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GEOENVIRONMENTAL ASSESSMENT OF TOTAL PETROLEUM HYDROCARBON CONTENT IN OLOGBO FIELD, NIGER DELTA, NIGERIA

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ABSTRACT

Hydrocarbon contamination is a common phenomenon associated with oil and gas exploitation in the Niger Delta area of south-south geopolitical region of Nigeria. The aim of this paper is to assess the geoenvironmental impact of hydrocarbon spill in Ologbo area of Edo state in the Niger Delta basin using GIS with a view to drawing attention to the remediation of the area. The study area lies between longitude 05° 38' 36.47"E to 05°4' 26.56" E and latitude 06° 4' 28.17"N to 06° 4' 33.79"N. 1km^2 of the study area was georeferenced, digitized and gridded at 100 m interval using Google earth imagery. Soil samples were collected at the grid intersections, at depth ranging from 0-15 cm (topsoil), 15-30 cm (mid depth) and 30-60 cm (last depth). Soil samples were analyzed using Gas Chromatogram – Flame Ionization Detector (GC-FID) instrument. The result showed that Total Petroleum Hydrocarbon (TPH) concentration at the subsurface ranged from 96.88±3.74 to 870.01 ±102.43 mg/kg, mid depth concentration was between 46.92±7.13 to 404.03±7.10 mg/kg while the last depth is between 10.74±6.62 to 106.52±23.04 mg/kg. Due to severe pollution level at intersections C, D and E; matlab curve fitting was used to predict the maximum depth at which hydrocarbon contaminant seized to exist in the soil; the results showed that at maximum vertical depth of 460m, TPH seizes to exist in the soil (below detection level). The result was exported into ArcGIS 9.2 software where it was used to generate the pollution assessment maps across the depths of exploration. The imageries showed that TPH concentration at the sub-surface of the study area far exceeded the permissible limits (50-100 mg/kg) recommended by WHO. It is recommended that government should provide adequate regulation and monitoring of the study area. This should be accompanied by enforcement of cleanup of oil spills and remediation of the environment already polluted with petroleum hydrocarbons.

Keywords: *Pollution, Bioremediation, Assessment, Exploration, Treatment*

INTRODUCTION

The study area is located in Ologbo, IkpobaOkha Local Government Area of Edo State and it lies between longitude 05° 38' 36.47"E to 05°4' 26.56" E and latitude 06° 4' 28.17"N to 06° 4' 33.79"N (Figure 1). The study area is 32 km south-west of Benin City and about 18km from NPDC link road, off Benin-Sapele Road. Soils and water around vicinity of petroleum pipelines in the study area are usually contaminated regularly as petroleum products are transported to the flow station

The emergence of new cities, large scale urban development, industrial revolution and population growth in the last decades have impacted adversely on the environment which is major cause of soil degradation, pollution and proliferation of ailments (Saha *et. al.,* 2017). Soil pollution either with heavy metal, crude oil spill and fertilizer application on farmlands are part of the major environmental challenges faced by evolving nations like Nigeria where arable land is becoming scarce. Crude oil spillage occurs in liquid form and can percolate into the ground thereby affecting groundwater, and also causing distortion of the physico-chemical properties of soils and the degradation of vegetation (Obeta and Ezeuzomaka, 2013). Recently, structural foundation failure, landslides and subsidence have been linked to crude oil soil contamination. This makes it essential to determine the pollution characteristics of soils so as to have safe structure and prevention of failure(Nwilo and Badejo, 2010).

Hydrocarbon spatial extent and mobility is a very crucial factor to be studied in soil contamination. It is very important to provide specific information pertaining to the origin, extent, mobilization, association and availability at different soil depth. The distribution and mobility of hydrocarbon with regard to soil profile and their bioavailability at different depth of soil is a bit complex to study (Yang *et. al.,* 2017; Fifi *et. al.,* 2013)

In order to minimize or completely eradicate the negative environmental impact and health hazard accompanying crude oil soil pollution, an evaluation of both the degree of hazard and extent of pollution requires continuous assessment using adequate techniques such as geospatial technologies (Kim *et. al.,* 2012). Contaminated soil characteristics can be deduced from the chemical, physical, engineering and index properties of the contaminated soil. Analogue data interpolation analysis and geospatial models are quite challenging to handle and time consuming in the course of analysis (Xiangdong *et. al.,* 2003). In this case, Geospatial Information System, GIS is used and as a result of its rapid application in different fields like pollution mitigation, noise pollution control, flood and erosion etc., where data are harvested as discrete with; interpolation mechanism utilized to obtain continuous data (White *et. al.,* 1997).

