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Moisture content and organic parameters of soils around heavy duty generators along iwofe-mile III axis, Port Harcourt, Rivers State, Nigeria

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Abstract
This research evaluated the levels of moisture content and organic parameters (organic carbon, organic matter, THC, PAHs and TPH) in soils around heavy duty generators which are installed along Iwofe-Mile III road axis in Port Harcourt. Soil samples were collected at three different points where heavy duty generators were installed for the determination of moisture content and some organic parameters. The different parameters investigated were examined using standard laboratory analytical methods. The average range of values recorded for the various parameters investigated in the studied stations at the period of study were moisture content; 24.741±0.434 to 27.906±0.647 %, % organic carbon; 4.274±0.085 to 4.644±0.079%, %organic matter; 7.369±0.146 to 8.008±0.135%, total hydrocarbon content; 92.333±4.110 to 125.667±4.110mg/Kg, polycyclic aromatic hydrocarbons 27.000±2.944 to 37.333±1.247mg/Kg, and total petroleum hydrocarbons; 65.333±1.247 to 88.333±3.300. The levels of the studied parameter in the different stations where the heavy duty generators are installed were inadequate for soils as required by relevant agencies. The results obtained showed hydrocarbon pollution and therefore proper control and monitoring is needed where theses heavy duty generators are installed in order to forestall any danger to the soil that is already degraded and humans that assess the areas where the generators are kept.

Keywords: heavy duty generators, hydrocarbon content, Iwofe-mile III, moisture content, organic parameters

Introduction

Human actions within the environment have led to increased level of contamination of the soil, such contamination/pollution has caused remarkable life challenges which portends great danger to the existence of animals, plants and even human life. Human activities like fertilizer and pesticides application for crop development, domestic, public and industrial release of wastes, mining, manufacturing of goods and rupture of storage tanks (Seifi *et al*., 2010) [64] has brought about significant changes in the physical and chemical composition of the soil and other natural environments. Soil contamination help in the blockage of air spaces that help in the diffusion of gases within the pores of the soil particles (Sutton *et al*., 2013) [65] and also produces alterations in the physical form of the soil by changing the penetrability and Atterberg limits (Nazir, 2011; Akunwumi *et al*., 2014; Devatha *et al*., 2019) [47, 6, 21]. Soil organisms and plants growth and development are affected as a result of alterations in the chemical composition of the soil like pH, total organic carbon/matter and mineral nutrients (Yalin *et al*., 2006; Akugugwo *et al*., 2009; Wang *et al*., 2010) [71, 70].

The incessant deficiency of these necessities is unfavourable and results into grave consequences that could lead to unsuitable soil situations which could ultimately result in poor crop development and growth.

The soil acts as a natural sink and it is fundamental and non-replaceable in nature and also acts as a natural linkage between other natural components such as the air and water and together complete the environmental cycle. The interactions that exist between these natural constituents of the environment has facilitated the provision of the needed requirements of life such as food, water, fuel and support for humans and other living creatures (DEFRA, 2009). The soil is very vital for human survival and when polluted or contaminated due to human activities poses serious consequences and very dangerous to the general environment and therefore invites a considerable of the public. One foremost way through which petroleum hydrocarbons come into the environment is through human activities, and when these activities are not appropriately monitored, managed or controlled becomes dangerous to human existence (Edori & Kpee, 2019) [25]. Public, agricultural, domestic and industrial activities release waste into the surroundings such as air, water and soil (Adipah, 2019) [3].

Petroleum hydrocarbons are presently the foremost organic pollutant in the soil. The incidence of hydrocarbons in the soil have harmfully influenced human health, growth and effective running of other creatures within the soil ecosystem. Soil contamination due to the occurrence of petroleum hydrocarbons has both durable and a temporary consequences on the quality of the soil and the effective functioning and also the level of food quality produced from the soil that has been affected (DEFRA, 2009; USEPA, 2011). The production of energy is associated with transformation of petroleum products and other chemicals. The process of crude oil exploration to the time of final consumption can lead to severe environmental pollution that may become irreparable (Daraei *et al*., 2013) [18]. The diverse chemicals that come from crude oil and its components, when existing in the soil and any other environment could cause some health challenges such skin colour change, neurological irregularities, pregnancy related issues in women and pulmonary disease and can pose harm in clean-up workers (Edori and Iyama, 2017; Edori *et al*., 2022) [27, 24].

