



Research Article

Physicochemical and Microbial Properties of the Soil Samples Collected from Auto-Mechanic Workshop, Orubor-Agbor, Delta State, Nigeria

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ABSTRACT

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Auto-mechanic workshops are major concerns due to the repeated discharge of spent engine oil to the receiving soil. This study investigated the qualities of soil samples from an auto-mechanic workshop located in Orubor, Abgor, Delta State, Nigeria. The collected soil (n=36) was characterized for physicochemical and bacteriological quality using standard procedures. The physicochemical results wet season were pH (5.25 ± 0.07 to 6.15 ± 0.07), electrical conductivity (45.0 ± 7.07 to $165 \pm 7.07 \mu\text{S/cm}$), organic carbon (1.53 ± 0.42 to $10.1 \pm 0.16 \%$), nitrogen (0.05 ± 0.00 to $0.44 \pm 0.01 \%$), phosphorus (0.69 ± 0.05 to $5.20 \pm 0.02 \text{ mg/kg}$) and total hydrocarbon content (151 ± 1.41 to $572 \pm 3.53 \text{ mg/kg}$). The dry season recorded pH (4.78 ± 0.04 to 5.73 ± 0.04), electrical conductivity (44.1 ± 6.29 to $1.62 \pm 4.60 \mu\text{S/cm}$), organic carbon (1.21 ± 0.07 to $7.52 \pm 0.13 \%$), nitrogen (0.47 ± 0.00 to $0.58 \pm 0.00 \%$), phosphorus (0.90 ± 0.57 to $6.79 \pm 0.09 \text{ mg/kg}$) and total hydrocarbon content (98.9 ± 0.44 to $373 \pm 6.36 \text{ mg/kg}$). There was no significant difference ($p > 0.05$) in the physicochemical parameters concerning the sampling periods. The total heterotrophic bacterial and total naphthalene utilizing bacterial counts were $9.67 \pm 1.04 \times 10^5 \text{ cfu/g}$ and $5.40 \pm 0.88 \times 10^5 \text{ cfu/g}$ respectively. The major bacterial isolates were *Serratia*, *Pseudomonas*, *Enterococcus*, and *Providencia* spp. Findings from this study revealed the necessity for public education and stricter waste management practices within auto-mechanic workshops to stem the negative effects of spent auto-engine oil pollution in the ecosystem

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INTRODUCTION

In recent times, auto-mechanic workshops have become relatively more in number owing to urbanization and improved standard of living. Rapid and increased urbanization has seen mechanic workshops being located in the vicinity of residential areas. One of the major consequences of the rise in auto-mechanics is the generation and discharge of spent engine oil within and around the workshops. The spent engine oil and other automobile wastes have continued to pollute the receiving soil environment particularly the microbiological and physicochemical properties (Ekhaise and Nkwelle, 2011).

The biological qualities of soil are greatly determined by the balance in the soil's physicochemical properties (Devatha *et al.*, 2019) hence the need to investigate the impact of auto-waste polluted soil environments in order to apply the necessary mitigation measures. Remediation of petroleum hydrocarbon-contaminated systems is currently a global challenge, chiefly in crude oil-generating nations such as Nigeria. Crude oil complex hydrocarbon contents constitute has been linked to a negative effect of petroleum. All over the world, polycyclic aromatic hydrocarbons (PAHs) have been identified as one of the most important complex hydrocarbons with diverse environmental toxicities to the ecosystem and health of humans (Falahatpisheh *et al.* (2001).

Polycyclic Aromatic Hydrocarbons (PAHs) are composed of double or multiple-bonded benzene ring structures (Karimi *et al.*, 2015). The nature of auto mechanic workshop soils makes them a highly potent reservoir of PAHs. This is because the spent engine oils and other petroleum compounds disposed of in the activities of the auto mechanic workshops contain high levels of PAHs which in most

cases are recalcitrant. Also, auto-mechanic workshops reportedly contain microorganisms with high biodegradation potentials due to their long-term exposure to quite a several hydrocarbons disposed of/spent petrol, diesel and engine oil.

