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Assessment of Crude Oil Contaminated Agricultural Soil in Emede Community in Isoko South LGA of Delta State, Nigeria

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Abstract

The pipeline rupture in 2008 exposed the agricultural soil of the Emede community to oil contamination from the oil spillage. After the cleanup of the affected area, seasonal flooding causes the spread of the splattered oil containing Total Petroleum Hydrocarbon (TPH) to the agricultural soil. This study examined the agricultural soil at different depths and selected plant samples to affirm if the TPH was lower than the expected intervention limit of 5000 mg/kg. Sixteen soil samples were collected from four (4) points in the study area. The soil samples were collected at four (4) soil depths (0–15 cm, 15 – 30 cm, 30–60 cm, and 60–90 cm) using a soil auger and analyzed for physical and chemical properties. The TPH of the soil sample concentrations were analyzed with a gas chromatograph-flame ionization detector (GC-FID). The results showed that the TPHs concentration of the soil samples ranges from 15,632.04± 4.31 to 37,243.01± 4.47 mg/kg (PT1); 13,580.52 ± 2.74 to 82,749.75 ± 8.21 mg/kg (PT2); 8,108.82 ± 8.26 to 69,375.80 ± 5.41 mg/kg (PT3) and 22,332.46 ± 1.28 mg/kg to 82,249.23 ± 8.61 mg/kg (PT4). The analysis of the soils revealed that the total petroleum hydrocarbons (TPHs) are above the intervention level of 5000mg/kg. Hence, the soil is not suitable for the cultivation of food crops.

Keywords

Soil; Plant; Crude Oil Contamination; Total Petroleum Hydrocarbons; Emede.

1. Introduction

The anthropogenic activities cause chemical and other contaminants to enter the soil. These contaminants could be at the allowable level or beyond the limit, requiring intervention or remediation. Niger Delta is not left out in the experience of contamination of soil since the start of exploration at Olobiri in 1958[1]. Niger Delta currently hosts about 606 oil fields, 360 onshore and 246 offshore [2]. The vast oil exploration and production in Niger Delta are frequent, and rampant crude oil spills occur. According to the Department of Petroleum Resources (DPR), over 4,835 oil spill incidents have been recorded between 1976 and 1996, with around 1.8 million barrels of oil spill into the environment [3]. Other examples of the oil spill in Nigeria include Shell Petroleum Development Corporation (SPDC) Forcados Terminal Tank in 1978 of about 580,000 barrels, Texaco Funiwa-5 blowout in 1980 of about 400,000 barrels, and Abudu pipeline spill in 1982 of about 18,818 barrels [3].

Emigration from one rural area to another in Niger Delta regions becomes necessary due to land loss, oil spillages, and increased pressures on natural resources in the areas that house the migrants [4]. Oil spillage on soil causes an anaerobic environment by smothering soil particles and blocking air diffusion in the soil pores, affecting microbial communities [5]. The oil spillage affects a virgin soil's physical and chemical properties, including moisture content, available phosphorous, temperature, colour, texture, soil organic matter, soil pH, and other chemical properties [5]. With spills on land, increasing soil infertility is expected to destroy soil micro-

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organisms and dwindle agricultural productivity. Farmers have been forced to abandon their land to seek non-existent alternative means of livelihood [6]. Oiled shoots of crops like pepper and tomatoes may wilt and die off because of stomata blockage, inhibiting photosynthesis, transpiration, and respiration [6].

Analysis of sediment and soils from Sapele shows that the oil spill has rendered thousands of hectares of land unproductive, and some medicinal plant species have been rendered impotent in their values [7]. The complex mixtures of organic compounds with different polarities extracted from crude oil using organic solvents are called total petroleum hydrocarbons (TPHs) [8]. The TPH affects plant germination and soil growth by creating situations that deny plants the essential nutrients (Nitrogen and Oxygen) needed for growth [9,10]. The petroleum hydrocarbon forms a thin layer around the seed to prevent oxygen from entering for germination, and some dissolved hydrocarbons for phytotoxic compounds. This study will assess the agricultural soil in Emede community for fitness to produce edible farm products without TPH contamination.

2. Materials and Methods

2.1. Sampling Area

The pollution arose because of the leakage of a petroleum pipeline that passes the agricultural soil area in Emede, which resulted in soil contamination. Emede is a town in Isoko South LGA in the Delta State of Nigeria. The Emede people are predominantly farmers, and the sampling location within the community, where samples were collected, is shown in Fig 1.