Pollution effect resulting from petroleum hydrocarbons could take a long-term or a short-term consequence on the affected environment (Veellu, 1989) [66], human and other creatures that occupy the environment where pollution occurred. Fallout from petroleum products in the soil could portend serious environmental damages and pollution that could possibly change the overall ecology of an environment and even affect human life severely. The consequence of the contamination of the soil by petroleum products has grievous negative implications since it naturally flows from soil and water to humans **(**Ahmed & Anm, 2018) [4]. The subsequent result of soil pollution due to petroleum hydrocarbons comprise the decline in the physical, chemical and biochemical characteristics of the soil, constraint in plants growth, insufficiency of soil oxygen and water, deficiencies of nutrients base related to the presence of nitrogen and phosphorus in the soil **(**Ahmed & Anm, 2018; Mohammadi *et al*., 2020) [4].

Pollution or contamination of the soil due to petroleum hydrocarbons could result into an increase in the acidic content and high concentration of heavy metals within the soil ecosystem (Meindinyo & Agbalabga**,** 2012; Ogboi, 2012) [49, 53]. The ultimate consequence of such occurrence in the soil is the achievement and initiation of deviations from the original values thus resulting in undesirable environmental and health consequences. The availability of such lands for usage turn out to be limited in value because of presence of petroleum hydrocarbons and so necessitates speedy remediation activities, which if ignored could affect the groundwater system, rivers and the general ecology, thus resulting into more harm (Nwankwo *et al*., 2015) [51]. Soil contamination by hydrocarbons have a consequential result on the value of pH by reducing it and utterly affects agricultural and horticultural crop production by reduction in output (Odu *et al*., 1985; Ojimba & Iyagba, 2012) [52, 54]. Soil contamination/pollution by hydrocarbons introduces diverse compounds into the soil which have differing chemical properties from the original composition or mixture. The volatile constituents of the hydrocarbon mixture readily evaporate while the heavier components leach through the soil thereby contaminating the groundwater (Laskova *et al*., 2007; Paulauskiene *et al*., 2009) [41, 57]. These pollutants attach to **s**oil particles and could stay for a long time, and also soil microorganisms may find it difficult to breakdown other components through the process of degradation (RTI, 1999).

Materials and Methods

Collection and Preparation of Samples

Soil samples were collected along Iwofe-Mile III axis of Mile III-Iwofe Road, Port Harcourt where heavy duty generators are installed to provide power for street lights. The stations used for the study were Police Station and Specialist Hospital in Iwofe axis and are designated as station 1 and 2 respectively while Station 3 was at Sure Foundation School in Ada George-Mile III axis. Soil samples were randomly collected at the designated point from 0.00-30cm depth with soil auger. Soil samples collected from each location were mixed together thoroughly to give a composite sample. The soil samples were put into an already sterilized polythene bag with the help of a spatula and was taken to the laboratory for pretreatment. A sieve of 2mm size was then used in homogenizing the soil samples and larger soil particles such as stones were removed. The homogenized samples were properly labelled and designated in accordance to their origin. Each of the parameters studied were examined thrice and the mean value recorded.

Moisture content determination

Soil moisture content is an indication of the quantity of water existing in soil. Moisture content was examined according to the method used by Anderson and Ingram (1993) [9]. 1g of the pretreated soil sample was placed in a previously cleaned and dried container of known mass with its cover security in position. The mass of the crucible and the moist soil was analyzed with a weighing balance model AE163. Afterwards, the cover was detached and the crucible was placed in oven at a temperature of 110±5ºC for 4h to attain a constant weight of the soil. The moisture content was then calculated using the expressing:

$$\text{Moisture content } \%\, ^{n} = \frac{Moist\ soil - Dry\ soil}{Moist\ soil}\ x\ 100$$