Agbor is a semi-urban metropolis with a thriving economy. It is a predominantly agrarian community with a few government establishments. This semi-urban town harbours diverse auto-mechanic workshops sited along major roads and streets around the town. These auto-mechanic workshops discharge spent engine oil from service cars within their vicinities. Others directly discharge their waste materials into nearby dams and drainage systems. It is their penitent to evaluate soil samples within auto-mechanic to provide additional information on their chemical and biological impacts. There is a paucity of such information within auto-mechanic workshops in Agbor, a rapidly developing community within the south-south of Nigeria.

Hence, this study was aimed at evaluating the physicochemical and bacteriological qualities of soil samples sourced from a major auto-mechanic workshop within Agbor, Delta State.

MATERIALS AND METHODS

Study area

The study was carried out in Agbor Delta State. Agbor is a semi-urban town within the southern axis of Nigeria. It is geographically situated within Latitude $6^{\circ}07'$ and $6^{\circ}20'N$ and longitudes $6^{\circ}05'$ and $6^{\circ}20'E$ the southern hemisphere of Nigeria (Fig. 1). The town Agbor occupies a total land mass of about 650 km², with a population of 162,594. As at the 2006 Census (Olobaniyi *et al.*, 2007: Edjere and Iyekowa 2017).

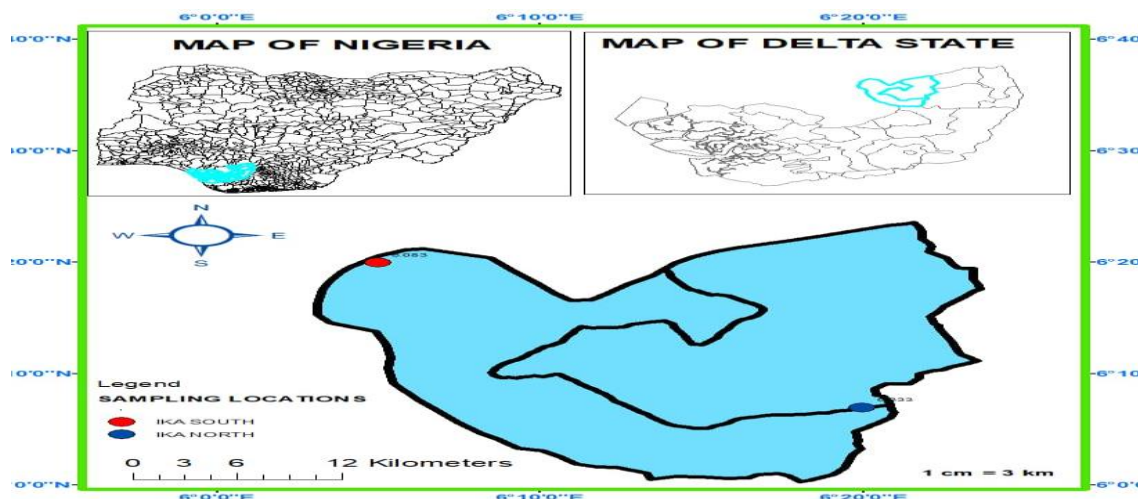


Figure 1: Location map of Agbor showing sampling location

Sample collection

A total of twelve (12) samples of stratified top soils (0-5 cm and 6-10 cm) were randomly collected from spots identified as major polluted zones within Orubor auto-mechanic workshop in Agbor metropolis, Delta State. The samples were collected using a soil auger during the wet and dry seasons in 2020. The collected samples were carefully packaged in sealed polyethene bags containing ice cubes to maintain a relatively low temperature during the laboratory for further analysis.

Determination of physicochemical parameters:

pH: The soil samples (20 g) were weighed into a beaker containing distilled deionized water. The content was well mixed manually before taking a pH reading of the suspension with a pH meter (UNISCOPE Model No. PHS-3E) (Mahawar and Akhtar, 2015).