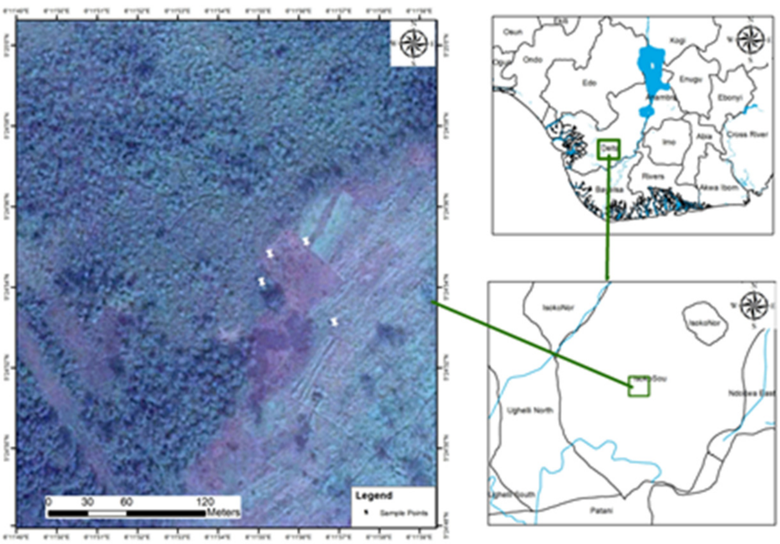

Figure 1. Showing map of sampling locations at Emede Isoko South Local government

2.2. Sample Collection

This study collected soil samples with an auger at various depths in the range of 0 -15 cm, 15–30 cm, 30 - 60 cm, and 60 - 90 cm from an area of 10,000 m^2. In addition, plant shoots and roots were collected at the same points where soil samples were collected. Sixteen soil samples from four locations and four plants (four shoots and four roots) were collected for assessment.

2.3. Physical and Chemical Soil Property

2.3.1. pH:

The pH of the soil was determined by a potentiometric pH meter. 10g of air-dried sample was added to 20ml of double deionized water and stirred intermittently for 30 minutes. The suspension was left for about 1 hour to form a clear solution, and the pH readings were taken by immersing the electrode in the clear solution.

2.3.2. Moisture Content

Moisture content was determined by the oven-dry method. 5g of ground soil particles were measured and transferred into a porcelain crucible and oven-dried at 105℃ overnight to reach a constant weight. Furthermore, the moisture content in weight percentage is obtained by the following:

$$\text{Moisture(wt\%)} = \frac{\text{final weight of soil X 100\%}}{\text{initial weight of soil}}$$

2.3.3. Total Organic Carbon TOC

The Walkley-Black method was followed to determine TOC. This involves wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid at about 125℃. The residual dichromate is titrated against ferrous sulphate. An amount of 10ml dichromate is added to 1.0g of the air-dried soil sample. After which 20ml was carefully added to the solution, the solution was swirled and left in a fume cupboard for 30 minutes. 250ml of water and 10ml of phosphoric acid was added and allowed to cool. An indicator of 1ml (Barium diphenylamine sulphonate) was added to the solution and titrated with ferrous sulphate solution. The carbon content of the soil was calculated by using [11]:

$$\% \text{ C} = \text{M X } \frac{V_1 - V_2}{S} \text{ X 0.39 X mcf}$$

Where:

M = Molarity of ferrous sulphate solution (from blank titration), V_1 = volume of ferrous sulphate solution required for blank, V_2 = volume of ferrous sulphate solution required for sample, S = weight of the air-dried sample 0.39 = 3 x 10^{-3} x 100%, mcf = moisture correction factor = 1.3.

2.3.4. Sample Extraction and Analysis for TPH

The analyte was extracted from a 20g soil sample with a solvent mixture of 40ml n-hexane/dichloromethane (DCM) mixture (40:60) in a tightly corked bottle placed in a mechanical shaker which was agitated for 1 hour at room temperature. Next, the sample mixture was filtered into a vial to concentrate the aliquot to 1ml before a 1µl syringe was used to inject the oil extract into HP 5890 Series II gas chromatograph. Likewise, 2g of air-dried and pulverized roots shoot were extracted separately with 16ml of the n-hexane/dichloromethane (DCM) mixture. The extraction was left overnight before concentrating the plant extracts into 1ml inside a vial. Then, the 1µl syringe was used to inject the extracts into HP 5890 Series II-Plus gas chromatograph (GC) with an HP 7673 Autosampler and FID detector coupled with a 30X0.32 mm DB-5 (95 metil-5%-fenilpolisiloxane) fused silica capillary column. The blank DCM was injected into a micro-syringe of GC to clean the syringe (3 times) before using the micro-syringe to transfer the sample to GC for analysis. The oven temperature was programmed from 40℃ (3 min.) to 300 at 15℃/min. Samples were injected in splitless mode, with the relay open at 20 sec. Injector and detector temperatures were 250 and 320℃, respectively. Helium was used as the carrier gas at a linear velocity of 38 cm sec^{-1}. Data was handled using Agilent Chemstation chromatography software [8].