Percentage organic carbon and organic matter

The method used by Walkey and Black (1934) [69] was adopted in examination of the quantity of organic carbon in the soil. 2g of the soil sample was weighed and put into a conical flask and a 10ml standard solution of $K_2Cr_2O_7$ was then added to the pretreated soil sample. Furthermore, 20ml of concentrated H_2SO_4 was also added in order that chloride ions will not affect the process. The prepared soil solution was allowed to settle down for about 30 minutes interval while stirring occasionally. The content was diluted in a conical flask by the further addition of about 10ml of distilled water. A ferroin indicator was adopted as an indicator to examine the surplus $K_2Cr_2O_7$ which was titrated with 1,0N standard solution of ferrous sulphate.

The percentage organic carbon in the soil sample was calculated by applying the mathematical expression

$$\% \text{ Organic Carbon} = \frac{(McK2Cr2O7 - McFeSO4)\ x\ 0.003\ x\ 100\ x\ F}{weight\ of\ soil(g)}$$

Where,
Mc = normality of solution x volume (ml) of solution used
F = correlation factor = 1.33
The percentage organic matter was calculated by applying the formula
% Organic Matter = % organic carbon x 1.724

Preparation of Soil Samples for polycyclic aromatic hydrocarbons Analysis
The method employed by Prycek *et al.* (2007) [62] was adopted in the preparation and extraction of polycyclic aromatic hydrocarbons obtained from the soil for examination. 125ml volume of methanol was put into soxhlet extractor for the extraction of PAHs in the soil samples for 4 hours. A further addition of 250ml of dichloromethane was made into the already extracted content and then allowed to cool and the process of extraction was continued for about 24 hours and thereafter dichloromethane was again added. The extracts were filtered with a separatory funnel of 500ml capacity and was eluted with a 250ml funnel into an already prepared beaker and was further purified by washing thrice with the aid of 50ml beaker that contain dichloromethane solvent. The portion extracted was then placed in a rotary evaporator in order that the volume will reduce to 5 cm^3. The sample was further purified by putting the extract into a 50ml capacity round bottom flask, and then 15 ml of n-pentane was again added. The sample was further reduced by evaporation to about 2ml with a rotary evaporator. The n-pentane extract was reduced further with the aid of the evaporator to 0.5ml using nitrogen gas in order to allow an easy passage through the column that was filled activated silica gel and packed with slurry for 8 hours at a temperature of 200 ^oC. Water was removed totally from the extract by allowing the extract to pass through a column that is dry-packed and formerly cleaned using anhydrous sodium sulphate. Saturated hydrocarbons were first separated and eluted after the addition of n-pentane and then PAHs were ultimately eluted after the addition of 14% CH_2Cl_2.

Extraction of soil sample for total petroleum hydrocarbon determination
10g of the soil sample was weighed using an analytical weighing balance after which it was put in an amber bottle. The soil sample was strongly agitated when 5g anhydrous sodium sulphate (Na_2SO_4) was added into an amber glass bottle that contains the soil sample for the particles to mix together effectively. Anhydrous sodium sulphate was added so that the moisture content of soil sample will be reduced. After thorough mixing of the soil sample, 30ml dichloromethane was added as an extraction solvent. The amber bottle was closed tightly after the addition of 30ml dichloromethane and was then taken to a mechanical shaker. The sample was agitated at room temperature and kept to settle down for an interval of 1hr. The agitated soil sample was filtered and put into a hitherto washed beaker which has a board with a 110mm filter paper. The filtered soil sample was finally concentrated to 1ml by evaporation (LAWI, 2011).

Sample Clean Up
The sample was properly cleaned up by thoroughly washing and preparing the chromatographic column through the introduction of glass-wool into an already washed chromatographic column. At that point silica gel was put into a beaker that was previously cleaned by adding slurry into the chromatographic column. Anhydrous sodium sulphate was added into the column and then n-pentane was added afterwards. Cyclohexane was mixed with the concentrated sample in a beaker that has been pre-cleaned and was then added into the chromatographic column which was already prepared. The sample was collected using a beaker placed at the bottom of the column once it has been eluted with n-pentane. A further elution of the sample was done by adding more n-pentane, subsequently the column was then washed with dichloromethane. The sample that was eluted was kept in a steady cupboard and allowed to evaporate at room temperature (LAWI, 2011).