Electrical Conductivity (EC): The soil suspension used in the determination of pH was used for the EC analysis as described previously (Edwin-Wosu and Nkang, 2019).

Moisture content: Empty moisture dishes were preweighed (W_1) before adding 20 g of the soil samples and measure again (W_2). The lid was removed and placed underneath the can and put into the drying oven at a temperature of

between 105 ° and 110 °C, 24 h. The final weight of the dish with dried soil was recorded (W_3) (Mahawar and Akhtar, 2015). Equation 1 was then used to determine the percentage moisture content.

$$\text{Moisture content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100 \quad (1)$$

Where:

W_1 = Initial weight of the empty dish

W_2 = Weight of the dish + wet soil sample, and

W_3 = Weight of the dish + dried soil sample.

Organic carbon contents: The method described by (Akpoveta *et al.*, 2011). Exactly 1 g of each soil sample was into an Erlenmeyer flask containing 10ml potassium dichromate, mixed very well before adding a few drops of phenolphthalein indicator. After diluting the resulting suspension with 100 ml distilled water, the final solution was then titrated until a colour change showing deep bluish-black was obtained as the endpoint. The procedure was repeated with all the chemicals added except the soil samples to get a blank titre. The percentage (%) of organic carbon was now calculated (equation 2) as follows:

$$\text{Organic carbon (OC \%)} = (\text{B}-\text{T}) \times 0.003 \times 0.5 \times 100 \times 1.33 \quad (2)$$

Where

Where: B: Blank, T: Titre

Nitrogen contents: The content of nitrogen in the soil samples was evaluated using the Macro– Kjeldahl method as reported earlier (Mahawar and Akhtar, 2015). Soil samples were measured (1 g) and added into clean flasks containing a mixture of sulfuric acid (20 ml), mercury oxide (0.48 g) and potassium sulfate (4.52 g) reagents. The content was digested at 420 °C for over 2 h and allowed to cool at ambient temperature. After cooling down, the content was diluted with about 30 ml of distilled water before distilling for 6 min after the addition of sodium hydroxide (20 ml). The resulting distillate, ammonia (30 ml) was then titrated against hydrochloric acid (0.25 M) and observed for colour changes. The progress of the titration process was monitored along a standard (Ammonium dihydrogen phosphate, NIST SRM 194). Also, solution blanks containing all the reagents served as control. In the end, the nitrogen content (%) was calculated (equation 3) as follows:

$$\text{Nitrogen contents (N \%)} = \frac{\text{T} \times \text{M} \times 14 \times 100}{\text{weight of soil used}} \quad (3)$$

Were:

T= Titre Vol

M= Molarity

Phosphorus contents: Three grams (3g) of each soil sample was weighed into shaking cups and 20 ml of Bray P-1 solution was added to each sample and then placed on a mechanical shaker for one minute. The content was then filtered and the filtrate (5 ml) was added into a volumetric flask containing a mixture of Murphy and Riley reagent (5 ml) and distilled water (20 ml). After letting the contents settle for about 15 min, the resulting blue-coloured solution was measured with a

spectrophotometer set at 650 nm (SpectronicCemspec M501) (Murphy and Riley, 1962).

Determination of total hydrocarbon content (THC): The soil sample (5 g) was dissolved in dichloromethane (20 ml) and vortex for 10 min. The soil extract was then filtered before measuring the absorbance at 460 nm alongside dichloromethane as blank (Akpoveta *et al.*, 2011). The THC (mg/kg) of the sample was calculated with reading obtained from the spectrophotometer (SpectronicCemspec M501) using equation 4:

$$\text{THC (mg/kg)} = \frac{\text{OD value reading} \times \text{Volume of Solvent used (ml)}}{\text{Weight of sample (kg)}} \quad (4)$$