Environmental monitoring targeted at mitigating degradation, needs a support tool with a statistics derived procedure. Geospatial modeling methods are such useful tools which aid in determination of crude oil contamination levels in polluted sites. Past studies have revealed that GIS techniques and geostatistics approach are useful in the evaluation and appraisal of pollutants in contamination sites (Henshaw *et. al.,* 2004;Largueche, 2006; Henriksson, 2013). A predominant challenge and important subject matter in environmental protection is remediation of contaminated soils. This is basically due to the fact that most contaminated areas are usually large while samples collection for analysis is usually limited thereby hampering adequate remediation measures. This challenge is, however, minimized using GIS; which can be used to model and produce pollution assessment maps of any contaminated site thereby reducing the stress of remediation choice. Therefore, the aim of this study is to apply Geospatial Information System (GIS) techniques in assessing the levels of crude oil pollution in Ologbo field with a view to determining: (i) the level of crude oil (hydrocarbon) spill in the study area; (ii) proposed appropriate remediation approach in the cleanup of the field; and (iii) provide useful information on pollution pattern

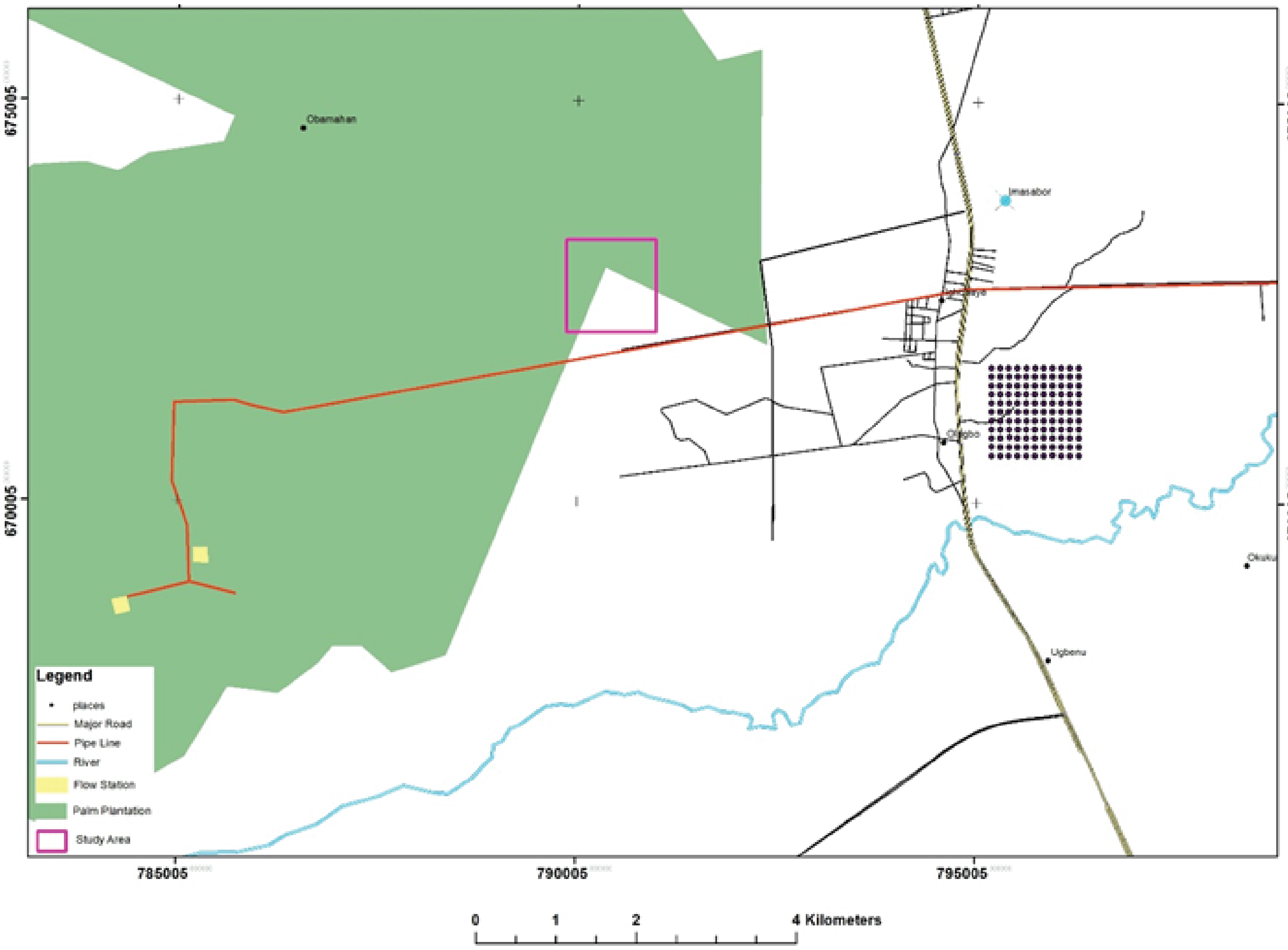


Figure 1: Location Map of the study area

MATERIALS AND METHODS

Sample Recovery and Treatment

To evaluate the baseline concentration level of Total Petroleum Hydrocarbon (TPH) content available in the soils in the study area, systematic soil sampling was carried out in the field. The coordinates of the sampling positions were determined and registered with the use of handheld global positioning system (GPS) receiver (Garmin GPS 72).The satellite imagery of the study area was obtained and a reference area of 1km^2 was gridded at 200m interval and divided into five zones denoted as A, B, C, D and E at grid intersection points where soil samples were collected using depth calibrated hand auger at depth of 0-15cm, 15-30cm and 30-60cm, respectively. Subsurface depth of 15cm was exceeded so as to collect samples at greater depth in order to examine the maximum vertical