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Assessment of Petroleum Oil Contamination Effects on Soil Characteristics in Farmland Surrounding Automobile Workshops: A Case Study in Yenagoa, Bayelsa State, Nigeria

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Abstract: The study investigates soil characteristics in farmland surrounding an automobile workshop in Yenagoa, Bayelsa State, to assess petroleum oil contamination levels. Soil samples from multiple locations reveal significant differences in pH, nutrient levels, and heavy metal concentrations between workshop sites and a control area. Results indicate a pronounced impact of petroleum oil waste on soil quality and heavy metal content. For example, pH levels at contaminated sites (L1-L3) were significantly lower ($P < 0.05$) than the control (L0). The findings underscore the urgent need for regulatory standards in waste disposal and ongoing monitoring of soil quality to mitigate environmental degradation. Recommendations include enforcing waste management guidelines, conducting regular soil assessments, and raising public awareness on preserving soil fertility. By implementing these measures, stakeholders can work towards sustainable land management and ecosystem protection.

Keywords: *Soil, farmland, characteristics, automobile workshop, Yenagoa*

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1.0 Introduction

Soil is a dynamic three-dimensional substance that covers some of the world's land surface (Wang *et al.*, 2008). It varies from place to place, in response to the five factors that form it: climate, topography, organisms, the parent rock below the surface, and time. Soils' properties vary with the soil depth and often limit the depth to which plant roots can penetrate. The physical properties of soil are characteristics that can be seen, felt, or measured including color, texture, structure, and water-holding capacity. These properties usually determine the suitability of soil as a growth medium. Some physical properties, such as texture, are not economically feasible to change on a large scale (Crouse, 2018).

Global contamination of air, water, and soil is one of the consequences of the civilization of the modern age (Etukudo and Osim, 2019). The transformation of petroleum oil into various products and components for use by industries and vehicles has led to contamination of the environment (Ahmed *et al.*, 2016, WHO, 2004). Petroleum oil contains toxic components, which contribute to deleterious effects on the ecosystem (Ujowundu *et al.*, 2011). Auto-mechanic workshops contribute a considerable proportion of petroleum waste to cultivated lands (Nkwoada *et al.*, 2008). It is important to note that environmental degradation is eminent in areas where auto-mechanic workshops are operational due to a lack of regulatory standards as regards the disposal of used oil and wastes (Kpakpavi, 2015). The adverse effects of crude oil pollution resulting from this irregular disposal of petroleum oil waste include among others, adsorption of oil to soil particles, generation of an excess carbon that may be limited to microbial use as well as reduction of important soil nutrients such as nitrogen and phosphorus

(George-Okafor *et al*., 2009; Okolo *et al*., 2005).

Crude oil is regarded as a highly toxic mixture of more than 10000 different hydrocarbons. Accidental spills of crude oil in the environment cause severe contamination of marine and continental ecosystems. Contamination due to spills of processed petroleum derivates such as diesel and fuel, is an important problem in waters (Lopez-Rodas *et al*., 2009). This contamination is usually generated from both natural and anthropogenic processes (Haghighat *et al*., 2008). Also, these environmental stresses influence the physiological activities of living organisms. In consequence, when a change in the environment exceeds a certain threshold level, some metabolic pathways are inhibited or abolished and some others are enhanced or induced as may be evident in petroleum oil-contaminated sites (Amirlatifi *et al*., 2013). There has been an increase in indiscriminate disposal of petroleum oil waste, unused petroleum oil, grease, metal scrapes, and even toxic liquid and solid waste as well as burnt debris from auto-mechanic shops around mechanic village locations. There are several small and large auto-mechanic locations in most areas with the consequence of extensive ecological pollution usually associated with the irregular and unguided disposal of auto-part wastes. This could lead to a reduction in soil fertility by causing soil contamination as well as degradation of soil physical and chemical properties. This in turn could be toxic to plants and of course cause health problems through the accumulation of contaminants like heavy metals (Amadi *et al*., 1992). Hence, this study becomes significant to evaluate soil chemical properties and their relationship to selected heavy metal profiles around vehicle repair sites in Yenagoa, Bayelsa State, Nigeria. Assessment of soil characteristics in petroleum-contaminated sites have been reported, however, this study was designed to evaluate soil chemical properties and their relationship to selected heavy metal profiles around an automobile workshop in Yenagoa, Bayelsa State, Nigeria.

2.0 Materials and Methods

2.1 Study area

The study was conducted at the vehicle repair site, in Yenagoa, Bayelsa State. The site is located around farmland and characterized by a secondary forest habitat with semi-flooded terrain at an irregular degree. Yenagoa is located at coordinates of $4^{o}42'$and $6^{o}19'$E and monthly temperature ranges from 25 to 31 C (Bayelsa State Media Team News, 2012).