Sand particle: Samples were sieved using a 4mm sieve afterwards 50 g of each sample was weighed and poured into a nest of sieves ranging from 2 mm to 0.01 mm. The sieves were shaken for some minutes and the different aggregates were distributed into the different sieves depending on their sizes. Each aggregate distributed in the different sieve was weighed differently (Beare and Ballard, 2013). The average weight diameter (AWD) of the sand particles was determined using equation 5.

$$\text{Sand particle size (\%)} = \sum S_{st} W_{st} \quad (5)$$

Where: S_{st} = Half of the range of nest of sieves; W_{st} = weight of samples

Silt: Samples were sieved using a 4mm sieve afterwards 50 g of each sample was weighed and poured into a nest of sieves ranging from 2mm to 0.01mm. The sieves were shaken for some minutes and the different aggregates were distributed into the different sieves depending on their sizes. Each aggregate distributed in the different sieve was weighed differently (Beare and Ballard, 2013). The average weight diameter (AWD) of the silt particles was determined using

equation 6.

$$\text{Silt particle size (\%)} = \sum S_s W_s \quad (6)$$

Where: S_s = Half of the range of nest of sieves; W_s = weight of samples

Clay: Samples were sieved using a 4mm sieve afterwards 50 g of each sample was weighed and poured into a nest of sieves ranging from 2 mm to 0.01 mm. The sieves were shaken for some minutes and the different aggregates were distributed into the different sieves depending on their sizes. Each aggregate distributed in the different sieve was weighed differently (Beare and Ballard, 2013). The average weight diameter (AWD) of the clay particles was determined using equation 7.

$$\text{Silt particle size (\%)} = \sum S_c W_c \quad (7)$$

Where: S_c = Half of the range of nest of sieves; W_c = weight of samples

Enumeration and isolation of bacterial from the soil samples

One gram (1g) of soil samples from automobile workshops was weighed into 10 ml of sterile distilled water as stock solution. A serial ten-fold dilution was then carried out until a 10^{-10} dilution was obtained. From dilutions 10^{-4} , 10^{-6} and 10^{-8} , 1 ml was withdrawn and plated (pour plate method) on sterile nutrient agar before incubation at 37°C for 24-48 h for the determination of total viable bacterial counts. Similarly, bacteria that can utilize naphthalene, one of the simplest and most prevalent hydrocarbon compounds, was enumerated by culturing 1 ml from dilutions 10^{-4} , 10^{-6} and 10^{-8} , 1 ml using sterile Bushnell Haas agar followed by incubation at 37°C for 48-72 h. The expressed colonies thereafter were then counted using a mechanical counting chamber to obtain their colony-forming units per gram (CFU/g). The bacterial cultures were then purified

by repeated sub-culturing and stored on an agar slant for further characterization using their cultural, microscopic and biochemical reactions (Cheesebrough, 2000)

Data Analysis:

All analyses were done in triplicates and the mean values were presented with their standard deviations (Paulson, 2008).

RESULTS AND DISCUSSION

Physicochemical analysis of soil sample

The results of the physicochemical parameters of the soil samples collected during the dry and wet seasons from automobile workshop in Agbor are shown in Tables 1a and 1b respectively. The results of the dry season analysis revealed pH ranged 4.78 ± 0.04 to 5.87 ± 0.02 , Electrical conductivity (EC) 44.1 ± 6.29 to 162 ± 4.60 , $\mu\text{S/cm}$, organic carbon 0.82 ± 0.05 to 7.52 ± 0.13 %, nitrogen content 0.07 ± 0.00 to 0.58 ± 0.00 %, phosphorus content was between 0.90 ± 0.57 to 6.79 ± 0.09 mg/kg, sand 88.5 ± 1.89 to 92.4 ± 1.97 %, silt 0.99 ± 0.01 to 2.98 ± 0.03 %, clay 5.47 ± 0.05 to 6.99 ± 0.06 %, moisture 1.09 ± 0.04 to 2.77 ± 0.01 % and total hydrocarbon content (THC) ranged from 98.9 ± 0.14 to 375 ± 6.36 mg/kg (Table 1a).