3. Statistical Analysis

The data from the study were presented in mean ± SD. Descriptive statistical parameters, Pearson correlations and principal component analysis (PCA) of the experimental data were calculated using XLSTAT 2018.6 excel add-in. PCA is a multivariate statistical method to reduce complex results to have linear correlation and factors influencing the distribution, concentration and origin of contaminants in environmental studies [12]. The information from the PCA could later be interpreted. The statistical analysis was performed with a level of significance of $p < 0.05$. The statistical analysis will reveal the interaction among the parameters and magnitude of the contaminants in the soil.

4. Geostatistical Analysis

The geostatistical analysis presents a suitable method to analyze the spatial dependence and spatial variability of the collected soil and plant physical properties. Spatial numerical analysis based on geostatistical 'Kriging' was utilized, an extension module in the ArcGIS 10.5 software package. The spatial analysis was carried out using the data from the plant and soil samples as inputs. First, the experimental variogram model was constructed using the Kriging method [13] with the above data. Then, the spatial transformation defined by kriging is expressed as [14]:

$$Z(S_0) = \sum_{i=1}^{N} \lambda_i Z\,(S_i)$$

where: $Z\,(S_i)$ (is the sampled valued at the location (ith), λ_i is the unknown weight for the sampled value at location (ith), and S_0 is the sample location.

Its unknown weight is distance-dependent and is a function of the relative distance between the prediction location and the sampled values. The closeness to sampled values is used to estimate the unknown values. In order to find out the extent of the difference between the sampled and predictor values, a minimization formula is used, thus:

$$[Z(S_0) \sum_{i=1}^{N} \lambda_i Z(S_i)]^2$$

According to Johnston et al. [15], the model can be assessed because the median error (ME) must be close to zero (0), and the RMSE (root mean square estimated error) should be close to one (1). In addition, the anisotropy effect was surveyed while implementing the geostatistical models.

5. Results and Discussions

5.1. Statistical Analysis of the Samples

The descriptive statistics of the experimental data are presented the Table 2. The samples were picked from four locations at four different depths (D15=0-15 cm; D30 = 15 – 30 cm; D60 = 30 – 60 cm and D90 = 60 – 90 cm).

MC- moisture content, SOM- Soil organic matter

The maximum values of the parameters were mostly found at PT4 (Moisture content – 20.4 ±1.2; Soil organic carbon – 23.1 ± 1.3; TPH – 82749.2 ± 8.6), and the maximum pH is approximately the same across all the sampling points (pH – 5). The soil organic carbon maximum values from the agricultural area were, in descending order, PT4 > PT3 > PT2 > PT1. The mean values of the soil organic matter had the highest value at PT4 and the lowest value at PT1. The highest moisture content was found at PT4 (14.8), and the lowest value was at PT3 (7.3). The maximum total petroleum hydrocarbon (TPH) content analyzed for all the sampling points were in descending order, PT4> PT2> PT3> PT1, but they varied slightly in their mean concentrations following descending order, PT2> PT4> PT1> PT3. The mean concentrations TPHs of at the sampling points were all higher than the intervention values set by DPR, which is 5000 mg/kg [16]. The maximum concentrations level at PT4, PT2, PT3 and PT1 were 17, 16, 12 and 7 times higher than the intervention values. The minimum concentrations for PT4, PT2, PT1 and PT3 were 4, 3, 3 and 1 times higher than the 5000 (mg/kg) intervention value. The analysis indicated that agricultural soil contamination requires remediation, and the soil will not support profitable agricultural practices. The TPH will form a thin layer on the seed planted, which will deny the seed from accessing vital nutrients and germination [9,10].