Gas chromatography-mass spectrometry conditions
The procedure of Prycek *et al*. (2007) [62] was used this investigation. The Agilent 6890N chromatograph model gas chromatography-mass spectrophotometer, with serial No. US 10530055 (Agilent Technologies Avondale, USA) was employed in the analysis of the polycyclic aromatic hydrocarbons in the soil samples. The equipment was connected to a mass detector model 5975 series MSD, Agilent, Avondale, USA. The separation of PAHs was achieved by use of a 5% phenyl-methylsilicone (DB-5MS) phase merged together with a fused-silica tube column that has dimensions 30 m X 250 μm ID and a film thickness of 0.25 μm. The tube column was designated with part number 19019J_413 and operated within a temperature range of -60 to 350 ^oC. The injector port was operated in splitless mode. The oven was kept at a temperature of 65 ^oC for one minute and was increased to 290 ^oC at a stable rate of 10 ^oC/min and was then steadily kept at 290 ^oC for a period of 11 minutes. The line through which the extract passes was kept at 300^oC. The prepared stock solution was used in determining the retention time for the PAHs analyte. The peaks obtained from the scan mode were used in the identification and quantification of the ion peaks and also to designate the PAHs in the samples. Helium was the carrier gas used and was supported by nitrogen gas for the gas chromatography analysis. The system was kept and operated using a pressure of 9.0855 Psi at a flow rate of 37.604 cm/sec.

Sample separation and detection of total petroleum hydrocarbons

Gas chromatography-flame ionization detector (GC-FID) Agilent 5890 model was employed in the detection of the levels of total petroleum hydrocarbons in the studied soil samples at the various locations (Cortes *et al*., 2012) [16]. The syringe was first cleaned by the injection of 3ml of the concentrated sample via the vial of the gas chromatography and afterward the blank dichloromethane was then injected into micro-syringe of gas chromatography for the detection of blank sample. The micro-syringe was cleaned thoroughly before it was used for the determination of the samples. The cleaning of micro-syringe was done thrice. The sample was initially used in rinsing the micro-syringe when it has been properly washed and after which it was injected into the vial of the gas chromatography for the total separation of total petroleum hydrocarbons in the sample. The amount of total hydrocarbon level determined at any particular chromatogram was measured in mg/Kg for that particular soil sample.

Results and Discussion

The results obtained for the parameters studied (% moisture content, % total organic carbon, % total organic matter, total hydrocarbon content, polycyclic aromatic hydrocarbon and total petroleum hydrocarbon during the period of study in the different stations where heavy duty generators are installed for traffic light-up are given in Tables 1 to 3 while the mean concentrations within the stations are given in Table 4.

Table 1: Concentrations of moisture content and organic parameters of soils around heavy duty generators in June

Parameters	Stations		
	1	2	3
% Moisture content	24.132	27.069	25.012
% Total Organic Carbon	4.250	4.540	4.350
% Total Organic Matter	7.330	7.830	7.500
Total hydrocarbon content (mg/Kg)	125.000	93.000	115.000
Polycyclic aromatic hydrocarbon (mg/Kg)	36.000	28.000	32.000
Total petroleum hydrocarbon (mg/Kg)	89.000	65.000	83.000

Table 2: Concentrations of moisture content and organic parameters of soils around heavy duty generators in July

Parameters	Stations		
	1	2	3
% Moisture content	25.109	28.004	25.989
% Total Organic Carbon	4.388	4.731	4.520
% Total Organic Matter	7.565	8.156	7.806
Total hydrocarbon content (mg/Kg)	131.000	97.000	119.000
Polycyclic aromatic hydrocarbon (mg/Kg)	39.000	30.000	34.000
Total petroleum hydrocarbon (mg/Kg)	92.000	67.000	85.000

Table 3: Concentrations of moisture content and organic parameters of soils around heavy duty generators in August