The wet season results revealed pH ranged from 5.25 ± 0.07 to 6.15 ± 0.07 , Electrical conductivity (EC) 45.0 ± 7.07 to 165 ± 7.07 $\mu\text{S/cm}$, organic carbon 1.09 ± 0.008 to 10.1 ± 0.16 %, nitrogen content 6.05 ± 0.00 to 0.44 ± 0.01 %, phosphorus 0.69 ± 0.05 to 5.20 ± 0.02 mg/kg, sand, 88.0 ± 0.00 to 91.9 ± 0.00 % silt content 0.98 ± 0.00 to 2.94 ± 0.00 % clay content 7.06 ± 0.00 to 9.02 ± 0.00 % moisture content, 1.32 ± 0.04 to 3.31 ± 0.02 % while total hydrocarbon content (THC) ranged from 151 ± 1.41 to 572 ± 3.53 mg/kg (Table 1B).

The results of pH values revealed that the soil samples were slightly acidic. Previous study have shown that contamination with petroleum and its products decrease soil pH and with

increasing concentration of contaminants, soils become more acidic (Ohanmu *et al.*, 2018). The electrical conductivity values of the sampled workshops were relatively high for all the sampled auto mechanic workshop soils. Electrical conductivity is a measure of soil contamination and pollution. It is an indication of the presence of some ions in the soil (Mahawarand and Akhtar 2015; Edwin-Nwosu and Nkang 2019). The electrical conductivity values for the sampled automobile workshops indicated increased electrical conductivity with corresponding increase in auto wastes. These findings are in consonance with the findings of Devatha *et al.* (2019) who asserted that petroleum hydrocarbons contain high amounts of ions which can increase the electrical conductivity of the soils they contaminate. The result revealed significance ($p < 0.05$) with depth in moisture. This observation for moisture content could be attributed to climatic conditions and the nature of the soils. It could be that the soils have higher water retention capacity owing to the particle sizes. These results agree with the findings of Devatha *et al.*, (2019) who stated that soil moisture content depends on climatic conditions and soil particle size also soil mixed with oil petroleum contaminants like crankcase oils show a decrease in moisture content proportionally with concentration of contaminants.

The high total hydrocarbon content values recorded in this study was an indication of the level and extent of petroleum contaminants released into the sampled sites. These values were higher than the 50mg/kg limit set by the Department of Petroleum Resources (DPR 2002). These results are in agreement with the earlier findings of Benka –Coker and Ekundayo (1995) and Aigberua *et al.* (2016). The levels of nitrogen and phosphorus content during the dry and wet seasons did not vary significantly and this suggest that seasonal fluctuations did not exert much effect their contents in the auto-

mechanic shop. The observed results for nitrogen and phosphorus content may be due to increase in crude oil contaminants which cause a decrease in their levels.

These findings are in agreement with the reports of Ohanmu *et al.* (2018) who stated that low nitrogen content of soil is not due to poor natural soil conditions but as a result of pollution with petroleum and its components. Though, the waste from the shop impacted negatively on their soil contents, the current level could encourage the application of bacterial agents to boost the remediation of hydrocarbons in the environment. Nitrogen and phosphorus are two important mineral needed by microorganisms for active growth and metabolic activities

The result for the total heterotrophic bacterial and total naphthalene utilizing bacterial counts from the soil samples during the dry and wet seasons are presented in Table 2. The total heterotrophic bacterial and total naphthalene utilizing bacterial counts were in the order of 105 cfu/g respectively. The results of dry season total heterotrophic bacterial counts was lowest (1.92 ± 0.13 cfu/g) at point C6-10, while it was highest (9.67 ± 1.04 cfu/g) at point A6-10. The enumeration of naphthalene utilizing bacteria had the highest count at point A6-10 (5.40 ± 0.88 cfu/g). However, the result for wet seasons total heterotrophic bacterial and total naphthalene utilizing bacterial counts from the soil samples ranged from 0.02 (C6-10) ± 0.00 to 3.83 ± 0.13 (C0-5), 0.00 ± 0.00 (C6-10) to 3.13 ± 0.17 (C0-5) respectively. The predominant bacterial isolates were species of *Enterococcus*, *Pseudomonas*, *Providencia*, and *Serratia*. The presence of these bacterial isolates have been implicated in hydrocarbon polluted environment (Ekhaise and Nkwelle, 2011; Pawar *et al.*, 2013; Karimi *et al.*, 2015; Sangkharak *et al.*, 2020)