Table 1. Descriptive statistics of the experimental data from the agricultural soil of Emede

SP	Depth	pH	MC (%)	SOM	TPH (mg/kg)
PT1	D15i	5.1	7.1	17.3	37201.3
	D30i	5.1	7.0	18.1	41028.1
	D60i	4.8	6.1	12.1	15632.1
	D90i	4.5	12.4	16.3	21726.3
	Mean	4.9	8.1	16.0	28897.0
	STD	0.3	2.9	2.7	12158.7
	min	4.5	6.1	12.1	15632.1
	max	5.1	12.4	18.1	37201.3
PT2	D15ii	5.2	9.8	14.1	21629.5
	D30ii	5.0	11.4	21.0	81115.4
	D60ii	4.9	16.0	16.0	73156.2
	D90ii	4.7	20.0	17.1	13007.3
	Mean	5.0	14.3	17.1	47227.1
	STD	0.2	4.6	2.9	34866.2
	min	4.7	9.8	14.1	13007.3
	max	5.2	20.0	21.0	81115.4
PT3	D15iii	4.7	7.6	13.3	7463.6
	D30iii	4.7	8.4	18.3	32368.3
	D60iii	4.5	5.2	23.0	60133.3
	D90iii	4.1	8.2	12.1	6282.3
	Mean	4.5	7.3	16.7	26561.9
	STD	0.3	1.4	5.0	25408.4
	min	4.1	5.2	12.1	6282.3
	maxi	4.7	8.4	23.0	60133.2
PT4	D15iv	5.0	20.4	19.2	21837.1
	D30iv	4.7	15.1	22.1	34012.1
	D60iv	5.0	8.6	19.1	82749.2
	D90iv	5.0	15.2	23.1	24527.9
	Mean	4.9	14.8	20.9	40781.6
	STD	0.2	4.8	2.0	28461.6
	mi	4.7	8.6	19.1	21837.1
	max	5.0	20.4	23.1	82749.2

5.2. Principal Component Analysis

The scree plot in Figure 2 shows the principal components influencing the data distribution and concentrations, the eigenvalues and the cumulative variability. The scree plot shows four principal components (PC) represented as Factor 1 (F1), Factor 2 (F2), Factor 3 (F3) and Factor 4 (F4) and their degree of influence on the TPH and other parameters obtained in this study. The eigenvalues above one were considered and are found in F1 and F2. The PCs show the complex linear significant correlation between the THPs concentrations and other parameters from all the sampling points. Those with strong correlations are grouped into the same factor.

Bearing in mind the influence the PCs exerted on the Emede Agricultural soil by determining the distribution and sources of the data in the exposed area of study, they were grouped into two: factor 1 (F1) with the strong anthropogenic influence of oil spilled and factors (F2, F3, F4) caused by a mixture of the oil spill, natural source and season contribution from flooding that occurs at Emede community. The parameters were grouped mainly into F1 and F2 because their eigenvalues were above one, and their cumulative variability was 72 %. F1 influences pH (0.7), Soil organic carbon (0.8) and TPHs (0.8), while F2 influences mainly the moisture content of the soil (Table 3).

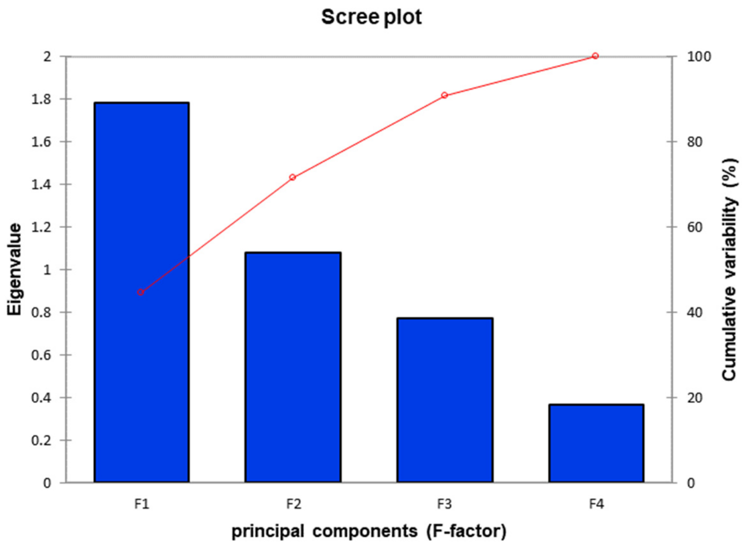

Figure 2. Scree plot of Emede crude oil contaminated agricultural soil.

The F1 indicated that the origin of pH, soil organic carbon and TPH were similar and will undoubtedly influence the concentration of one another observed in the soil. The moisture content indicated that the water has multiple sources due to flood, rain and natural water content of the soil in the soil's natural composition.