Parameters	Stations		
	1	2	3
% Moisture content	24.983	28.645	25.288
% Total Organic Carbon	4.184	4.662	4.290
% Total Organic Matter	7.213	8.037	7.396
Total hydrocarbon content (mg/Kg)	121.000	87.000	112.000
Polycyclic aromatic hydrocarbon (mg/Kg)	37.000	23.000	33.000
Total petroleum hydrocarbon (mg/Kg)	84.000	64.000	79.000

Table 4: Mean Concentrations of moisture content and organic parameters of soils around heavy duty generators during the period of study

Parameters	Stations		
	1	2	3
% Moisture content	24.741±0.434	27.906±0.647	25.430±0.411
% Total Organic Carbon	4.274±0.085	4.644±0.079	4.387±0.097
% Total Organic Matter	7.369±0.146	8.008±0.135	7.567±0.174
Total hydrocarbon content (mg/Kg)	125.667±4.110	92.333±4.110	115.333±2.867
Polycyclic aromatic hydrocarbon (mg/Kg)	37.333±1.247	27.000±2.944	33.000±0.816
Total petroleum hydrocarbon (mg/Kg)	88.333±3.300	65.333±1.247	82.333±2.494

1. Moisture content

The moisture content of the studied environments recorded in Tables 1-3 varied from 24.132 to 28.645% within the months of study in the different stations investigated with a mean range of 24.741±0.434 to 27.906±0.64±% in Tables 4. The percentage moisture content obtained in this work was higher than that which was reported in different abattoirs in Port Harcourt by Edori and Iyama (2017) [27] which ranged from 16.66±1.73 to 21.07±2.05%. The quantity of water retained in the soil is a direct function of the soil type and the area studied. Clay soil retain high quantity of moisture while sandy soil allows water to drain through it easily thereby retaining low moisture (Edori & Iyama, 2017) [27]. The ability of soil to hold high concentration of organic matter lies in its capacity to retain water over a long period and also take longer time for such soil sample to dry. The high content of moisture in the soil observed was due to the displacement of available air in the soil, hence low availability of soil oxygen which ultimately will result into reduction in microbial activities (Osuji & Nwoye, 2007).

2. Percentage Total Organic Carbon and Soil Organic Matter

The results obtained from Tables 1-3 showed that percentage total organic carbon varied from 4.184 to 4.731% within the months of study in the different stations investigated with a mean range of 4.274±0.085 to 4.664±0.079% in Table 4. The results recorded for percentage organic matter varied from 7.213 to 8.156% within the months of study in the different stations investigated with a mean range of 7.369±0.146 to 8.008±0.135% in Table 4. The recorded values for total organic carbon in this work was lower than that recorded in the work of Edori *et al*. (2022) [24] in different dumpsites in Port Harcourt which was in the range of 6.12 to 7.44% with a mean range of f 6.75±0.45 to 6.82±0.51%, and that which was recorded in abattoir in Port Harcourt by Edori and Iyama (2017) [27] with values that ranged from 12.69 to 16.97%. The recorded values of percentage organic carbon obtained in this investigation was within the same range or above that recorded in the work of Olayinka *et al*. (2017) [55] with a mean value of 4.80±2.65% at a depth of 0-5cm and 2.40±0.29% at a depth of 10-15cm. The recorded results in the work of Abdulhamid *et al*. (2015) [1] was in the range of 0.95-2.25% was below that obtained in this present work. The values recorded for percentage organic carbon in this research was below that appropriate for organic soil which ranged from 12-18%.