Table 1a: Physicochemical properties of soils collected during dry season from Orubor automobileworkshop, Agbor

Parameters	pH	E.C	Organic C	Nitrogen	P	Sand	Silt	Clay	Moisture	THC
Code/Units	-	uS/cm	%	%	mg/kg	%	%	%	%	mg/kg
A ₁ 0-5	5.59±0.11	162±4.60	7.52±0.13	0.58±0.00	0.90±0.57	91.5±1.96	1.99±0.01	5.47±0.05	1.70±0.00	375±6.36
A ₂ 6-10	5.01±0.10	98.0±1.41	0.82±0.05	0.07±0.00	3.52±0.99	89.5±1.91	1.98±0.01	6.99±0.06	1.91±0.03	156±4.92
B ₁ 0-5	5.58±0.11	44.1±6.29	1.21±0.07	0.09±0.00	6.46±0.18	91.5±1.95	1.99±0.01	5.47±0.05	1.34±0.07	98.9±0.14
B ₂ 6-10	5.87±0.02	107.8000	1.14±0.01	0.09±0.10	6.79±0.09	92.4±1.98	0.99±0.01	5.47±0.05	2.25±0.04	264±1.78
C ₁ 0-5	4.78±0.04	147±2.12	6.08±0.01	0.47±0.00	2.85±0.15	92.4±1.97	0.99±0.01	5.47±0.05	1.09±0.04	278±1.63
C ₂ 6-10	5.63±0.04	73.6±7.99	1.24±0.15	0.09±0.01	3.17±0.45	88.5±1.89	2.98±0.02	6.99±0.06	2.77±0.01	309±2.40
P-values	0.641	0.557	0.113	0.117	0.614	0.240	0.649	0.116	0.038	0.938

All values expressed as mean ±SD

Table 1b: Physicochemical properties of soils collected during wet season from Orubor automobileworkshop, Agbor

Parameters	pH	E.C	Organic C	Nitrogen	P	Sand	Silt	Clay	Moisture	THC
Code/Units	-	uS/cm	%	%	mg/kg	%	%	%	%	mg/kg
A10-5	5.85±0.07	165±7.07	10.1±0.16	0.44±0.01	0.69±0.05	90.9±0.00	1.96±0.00	7.06±0.00	2.03±0.01	572±3.53
A26-10	5.25±0.07	100±0.00	1.09±0.08	0.05±0.00	2.69±0.73	89.0±0.00	1.96±0.00	9.02±0.00	2.29±0.06	238±4.95
B10-5	5.85±0.07	45.0±7.07	1.62±0.14	0.07±0.00	4.95±0.09	90.9±0.00	1.96±0.00	7.06±0.00	1.60±0.07	151±1.41
B26-10	6.15±0.07	110±0.00	1.53±0.42	0.07±0.01	5.20±0.02	91.9±0.00	0.98±0.00	7.06±0.00	2.69±0.02	403±7.07
C10-5	5.00±0.00	150±0.00	8.16±0.06	0.35±0.00	2.18±0.09	91.9±0.00	0.98±0.00	7.06±0.00	1.32±0.04	425±7.07
C26-10	5.90±0.00	75.0±7.07	1.67±0.30	0.07±0.01	2.42±0.33	88.0±0.00	2.94±0.00	9.02±0.00	3.31±0.02	471±1.41
P-value	0.938	0.848	0.901	0.889	0.770	0.829	0.643	1.000	0.494	0.435