Table 2. Factor Loadings

Parameters	F1	F2	F3	F4
pH	0.7	0.0	-0.7	-0.1
MC (%)	0.3	0.9	0.0	0.2
SOM	0.8	0.1	0.5	-0.4
TPH (mg/kg)	0.8	-0.4	0.2	0.4

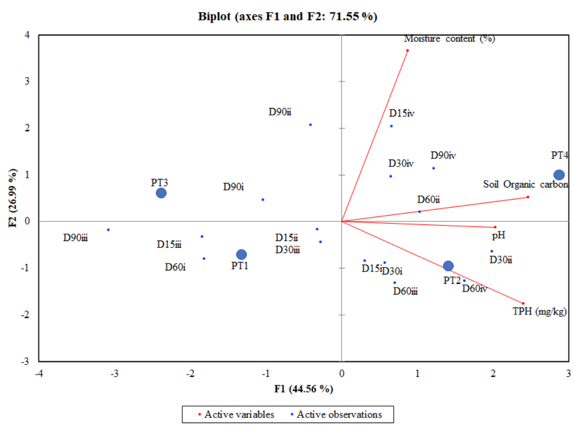

Figure 3. Biplot for data obtained from Emede crude oil contaminated agricultural soil

The biplot is the 2D representation of the loading factors variables analyzed and sampling points, as shown in Fig 3.

Fig 3 shows the distribution of the sampling points, locations and variables. The biplot shows that principal components influence the distribution of the variables, where F1 influences D15i, D30i, D30ii, D60ii, D60iii, D15iv, D30iv, D60iv and D90iv, D90i, D90ii and others were influenced by F2. The contribution of the sampling location with loading factors (%) shows that F1 influences the concentrations of soil properties examined at location PT3 (41%), while PT1 (20%), PT2 (29%) and PT4 (37%) were strongly influenced by F2. It means the concentration of pH, soil organic matter and TPH is strongly influenced by the crude oil spill at Emede years back. In contrast, PT1, PT2 and PT4 are influenced by mixed sources of oil spills and seasonal flooding in the agricultural soil yearly.

5.3. Soil Characterizations

Soil moisture content varies across the depths of soil analyzed at each sampling point (Table 2). The moisture content varies at different depths because of the soil structure and sampling during the rainy season. Crude oil is a complex substance with a nonpolar property, which causes the microstructural transformation of soil structures to form lumps. The soil lump form results in the liquid limit and plastic limit property of soil, reducing the influence of water particles. The reduced water retention capacity of the soil increases the leaching of water through the soil. Thus, the variation observed in moisture content at different soil depths [17,18,19]. Other factors controlling the moisture content may include precipitation, evaporation and plants [5]. The soil pH at the four locations at various depths ranges from 4.10±0.23 to 5.22±0.45, which is acidic. The acidic pH of the soil increases as the hydrocarbon content of the crude oil increases because it reacts with soil salts and minerals to change the alkaline nature of the minerals to acidic [19, 20, 21,22, 23]. The acidic nature of the soils affects plant growth, reducing microbes in the soil supporting plant wellness and exposure to fungi and bacteria attacks. The oil covers the root of the plant to reduce access to nutrients and break down organic matter essential for plant growth [18, 24, 25].

The organic matter is crucial to the sustainability of agricultural activities by improving soil texture, structure, bulk density, peat formation, water-holding capacity, nutrient availability, cation exchange capacity, reducing aluminum toxicity, allelopathy, nitrogen mineralization bacteria, dinitrogen fixation, mycorrhizae fungi and microbial biomass of the soil [19,26]. The percentage of soil organic matter concentration in the soil was obtained in this study by multiplying 1.729 by the value of the percentage of organic carbon obtained experimentally [27]. The organic carbon content percentage of the soil greater than three (3) indicates high soil fertility [27], suggesting the harvest experiences despite the spill of crude oil on the agricultural land area under study. The increase in the crude oil in the soil increases the carbon-hydrogen mixture, causing an upset in the carbon-nitrogen balance of the soil, which causes a decrease in the nitrogen and available phosphorous in the soil. The extreme microbial activities increase because the carbon material serves as an energy source and nitrogen consumption, which results in carbon mineralization and hydrocarbon immobilization that reduces the carbon and nitrogen concentrations to a minimal level. Therefore, the carbonaceous compounds in the soil react in the form of nitrogen as ammonium (NH^{4+}) or nitrate (NO^{3-}) ions and evaporate. Consequently, nitrogen content decreases with an increase in crude oil contaminants in the soil due to spillages [19].