2.2 Collection of soil samples

Three locations were randomly selected around the automobile workshop, Yenagoa, Bayelsa State, and soil samples were collected (0-20cm depth) from the three (3) sampling locations (L1, L2, and L3) while a corresponding area outside the automobile workshop was sampled and soil samples were collected to represent the control (L0). Soil samples obtained from $L_1$was 15m away from the automobile workshop and with a corresponding distance from L1 to L2 as well as L2 to L3. Soil samples were collected in triplicates using an acid-clean soil auger pack in a well-labelled black polythene bag and taken to the laboratory for analysis.

2.3 *Analysis of soil samples*

The soil samples were air-dried at room temperature depending on moisture content for two (2) weeks and crushed to pass through 2mm mesh sieve. Sub-samples of soil from each location were further ground to pass through a 100-mesh sieve for determination of organic matter. The rest samples were then analyzed for the chemical properties of the soil. Standard methods were used to analyse soil samples for physico-chemical properties (International Institute for Tropical Agriculture, 1979). Soil pH was measured in water at a ratio of 1:1 (soil: water) by a glass electrode pH meter (Mclean,1982). Organic matter was determined by wet dichromate acid oxidation method (Nelson and Sommers, 1982). Exchangeable Bases of soils (Ca, Mg, K and Na) were extracted with 0.05N NH4OAc buffered at pH 7.0 (Thomas, 1982). Exchangeable K and Na contents of the extracts were read on EEL photometer. Exchangeable Ca and Mg were determined by titration method (International Institute for Tropical Agriculture, 1979). Total Exchangeable Acidity (H+, Al3+) was extracted with 1 N KLC (Thomas, 1982) and determined by titration method 0.05N NaOH using phenolphthalein as an indicator. Effective Cation Exchangeable Capacity (ECEC) was determined by taking the summation of exchangeable bases and total exchangeable acidity (Okalebo *et al*., 2002). Available phosphorous (Av. P) was extracted with Bray solution 11 and the phosphorous was determined by the molybdenum method described by Udo and Ogunwale (1978). The percent organic matter (%OM) was calculated from the percent organic carbon (OC%) measured using Walker-Black (1934) wet oxidation method. Total nitrogen (TN) was determined using the modified Kjeldahl distillation methods (Juo, 1979).

2.4 *Determination of heavy metal contents of soil*

One gram of each of the sieved soil samples was digested using the nitric/perchloric acid digestion procedure, as described by Odu *et al.* (1986). The concentrations of heavy metals, Pb, Cr, Zn, Fe, Mn and Cd were determined using an atomic absorption spectrophotometer (UnicamSolaar32 model) following the standard procedures as given in APHA (1995).

3.0 Results and Discussion

3.1 *Chemical properties of experimental soils at the study site*

The chemical properties of experimental soils are presented in Table 1. The chemical properties of experimental soils are presented in Table 1. The pH of soils around the auto-mechanic workshop (L_1, L_2 and L_3) was slightly acidic (4.40±0.36, 4.60±1.32 and 4.80±0.52, respectively), with values approaching neutral status as the distance from contamination site increased. The values of pH at the contamination site (L_1-L_3) were significantly lower ($P < 0.05$) than those of the control (L_0- 5.30±2.10). The soil nitrogen and phosphorus levels decreased considerably with an increase in carbon contents in soils around the auto-mechanic workshop (L_1-L_3). The phosphorus and nitrogen levels of soils around the auto-mechanic workshop (L_1-L_3) were significantly lower ($P < 0.05$) than those of the control site (L_0). The calcium and magnesium contents ranged between 2.07±1.03 and 2.33±0.34 mg/100g, and 3.35±0.52 and 3.70±0.17 mg/100g, respectively, in soils around the auto-mechanic workshops. In addition, the contents of calcium, magnesium and potassium at the contaminated site were significantly lower ($P < 0.05$) than those of the control site (L_0). This result is in line with pH reduction in petroleum oil-contaminated soil as reported by Jia *et al*. (2009) and Eziegbo *et al*. (2013). Other studies have shown a decreased value of pH in soil due to total petroleum hydrocarbon (Gong *et al.*, 2008; Kisic *et al.*, 2009). The adverse effects of petroleum oil pollution on pH might have contributed significantly to poor growth parameters of the test crop in pollution treatment as shown in this study. Soil pH directly affects the solubility of many nutrients in the soil for proper plant growth and development (Anoliefo, 2006; Udoh *et al*., 2005). However, higher pH has been reported in petroleum hydrocarbon soil (Stanley *et al.*, 2017; Nyarko *et al*., 2019). The soil nitrogen and phosphorus levels decreased considerably with an increase in carbon contents in soils around the auto-mechanic workshop (L_1-L_3). This result is in line with the findings by Okolo *et al*. (2005) and Etukudo *et al*., (2015) that crude oil pollution adversely affects the soil components due to adsorption to soil particles, an increase in carbon that might be unavailable for microbial utilization and induction of a limitation in soil nitrogen and phosphorus. The phosphorus and nitrogen levels of soils around the mechanic village (L_1-L_3) were significantly lower ($P < 0.05$) than those of the control site (L_0), thus, contradicting the higher levels of these mineral nutrients in similar contaminated sites as reported by Nyarko *et al*. (2019), but corroborates with the lower levels of these mineral nutrients in crude oil contaminated soil (Udo *et al*., 2018; Etukudo *et al.*, 2011). Reduction in nitrogen and phosphorus contents in soil as affected by petroleum oil contamination results from anaerobic soil conditions, thus, leading to the unavailability of these important elements (Okonwu *et al.*, 2010; Chen *et al*., 1995).