All values expressed as mean ± S

Table 2: Total heterotrophic and total naphthalene utilizing bacterial counts of soils sampled during wet and dry season from Orubor mechanic workshop, Agbor

Sampling	THBC ($\times 10^5$ cfu/g)		TNUBC ($\times 10^5$ cfu/g)		Predominant Bacterial isolates	
	Dry Season	Wet Season	Dry Season	Wet Season	Dry Season	Wet Season
A0-5	9.67 \pm 1.04	3.70 \pm 0.09	5.08 \pm 1.76	1.50 \pm 0.27	<i>Pseudomonas</i> sp., <i>Serratia</i> sp.	<i>Enterococcus</i> sp., <i>Pseudomonas</i> sp.
A6-10	1.75 \pm 0.06	1.80 \pm 0.01	5.40 \pm 0.88	1.77 \pm 0.06	<i>Serratia</i> sp., <i>Enterococcus</i> sp.	<i>Serratia</i> sp., <i>Pseudomonas</i> sp.
B0-5	2.78 \pm 0.01	3.53 \pm 0.13	4.58 \pm 0.74	0.19 \pm 0.02	<i>Enterococcus</i> sp., <i>Providencia</i> sp.	<i>Enterococcus</i> sp., <i>Providencia</i> sp.
B6-10	3.08 \pm 0.09	0.71 \pm 0.09	2.75 \pm 0.53	0.67 \pm 0.02	<i>Pseudomonas</i> sp., <i>Providencia</i> sp.	<i>Serratia</i> sp., <i>Providencia</i> sp.
C0-5	2.67 \pm 0.87	3.83 \pm 0.13	3.32 \pm 0.27	3.13 \pm 0.17	<i>Enterococcus</i> sp., <i>Serratia</i> sp.	<i>Enterococcus</i> sp., <i>Serratia</i> sp.
C6-10	1.92 \pm 0.13	0.02 \pm 0.00	0.00 \pm 0.00	0.00 \pm 0.00	<i>Providencia</i> sp., <i>Serratia</i> sp.	<i>Providencia</i> sp., <i>Serratia</i> sp.

THBC (Total Heterotrophic Bacterial Counts), TNPBC (Total Naphthalene Utilizing Bacterial Counts).

The presence of higher levels of naphthalene utilizing bacterial population from soil samples in these locations suggest higher concentration of naphthalene degraders in the soils compared to other heterotrophs. This may be attributed to the adaptation of some of the indigenous bacteria to auto-mobile wastes which consist of crankcase oil and other petroleum hydrocarbons. The high population of naphthalene utilizers is also an indication that the soil contains high level of residual naphthalene and possibly other polycyclic aromatic hydrocarbons which account for their ability to proliferate in these workshop soils. These results agree with the reports of Akoachere *et al.* (2008) who reported higher oil degrading bacterial counts than heterotrophic bacterial counts and also reduction in both heterotrophic and oildegrading bacterial counts with increasing depths.

CONCLUSION

This study investigated the physicochemical and bacteriological properties of soil samples collected from auto-mechanic workshops in Abgor. The soil was found to be relatively higher in acid, EC, sand particles and THC but relatively lower in organic compounds, nitrogen, and phosphorus contents. The presence of higher contents of naphthalene utilizing bacterial population from soil samples

showed that suggests a higher concentration of naphthalene degraders in the soils compared to other heterotrophs. The predominant bacterial isolates were species recovered from the soil samples *Enterococcus*, *Pseudomonas*, *Providencia*, and *Serratia*. These bacterial species could be considered potential candidates for the remediation of hydrocarbon-polluted auto-mechanic workshops within the study locations. Moreover, there for enhanced public awareness campaigns on the negative effects of hydrocarbon-polluted environments coupled with the deployment of proper waste management techniques within such location to mitigate the environmental impact of the generated wastes.

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CONFLICT OF INTEREST

The authors declare that they have no competing interests among them

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