5.4. Geostatistical Analysis

5.4.1. Spatial Dependence of Soil Parameters

Knowledge of spatial dependency and distribution of soil properties is crucial for natural resource evaluation and environmental management in unsurveyed locations using known points. The semivariogram range is the maximum distance between correlated measurements, and it can be a valid criterion for evaluating sampling design and mapping of soil properties [28,29]. Table 3 shows that the soil parameters' spatial correlation (range) widely varied from 126 m to 380.15 m across all the depths. There is no spatial dependence beyond these ranges. The spatial dependence can indicate the level of similarity or disturbance of the soil condition

Table 3. Models used for the best semi variogram to predict soil parameters

Soil parameters	Theoretical Model	Nugget Co	Sill C+Co	DSD Co/(C+Co)	Range (m)	RMS
0-15 cm						
pH	Gaussian	0.0	0.9	0.10	380.2	0.2
MC	Gaussian	38.9	38.9	100.00	380.2	7.2
SOM	J Bessel	0.5	11.8	4.30	126.4	2.2
TPH	Exponential	5.8E+07	3.2E+08	18.23	380.2	12526.0
15-30 cm						
pH	Gaussian	0.1	0.1	100.00	380.2	0.3
MC	Gaussian	13.0	13.0	100.00	380.2	4.2
SOM	Exponential	3.9	3.9	100.00	380.2	2.3
TPH	Exponential	3.0E+08	6.5E+08	45.83	126.4	26274.1
30-60 cm						
pH	Gaussian	0.0	0.5	5.01	380.2	0.3
MC	Stable	12.4	26.0	47.70	126.4	5.7
SOM	Exponential	13.8	35.3	38.98	380.2	5.1
TPH	Exponential	8.E+08	8.8E+08	100.00	380.2	34265.6
60-90 cm						
pH	Gaussian	0.1	1.4	5.2	380.1	0.5
MC	Gaussian	7.9	53.7	14.7	126.4	7.3
SOM	Exponential	7.6	32.0	23.7	190.1	0.5
TPH	Gaussian	2.2E+05	2.2E+08	0.1	142.9	4621.4

According to Lopez-Granados et al. [30] and Ayoubi et al. [31], a broad range indicates that the measured soil parameter value is influenced by natural and anthropogenic factors over greater distances than parameters which have smaller ranges. It means that soil variables with a smaller range are good indicators of the more disturbed soils. The different ranges of spatial dependence among the soil properties may be attributed to differences in response to the season flooding factors, agricultural practice, topography, parent materials human and livestock interferences in the study area.

The nugget, an indication of micro-variability, was highest for TPH and lowest for soil pH across all the depths studied. It indicates that pH had low spatial variability within small distances. Kerry and Oliver [31] and Fu et al. [29] suggested that the sampling interval should be less than half the semivariogram range. Ayoubi et al. [32] postulated that the knowledge of the range of influence for various soil properties allows one to construct independent, accurate datasets for similar areas in future soil sampling design to perform statistical analysis. This aids in determining where to resample if necessary and design future field experiments that avoid spatial dependence. Therefore, for future studies aimed at characterizing the spatial dependency of soil properties in the study area, it is recommended that the soil parameters are sampled at distances shorter than the range found in this study. According to Cambardella et al. [33], the classification of DSD, as applied in this study, shows results from strong to moderate and weak spatial dependences.

The semivariograms for strong spatial dependence is DSD < 25%, moderate spatial dependence is 25 < DSD < 75% and weak spatial dependence is DSD > 75%. In this study, moisture has the weakest spatial dependence and pH, TOC and TPH have strong spatial dependence for 0-15 cm depth. All the parameters had weak spatial dependences except TPH, which has moderate spatial dependence for 15 – 30 cm depth. For 30 -60 cm, pH was strong, moisture and organic were moderate, while TPH is a weak dependence. Lastly, all parameters in 60-90 cm show strong spatial dependence. The strong spatial dependence of the soil properties may be controlled by inherent variations in soil characteristics such as texture and mineralogy. In contrast, extrinsic variations such as burning, farming, and the seasonal flood of the agricultural soil may affect spatial dependence.