depth of TPH contaminants in accordance with USEPA New Test Methods 8015C (2003). Additional samples were obtained as control sampleswithin the uncontaminated areas of the study area. The TPH values of the control sample were compared with the contaminated samples so as to determine the extent of hydrocarbon contamination in the contaminated site. The auger used for sample recovering was washed with water and methanol after every sampling. Recovered samples was placed in plastic bags and tightly sealed, and transported to the laboratory where the soil were analyzed. The results from the laboratory were compared with WHO Standard for crude oil concentration limit in soils.

This sample treatment involved; sample preservation, sample extraction and clean-up to obtain reliable values for analysis. Samples were placed in plastic bags and put into a glass jar with seal. Each sample was labeled differently and stored in a refrigerator at 4oC. Sample extraction was carried out using extraction procedure detailed in USEPA Method 3540 and ASTM Method D5369 with little adjustments on the flask size, choice of solvent, volume of solvent and extraction time. Hydrocarbons in the soil samples were then determined using Agilent 6890 Gas Chromatograph– Flame Ionization Detector (GC-FID) fitted with a split injection auto sampler. Samples were injected and separated onanHP-5MS or DB-5MS column with 0.25mm diameter, approximately 30 m long with a 0.25 µm film thickness and placed in a 2 mL chromatographic vial. The carrier gas was Nitrogen with a makeup flow of 25 mL/min and the temperature throughout the chromatographic operation was kept at 80^0C for 3 minutes, then 20^0C/minute until 280^0C value were obtained and held for 20 minutes while the detector flame was set to 300^0C.

Geospatial Assessment of TPH Concentration

Geospatial distribution is a graphical display that summarizes the data in two or more axes to aid the determinationof conclusions. Spatial distribution of TPH concentration is a geospatial model of the TPHof the study area. The geospatial distribution was done using Geographical Information system (GIS) software ArcGIS 9.3.Results obtained from GC-FID analysis were used for the geospatial analysis of TPH from the study area.