3.2 *Heavy metal contents of experimental soils at the study site*

The heavy metal contents of experimental soils are presented in Table 2. The heavy metal (zinc, copper, iron and lead) contents in the soils of the contaminated site were significantly ($P < 0.05$) higher than those of the control site (L_0). The content of Copper showed increases over that of the control but was below the WHO limit of 150.0 mg/kg. Similarly, Lead and Zinc showed increases over the control values, but were generally below their permissible values of 40.0 and 500.0 mg/kg, respectively (Table 2), and comparable with the World Health Organization standard (WHO, 1984). These variations may be attributed to differences in the chemical, physical and biological composition of the sites (Baker *et al*., 2000).

Table 1: Chemical properties of experimental soils at the study sites

Soil parameters	**Sampling Locations**			
	L0 (control)	L1	L2	L3
pH	5.20±2.12	4.30±0.60	4.50±1.20	4.70±0.50
Organic matter (%)	2.23±0.14	1.94±0.23	2.05±0.17	1.87±0.26
Total N (%)	2.70±0.61	1.06±1.20	1.25±0.40	1.37±0.21
Avail. P (%)	2.93±0.60	1.46±0.42	1.37±0.21	1.44±0.20
Ca (mg/100g)	4.20±0.25	3.03±0.39	3.06±1.51	3.15±1.01
Mg (mg/100g)	3.16±0.60	2.06±0.50	2.07±0.30	2.09±0.32
K (mg/100g)	1.66±0.42	1.34±0.31	1.36±0.21	1.28±0.41

****Mean ± standard error from 3 replicates**

Plant nutrient availability is strongly tied to the pH in the soil solution. Decreasing soil pH directly increases the solubility of the plant nutrients manganese (Mn), zinc (Zn), copper (Cu), and iron (Fe). Acidic soils make these nutrients more available. At pH values less than about 5.5, toxic levels of Mn, Zn, or aluminium (Al), a non-nutrient element very common in our southern soils, may be released. The impact of pH on nutrient availability is very important—both for maximum plant availability and to avoid potentially toxic levels at very low or very high pH. This implies that the movement of solute, salt solubility, chemical reactions and microbial activities, and ultimately the bioavailability of the metal ions depends on the soil structure, texture and moisture (Wang *et al*., 2008; Whitting, 2011).

Table 2: Heavy metal contents of experimental soils at the study sites

Soil parameters	**Sampling Locations**			
	L0 (control)	L1	L2	L3
Zn (mg/100g)	0.17±0.04	1.77±0.40	1.66±0.40	1.63±0.10
Cu (mg/100g)	0.35±0.02	1.21±0.20	1.26±0.22	1.28±0.12
Cd (mg/100g)	0.23±0.03	1.52±0.74	1.58±0.26	1.55±0.30
Fe (mg/100g)	0.13±0.02	1.38±0.70	1.35±0.82	1.43±0.36
Pb (mg/100g)	0.08±0.03	1.13±0.13	1.15±0.30	1.10±0.20

****Mean ± standard error from 3 replicates**

4.0 Conclusion

The study investigated soil characteristics in farmland surrounding an automobile workshop in Yenagoa, Bayelsa State, to assess the level of petroleum oil contamination. Soil samples were collected from multiple locations, revealing significant differences in pH, nutrient levels, and heavy metal concentrations between sites near the workshop and a control site. These findings highlight the detrimental impact of petroleum oil waste on soil quality and heavy metal content in the study area.

In conclusion, the study underscores the urgent need for effective measures to address petroleum oil contamination in agricultural regions. The observed alterations in soil properties and heavy metal levels near the automobile workshop emphasize the importance of implementing regulatory standards for waste disposal and conducting regular monitoring of soil quality in affected areas. Failure to address these issues could lead to continued environmental degradation and pose risks to ecosystem health and human well-being.

Based on the study's findings, it is recommended that regulatory authorities enforce stringent guidelines for the proper management of petroleum oil waste from auto-mechanic workshops. This includes promoting responsible disposal practices and providing training and support to workshop operators on waste management techniques. Additionally, ongoing monitoring and assessment of soil quality should be conducted to track changes over time and guide remediation efforts as needed. Public awareness campaigns can also play a crucial role in educating communities about the importance of preserving soil fertility and safeguarding the environment from the adverse effects of petroleum oil contamination. By implementing these recommendations, stakeholders can work together to mitigate the impact of petroleum oil waste on agricultural lands and promote sustainable land management practices for future generations.

5.0 **References**

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Declarations

The authors declare that they have no conflict of interest.

Data availability

All data used in this study will be readily available to the public.

Consent for publication

Not Applicable

Availability of data and materials

The publisher has the right to make the data Public.

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