5.4.2. Spatial Distribution of Soil Properties Across All the Depths

Spatial analysis indicated the spatial variability of soils across the study area at different depths of the four sampling points. The semivariogram parameters were used for kriging that produced an interpolation map of the soil at different depths across the four points (point 1, point 2, point 3 and point 4) representing PT1, PT2, PT3 and PT4, as shown in Figure 4, 5,6 and 7. The kriging maps separate the low and high contamination spread for each depth of the study area.

i. Spatial analysis of 0 -15 cm depth

The map in Figure 4 revealed 0-15 cm TPH variables from 7,464 to 37,197 mg/kg. The areas with extreme high TPH (> 37,197 mg/kg) concentration were located at PT1 along the northeast boundary of the agricultural soil study area, followed by PT4 and PT2 with values ranging between 21,468 and 22.331mg/kg. The lowest concentration at PT3 (7,464 – 20,045 mg/kg) spread from the southwest and covered a significant part of the interpolation map for 0-15 depth. The spread of the TPH observed follows the topography of the area because the PT1 area is higher than the PT3 of the study area. During raining season, the PT3 tends to be more flooded than PT1, which accounts for the reduction of the concentration of the TPH

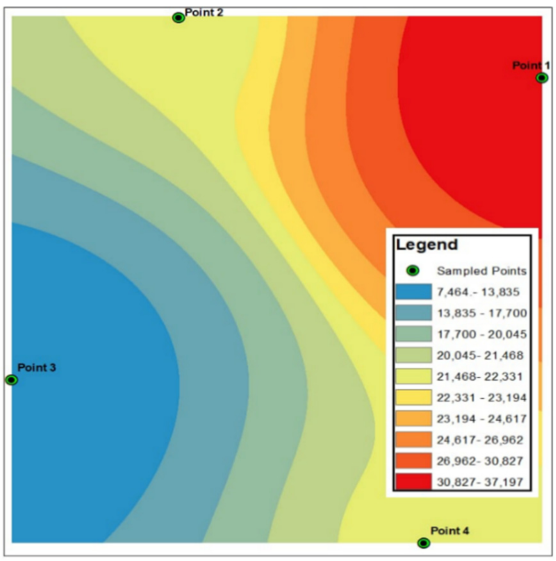

Figure 4. Spatial distribution of total petroleum hydrocarbons at depths 0-15cm

ii. Spatial analysis of 15 – 30 cm depth

The TPH concentrations in the interpolation map in Figure 5 for 15- 30 cm depth show a different pattern from 0- 15 cm depth. The highest values spread northwest of the map and cover a major part of the map from PT2, while TPH at PT3 and PT4 spread within the same range of 32,369 to 37,932 mg/kg to cover the southwest to the southeastern part of the map. The spread of the TPH (37,932 to 42,225 mg/kg) at PT1 was intermediate between PT2 and the other two sampling points (PT3 and PT4). The observation was expected from the study area because PT3 and PT4 had the topography were lower and experience flooding more during raining season.

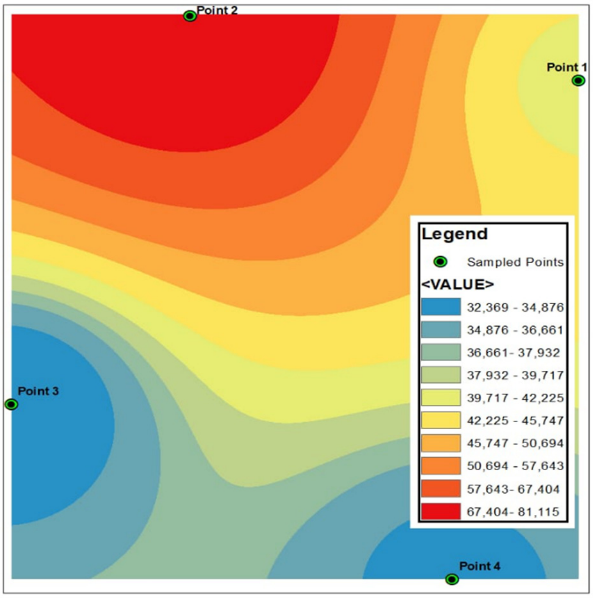

Figure 5. Spatial distribution of total petroleum hydrocarbons at depths 15-30 cm

iii. Spatial analysis of 30 - 60 cm

PT1 has the lowest value ranging from 15.642 to 37-616 mg/kg because of the slow movement of the TPH to the lower part of the movement with low moisture content and less flooding experience compared to PT3 and PT4.