RESULTS AND DISCUSSION

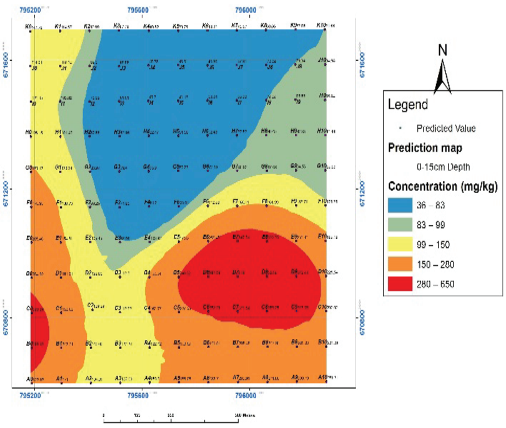
The summary of distribution of TPH from each sampling depth in the study area is presented in Table 1. The mean TPH concentration levels ranged from 10.74± 6.62 to 870.01 ±102.43 mg/kg. TPH concentration at depth 0-15 cm ranged from 96.88±3.74to 870.01 ±102.43 mg/kg. Depth 15- 30 cm had concentrations that ranged from 46.92±7.13 to 404.03± 7.10 mg/kg while the lowest depth (30- 60 cm) had concentration values ranging from 10.74±6.62 to 106.52±23.04 mg/kg

Table 1: Summary of Total Petroleum Hydrocarbon Content in the Study Area (n=5)

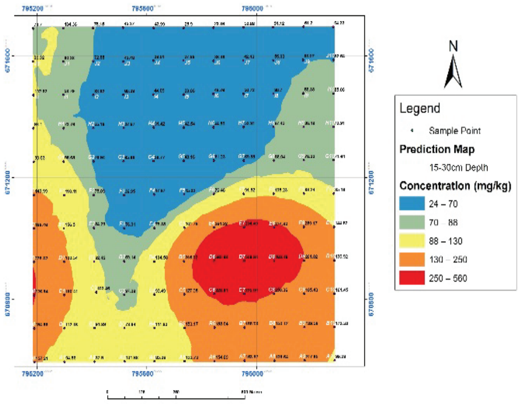
Zone	Location Coordinates		Mean Hydrocarbon Content (mg/kg)			Range
	Northings	**Eastings**	**0–15cm**	**15–30cm**	**30– 60cm**	**0 – 60cm**
1	060 3’ 39.06’’N 060 3’39.076’’N 060 4’ 14.661’’N 060 4’ 14.676’’N	050 39’ 59.843’’E 050 40’ 06.947’’E 050 39’ 59.846’’E 050 40’ 6.941’’E	510.52± 134.28	281.75 ± 8.47	59.24 ± 9.53	47.83 – 872.04
2	060 3’39.076’’N 060 3’39.073’’N 060 4’ 14.676’’N 060 4’ 14.650’’N	050 40’ 06.947’’E 050 40’14.056’’E 050 40’ 6.941’’E 050 40’14.116’’E	112.37±6.14	59.24 ± 9.53	26.84±8.72	16.77– 372.93
3	060 3’39.073’’N 060 3’ 39.058’’N 060 4’ 14.650’’N 060 4’ 14.65’’N	050 40’14.056’’E 050 40’ 21.154’’E 050 40’ 14.116’’E 050 40’ 21.198’’E	225.65±13.89	105.04±10.21	62.04±9.33	41.83 -455.61
4	060 3’ 39.058’’N 060 3’ 39.058’’N 060 4’ 14.65’’N 060 4’ 14.659’’N	050 40’ 21.154’’E 050 40’ 28.252’’E 050 40’21.198’’E 050 40’28.25’’E	870.01 ±102.43	404.03±7.10	106.52±23.04	84.38- 1017.45
5	060 3’ 39.058’’N 060 3’ 39.067’’N 060 4’ 14.659’’N 060 4’ 14.656’’N	050 40’ 28.252’’E 050 40’ 35.363’’E 050 40’ 28.25’’E 050 40’ 35.369’’E	96.88± 3.74	46.92± 7.13	10.74± 6.62	03.36 - 273.11
Cntrl 1	060 4’ 11.104’’N 060 4’ 11.078’’N 060 4’ 14.676’’N 060 4’ 14.702’’N	050 40’ 3.40’’E 050 40’ 10.518’’E 050 40’ 3.42’’E 050 40’ 10.513’’E	14.84± 9.63	8.27± 6.14	2.03±0.04	0.0 -17.32

Pollution Assessment Maps

The TPH pollution assessment maps of the area as shown in Figure 2, are indicative of the pollution status of hydrocarbon at 100 m horizontal intervals across sampling depth of 0-15, 15-30 and 30-60 cm respectively. Additionally, the severely contaminated locations (hot spots)can easily be delineated from the TPH pollution assessment maps of the study area.