The values obtained for percentage organic matter in this work was above that reported by Abdulhamid *et al*. (2015) [1] that ranged from 1.63-3.87% and that recorded by Fomenky *et al*., (2018) which ranged from 0.81 to 3.53% and also that recorded in the work of Martinez-Mera *et al*. (2019) [44] that was in the range of 2.90-6.45% in Colombia where it is used for irrigation. Total organic carbon and total organic matter are useful tools and guides in understanding the degree of existence of organic matter in the soil and also show the degree of soil fertility, moisture level and level of the soil development, usefulness and appropriateness for agricultural usage (Edori & Iyama, 2017) [27]. Soil organic matter is a sink and also the major source of soil organic carbon and its content differ from place to place (Perie & Quimet, 2008; Abdulhamid *et al*., 2015) [58, 1]. A resultant increase in soil organic matter increases the possibility of the soil to hold much water, it also affect the actual soil structure, the rate at which air and water permeates, biological activities and also add to the general nutrients of the soil. Soil organic matter shows the level of cation exchange capacity of the soil (Horworth, 2005) [35]. The level of organic carbon and organic matter recorded in this work was as a result of the heavy duty generators installed close to drainage points along the roads and hence the oily materials are easily washed into the drains by rain. This observation is similar to that observed by Edori *et al*. (2022) [24] in dumpsites which were situated near drainage points and hence low organic matter content.

3. Total hydrocarbon content

The results obtained from Tables 1-3 showed that total hydrocarbon content varied from 87.000 to 131.000 mg/Kg within the months of study in the different stations investigated with a mean range of 92.333±4.110 to 125.667±4.110 mg/Kg in Table 4. The values observed for total hydrocarbon content in this work was higher than that obtained in the work of Edori and Iyama (2017) [27] in selected abattoirs in Port Harcourt which ranged from 11.85±0.48 to 27.12±0.48 mg/Kg but was far lower than that which was recorded by Iyama and Edori (2021) from selected universities in Port Harcourt where heavy duty generators are installed. Environmental regulation authorities put guidelines to levels of total hydrocarbon content in soil as 100mg/Kg, 200mg/Kg and 1000mg/Kg for normal, sensitive and alert values (Dumitru & Vladimirescu, 2017) [22]. The results obtained in this research indicated that the values recorded were at the level of normal values for soils. The contamination of the soil by total hydrocarbon content could lead to toxic effects on humans and other environmental receptors that come in regular contact with it (Edori and Iyama, 2017) [27]. The occurrence of total hydrocarbon content could also be as a result of transportation, spillages and disposal from other sources (Britto & Kronzucker, 2005) [13]. This assertion is true to the fact that these heavy duty generators are installed just by the sides of the roads or streets.

4. Polycyclic aromatic hydrocarbons

The results obtained from Tables 1-3 showed that polycyclic aromatic hydrocarbons varied from 23.000 to 39.000 mg/Kg within the months of study in the different stations investigated with a mean range of 37.333±1.247 to 27.000±2.944 mg/Kg in Table 4. The observed values in this work were above the required 10 mg/Kg for recreational land use suggested by the Italian legislation (Guarino *et al*., 2019) [33]. The results obtained in this work for polycyclic aromatic hydrocarbons (PAHs) was higher that the concentrations obtained in soil samples collected from power generating houses in three universities in Port Harcourt by Edori *et al*. (2022) [24] which range from 16.53 to 18.18 mg/Kg and also that recorded in an urban and natural forest soils in the Atlantic Forest, (São Paulo State), Brazil (Bourotte *et al*., 2009). The total concentrations of PAHs recorded in this work was below that recorded in soils in Lagos, Nigeria (Fatunsin *et al*., 2019) [30], and that obtained at contaminated stations in Hisar, India (Bishnoi *et al*., 2009) [11]. The recorded concentrations of PAHs in the studied soils at the various locations could be due to the regularity of the discharge sources and contributions due to the duration period that the generators have been in use**.** This observation is in agreement with that observed by Holoubek *et al*. (2009) [34] and Edori *et al*. (2022) [24]. The concentrations of PAHs from the studied stations were lower than expected due to the fact that emissions from the generators were associated basically with the nature of the discharged emissions, atmospheric transport and the land cover (Nam *et al*., 2008; Edori *et al*., 2022) [46, 24]. Environmental contamination by PAHs have diverse health challenges on both humans and the environment, which lies on the level of contact, dosage and the pathway of exposure (Ekpete *et al*., 2019) [28]. Although, the effects might not be noticed on the workers now, both the chances of being affected later may be there. The effect of PAHs can be promoted and enhanced by the health conditions and the age of the workers that take charge of the daily operation and maintenance of these heavy duty engines, which was also reported in the work of Adedosu and Adeniyi (2015) [2] and Edori and Iyama, (2019) [25]. The utmost outstanding and notable effects of PAHs are linked to their carcinogenicity and teratogenicity, inducing of dioxin-like activity and weak estrogenic reaction (Villeneuve *et al*., 2002, Nwineewii and Marcus, 2015) [48]. The concentrations PAHs recorded in this study basically come from the partial combustion of diesel, spilled diesel during top up or refueling of the generators, precipitation by rain of discharged fumes, engine oil and petrol used in maintenance and servicing of the generators**.** This observed fact is corroborated in the work of Edori *et al*. (2022) [24] and also that of Korosi *et al*. (2013) [39] who observed that the presence of PAHs in soils was mainly due to fume waste and dumps within a particular location. The presence of PAHs in the soil lead to the contamination of ground water by percolation through the soil profile and also affect the surface water during rainfall whereby it is being drained into water bodies (Al-Delaimy *et al*., 2014) [7].