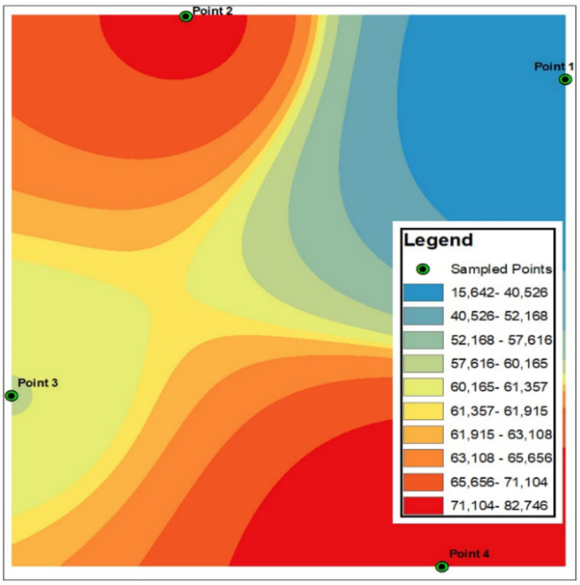

Figure 6. Spatial distribution of total petroleum hydrocarbons at depths 30-60cm

The PT2 values were higher because of the loose soil structure observed during soil sampling because harvesting cassava planted before studying the area requires changing the soil structure by digging deep, which affects the soil pore volume and allows the TPH to sink downward. The PT4 spread of the TPH was expected due to washdown runoff water and seasonal flooding of the area.

iv. Spatial analysis of 60 -90 cm

The concentrations of TPH were generally low compared to previous depths (Figure 7). PT4 has the highest concentration of TPH, followed by PT1, and the least values are shown at the location of PT3 in the southwest of the map. Also, the PT3 has a similar trend observed at 0 – 15 cm and 15 – 30 cm as the lowest values for TPH. The trends show that majority of the TPH was washed off by the seasonal flooding. The PT4 was the lowest land area within the study area with the highest experience of seasonal flooding, which explain the highest value of TPH because of washdown and possible translocation of the TPH from other areas within the sampling points to PT4.

The interpolated maps of the four sampling points for TPH analysis show maximum concentrations of 82,749.3 mg/kg at PT4 and the lowest concentration of 6282.3 mg/kg at PT3. The interpolated maps of the four depths considered across the four points predicted that the spread of the TPH was higher than the intervention value of 5000 mg/kg set by DPR [16]. Thus, the soil needs to be remediated towards achieving the zero-hunger goal for sustainable development of the United Nations in the community.

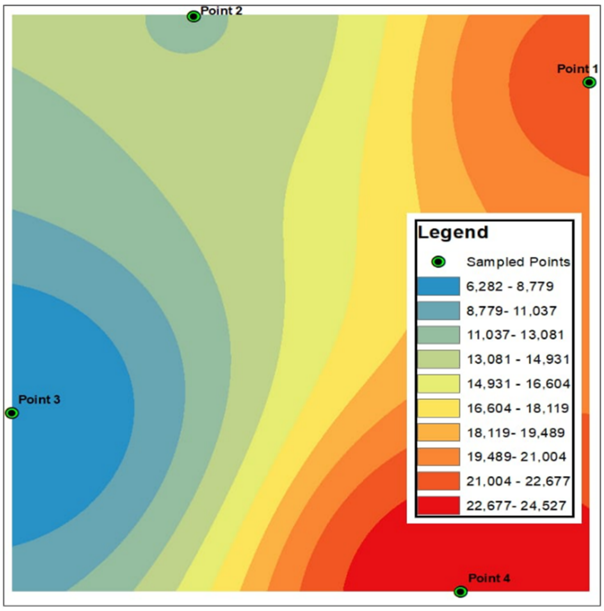

Figure 7. Spatial distribution of soil properties at depth 60-90cm

6. Conclusion

The total petroleum hydrocarbons analyzed in the soil samples vary with depth and locations across the study area. According to the villagers, there was a rupture of a pipeline close to the agricultural area belonging to a shell petroleum development company in 2008, which caused oil spillage in the agricultural area. Therefore, the post-assessment of TPH in the soil performed in this study is necessary to examine the concentration of the TPH in the soil. The data obtained exceeded the 5000 mg/kg intervention limit. The results indicated that the study area is not safe for agricultural activities, and there is a need to perform a remediation process on the soil. The results of the current study revealed the cause of the crop failure, poor yield, rotting tubers and stunted crop growth experienced by farmers in Emede community. Further work will be required on the soil during the dried season for seasonal comparison and after proper remediation is carried out on the agricultural land.

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