(a)



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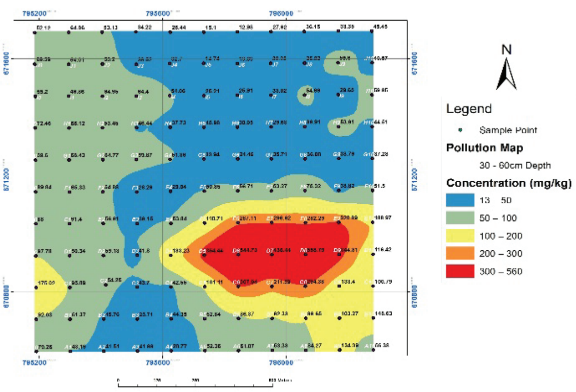


(c)

Figure 2: Pollution Assessment Maps of the Study Area (a) 0-15 cm depth (b) 15-30 cm depth (c) 30-60 cm depth

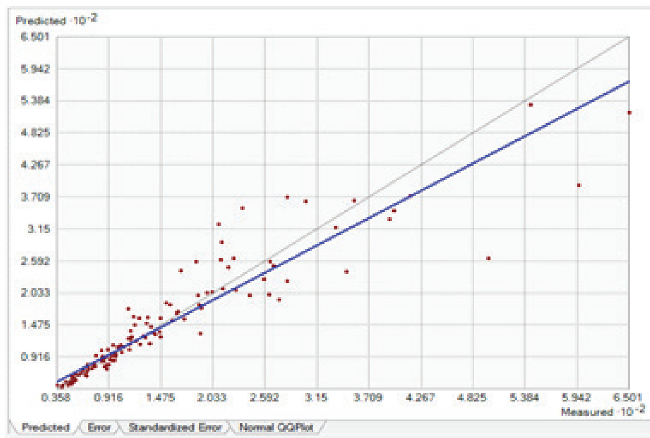
The distribution of petroleum contamination was presented using various colour codes. The maximum permissible concentrations of TPH were represented with blue, grey and yellow, while polluted sites were represented in red and brown colours. On the other hand, unpolluted sites and the pollution variation across the ground surface were easy to spot on the map. From the map of the study area, it was observed that petroleum pollution was generally strongest in the first layer from 0-15 cm but gradually declined at deeper depths from 60 cm and beyond.

Analyzed samples collected from the study area, showed significant concentration of TPH (Table 1). Published literatures have established that some living organisms do bio-accumulate petroleum hydrocarbons within their cells that can in turn have retributive effect and adverse health implications to humans and lives stock because of the possibility of the contaminants getting into the food chain. At depth of 0-15cm, TPH concentration in the study area was significantly above the WHO permissible limits. The high petroleum contamination was also noticed to be domiciled to areas associated with old oil well heads which may have become environmental source of petroleum pollution probably due to poor maintenance culture or vandalism by oil thieves in their quest to sabotage the government.

Matlab Prediction of Total Petroleum Hydrocarbon at Some Grid Intersections

This objective of this study is to determine the maximum vertical distance at which the pollution exists and demised in the soil. From the results, vertical downward concentration of TPH at grids intersection points such as C6, C7, C8, C9, D5, D6, D7, D8, D9, E6, E7, E8 and E9 were fitted into a linear polynomial, cubic polynomial, quadratic polynomial and power distribution models respectively. The high values of R^2 show a high correlation between TPH concentration and vertical downward distance (Figure 3).

a



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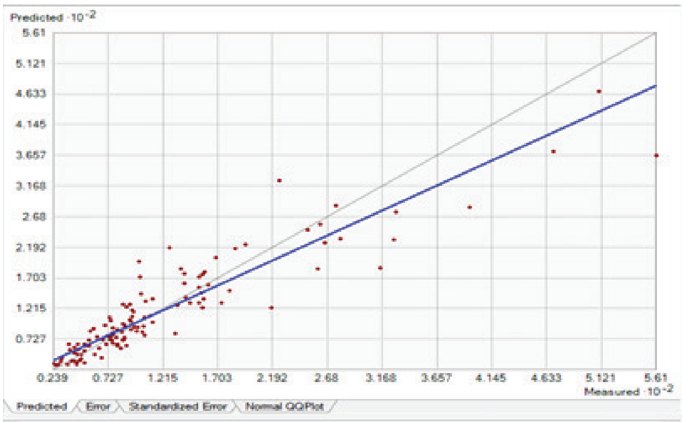