5. Total petroleum hydrocarbon

The results obtained from Tables 1-3 showed that total petroleum hydrocarbons varied from 64.000 to 89.000 mg/Kg within the months of study in the different stations investigated with a mean range of 65.333±1.247 to 88.333±3.300 mg/Kg in Table 4. The recorded values of total petroleum hydrocarbons recorded in this investigation were higher than the permissible level in soil by the Department of Petroleum Resources (DPR), (2019) of 50mg/Kg. The level of occurrence of total petroleum hydrocarbons in the studied soils samples from the stations where heavy duty generators are installed along the Iwofe-Mile III axis of Port Harcourt were far lower than that reported by Edori *et al*. (2020) [23] in three universities in Port Harcourt were heavy duty generators are installed to provide power for the institutions that ranged from 953.14203 to 1475.56904mg/Kg. The results recorded were also far lower than that reported by Alinnor, *et al*. (2014) in soils contaminated with total petroleum hydrocarbons with values recorded as 519952, 2341, and 1116.96mg/Kg within 0.00-2.0m depth range and also that which was reported in the work of Ibezue (2013) on soil collected in Gokana, Rivers State with total petroleum hydrocarbon level of 13949.42 and 8279.35mg/Kg. Human activities were majorly responsible for the level of total petroleum hydrocarbons observed in this work, for such level of hydrocarbon contamination could not be made possible through natural occurrence (Birke, 2007; Edori *et al*., 2020). The level of total petroleum hydrocarbons contamination is a global instrument applied in instituting soil clean-up measures as required by regulatory bodies (PMS, 2005**;** VROM (2012))**.** The recorded values in this research showed that total petroleum hydrocarbons levels in the study at this stage were little above the recommended level by the national body in charge of hydrocarbon regulation in the soil Pinedo *et al*., 2010). The recorded data from this investigation could help in the monitoring of petroleum hydrocarbon contamination of the soils were these heavy duty generators are installed in order to prevent possible pollution of the environment concerned. This agreed with what was observed and reported by Makadia, *et al*. (2011) [42] and Pinedo, *et al*. (2013) [60].

Conclusion

The results obtained in this research revealed that the moisture content, percentage organic carbon, percentage organic matter, total hydrocarbon content, polycyclic aromatic hydrocarbons and total petroleum hydrocarbons in the soils where the heavy duty generators were installed have been affected and compromised as a result of the operation of the heavy duty generators

The operation of the heavy duty generators and other anthropogenic activities such as transportation, precipitation from rain and other sources could have led to the level of degradation observed in the soils within the locations investigated. This has brought about the lowering of soil quality within the area investigated and created some level of soil pollution within the immediate soil environment studied.

The occurrence of these environmental markers within the stations where the heavy duty generators are installed have negative consequences on the soil, soil organisms and even on humans. It also has direct negative consequences on humans that come in contact with the soil due to operation of the heavy duty generators. The occurrence of these pollution indicators or pointers have also led to the degradation and deterioration of the soil and its immediate environments and has brought about environmental imbalance to the terrestrial ecology of the area investigated.

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