsorption of metal deposition from topsoil to the subsoil (Kicińska *et al.*, 2022). Anthropogenic activities in the automobile workshops could be a contributing factor to the acidity of the soil, while the acidity of the control soil could be as a result of the geochemical composition of the soil and the nature of the soil texture.

Similar to the pH, the EC values for both automobile workshops and control were found to increase from topsoil to subsoil. The result of this study is similar to the study of Idugboe *et al.* (2014) who reported soil pollution in two mechanic villages in Benin city, Nigeria and higher than the results reported by Akporeta *et al.* (2010) for automobile dumpsite at Agbor and Abraka, Nigeria. The high EC recorded in this study could be due to the availability of high amount of metal substances in the soil, which eventually leached into the underlying soil and hence led to an increase in the concentration of heavy metals. Electrical conductivity is an important indicator of soil health, it affects crop yields, crop suitability, plant nutrient availability and

soil microorganisms' activity which influence key soil processes (Anegebe *et al.*, 2017). These excess salts can also hinder plant growth by affecting the soil water balance (Anegebe *et al.*, 2017).

Results showed that the concentration of the heavy metals investigated was higher in the automobile workshop than in the control site. This is in line with the report of Adeleken & Alawode (2011) that areas with high vehicular traffic and a higher tempo of anthropogenic activities of urban settlements are characterized by higher soil contaminants. According to Nwachukwu *et al.* (2010), engine oil and other transmission fluids collect heavy metals while an automobile engine is running, these metals are accumulated and remain in the used oil. When the oil is discharged in the soil, it increases the concentration of heavy metals in the soil. The control site is free from human contamination by heavy metals, but the presence of these heavy metals could be due to the geological and geochemical composition of the soil.

Nwachukwu *et al.* (2010) reported similar results in Okigwe, Orji, and Nekede mechanic villages in Imo State, Nigeria. Likewise, Adekunle and Abegunde (2011) reported high contamination of heavy metals in automobile workshops in Ibadan, Nigeria. This high level, observed, could be connected with large amounts of waste engine oil and other chemical fluids discharged indiscriminately, metal scrap deposits, welding, and other waste that are potential sources of heavy metals. Pb levels were higher in the study areas, indicating the overall level of environmental contamination with this metal, which can be mainly attributed to activities in automobile workshops. It is reported that lead has the highest composition of heavy metals in waste engine oil and other transmitted fluids. (Oguntimehin and Ipinmoroti, 2008). The lead concentration recorded in this research was lower than those reported by Oguntimehin & Ipinmoroti (2008) and Nwachukwu *et al.* (2010).

Based on the NESREA standard, the concentration of Pb was within the acceptable range in locations A and B at depths of 5-10 cm, 10-15 cm, and 15-20 cm, however, the remaining depths and locations were above the NESREA standard. The high concentration of Pb in some study areas compared to the control could be attributed to indiscriminate dumping of expired motor batteries in the surrounding areas by mechanics. Elevated values of Pb are due to ongoing Pb deposition in soil within the automobile workshops and its subsequent retention in the topsoil leading to build up of Pb in the soil. Lead is a cumulative pollutant to plants and animals, the pollution of the automobile workshops by Pb remains a problem that should be given much attention by environmentalists. Also, efforts should be made to educate the public on the effects of Pb to the health which include organ damage such as brain and kidney, miscarriage in pregnant women and damage of sperm production capability in male (Sabine

and Wendy, 2009).

The ferrous-steel industry is the primary source of cadmium pollution in the environment (Onder *et al.*, 2007). According to Dabkowska-Naskret (2004), Cadmium accumulation in automobile workshops is likely due to lubricating oils, vehicle wheels, and metal alloys used for hardening engine parts. The cadmium levels in automobile workshops are worrisome because they exceed NESREA standards. Since cadmium has no nutritional value to the soil, it was listed by the EPA (1991) as one of the 129 priority pollutants and among the 25 hazardous substances. Ingestion of high levels of Cd can lead to severe irritation to the stomach, causing vomiting and diarrhea (Fatima *et al.*, 2019).

The findings indicate that activities relating to automobiles have caused higher levels of heavy metals in the soil. All the heavy metals analyzed in this study showed concentration exceeding the background levels of the control samples, indicating environmental pollution. According to Puyate *et al.* (2007), a background value for an element denotes the highest permissible concentration in an environment; exceeding this concentration indicates contamination. The increased average concentrations of these metals in the workshop soils suggest that their presence is not a natural part of the area's geological composition but instead linked to human activities (Kodom, *et al.*, 2012).

Heavy metals contamination in settled dust

The overall mean value of Pb concentrations in the four automobile workshops was higher than 16 mg/kg reported by Okoro *et al.* (2007) in the Pb characterization of street dust in some cities in Southeastern Nigeria, which is a natural environment.

These high values may be attributed to vehicle traffic emissions, waste containing lead-acid storage battery leakage, vehicle painting, panel beating, etc. The bio-accumulative effects of the high concentration of Pb in the dust samples in these automobile workshops include mental retardation in babies and young children, cardiovascular, morphological changes, and gastrointestinal disturbances in humans (Dava, 2004).

This high concentration of cadmium in the automobile workshops portends a level of pollution in these automobile workshops. Waste motor batteries, engine oil, and motor tires, which have been implicated as the primary source of Cd, were found in these automobile workshops. Cadmium inhibits enzymes and is affixed to essential Ligands/nutrients in living cells. Cadmium has been reported to interact with Copper, Iron, and Zinc in the body to induce deficiency symptoms such as respiratory disorder, kidney and liver damage, hypertension, irritability, pneumonitis, and Bronchopneumonia (UNEP, 1999).

CONCLUSION

It was established that high concentrations of heavy metals were recorded in both soil and settled dust of

automobile workshops in Ebonyi State, Nigeria. The pH of the soil samples was found to be acidic for both the automobile workshops and the control. These acidic soils may be the cause of the high concentration of heavy metals. Electrical conductivity was equally on the high side, showing that the soil samples for both the control and the automobile workshops have high levels of salt content, and it can be concluded that the soil samples in Afikpo have high electrical conductivity invariable of being the automobile workshops or the control.

This study has equally revealed a high level of heavy metal concentration in both soil and settled dust around the various automobile workshops in the study area. Automobile workshops could be responsible for the buildup of these heavy metals in settled dust through the emission of metal particulates. Further studies need to be done to ascertain the reason for the presence of heavy metals in the control soil, which was free from automobile activities.

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