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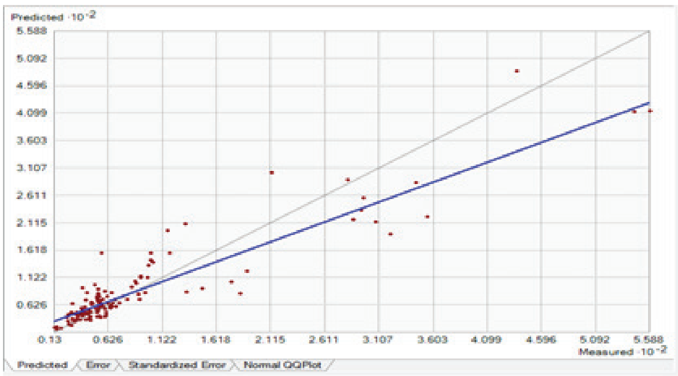

Figure 3: Prediction Chart for Severely

Polluted Intersections a, b and c

the value of SSE, RMSE, R^2, and adjusted R^2 justified the suitability of the fitted models and the adequacy of the field data. The location of the field data curve between the upper and the lower bounds and the curve trend pattern at 95% confidence bound, further validated the model and also justified the adequacy of the collected field data. The mathematical models generated were used for prediction. The models indicated that there was vertical downward concentration of TPH outside the experimental range of 10 -60 cm, at 95% confidence limit (Table 2).From Figure 3 the prediction models at 95% confidence revealed that the deepest downward vertical distance travelled was 480 cm at point C9.Also, at predicted depth of 265 cm, minimum concentration of 5.12 mg/kg was observed.

Table 2: Summary of Vertical Modeling and Prediction of Data at Grids Intersections Points

Location	Predicted Model	R2	Adjusted R2	RMSE	SSE	Predicted Maximum Depth of TPH Concentration (cm)	Concentration (mg/kg)	Predicted Depth at which TPH Fade from Soil (cm)
C6	Linear Polynomial	0.9949	0.9932	0.9852	2.912	137	18.06	182
C7	Linear Polynomial	0.9579	0.9439	1.106	3.667	164	23.86	259
C8	Linear Polynomial	0.9571	0.9420	34.42	3.556	122	10.72	141
C9	Linear Polynomial	0.9509	0.9346	1.153	3.988	265	5.12	480
D5	Linear Polynomial	0.9527	0.9369	0.6736	0.892	114	14.82	136
D6	Linear Polynomial	0.9481	0.9308	5.969	10.69	103	25..72	147
D7	Linear Polynomial	0.9313	0.9085	0.8179	2.007	245	41.65	308
D8	Linear Polynomial	0.8959	0.8612	4.394	57.91	100	3.84	83
D9	Linear Polynomial	0.9364	0.9152	1.685	8.516	146	32.86	192
E6	Linear Polynomial	0.9918	0.9891	0.5967	1.068	162	16.35	180
E7	Linear Polynomial	0.9384	0.9178	4.857	7.76	138	27.62	155
E8	Linear Polynomial	0.9726	0.9181	0.8907	17.54	130	15.73	163
E9	Linear Polynomial	0.9537	0.9383	14.43	13.78	105	14.03	146

CONCLUSION

The study's aim and objectives were achieved. It has been established that the indiscriminate siting of oil well heads, poor maintenance culture and oil thieves vandalism are factors that contributed to the severe petroleum contamination in the study area. The maximum vertical distance at which pollution existed and demised were determined to range from 0 – 15 cm and 30- 60 cm, respectively. However, the multivariant and power distribution plots and models further assisted in making prediction of possible pollution distribution in the study area.

It is recommended that government should provide adequate regulation and monitoring of the study area by enforcing cleanup of oil spills. Bioremediation is recommended for cleanup of the environment already polluted with petroleum hydrocarbons.

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