MODELING SOIL PH FATE IN CRUDE OIL CONTAMINATED SOIL IN THE NIGER DELTA

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Abstract: Environmental degradation issues are of topical concern to communities in the Niger Delta region of Nigeria. Over the years, there has been strong agitation over polluted farm lands in the Niger Delta region by oil companies operating in the area. This is as a result of oil exploration and exploitation in the region. The people in the region can no longer expect good harvest from their farm lands due to oil pollution. This paper is set to investigate the effect of crude oil pollution on soil pH with time. The soil sample collected from the university research farm was artificially polluted with 0.05, 0.1, 0.15, 0.2, and 0.25 liters per kg of soil. The polluted soils were tested using standard methods at 14days interval. The panel Data Regression model (PDRM) was used to analyze the data. The result reveals that the soil pH content of the soil at various level of crude oil pollution varied with time. This can be attributed to mineralization and immobilization processes in the polluted soil environment. Over time, the soil pH content of the control sample was two (2) times lower than the values of soil pH content at various level of crude oil pollution. The high soil pH at various crude oil pollution level could also be due to reduced microbial activity and depressed soil pH mineralization occasioned by the alkalinity of the soil as a result of the carbonaceous substance in the crude oil. A model which can be used as a predictive tool to determine the level of soil pH fate in crude oil polluted soil has been developed.

Keywords: Crude oil, Pollution, soil pH, model, fluctuation.

1.0 Introduction

Globally there is a growing concern over environmental pollution and it's management. The three major areas of environmental pollution include water, air and land. One of the major causes of this environment pollution in Nigeria especially the Niger Delta region is as a result of hydrocarbon exploration and exploitation (Okwuosha, 2000). This has led to the degradation of farm lands, pollution of air, surface and ground waters due to gas flaring. The natural recovery of crude oil polluted land is slow. Communities affected are denied meaningful and economic use of their lands a long time. Hence modeling soil pH fate over time as a result of oil pollution has become imperative. The prediction will help to determine the level of degradation and possible bioremediation work to be carried out. A model may help to explain a system and to study the effect of different component and to make predictions about behavior. Modeling is a process of generating abstract, conceptual, graphical and or mathematical model. (Nwaogazie, 2006) defined modeling as the act of constructing or fashioning a model of something or finding a relationship between variables. The trend in modeling is to collect existing records (data), establish relations through mathematical equations, calibrate such equations in the way of assigning values of associated constant and adopting such equations for forecasting or prediction. Prediction takes us into the future for decision making as we examine different responses arising from changes in control variables. The panel data multiple regression analysis was chosen after considering some other engineering tools like finite element method, finite differences, neural network and Matlab due to its capacity to analyze data with several variables. It also gives the researcher a large number of data points by increasing the degree of freedom and reducing the collinearity among explanatory variables hence improving the capacity to produce the expected results in this research work. Analysis of the linear regression can be extended to cover situations in which the dependent variable is affected by several controlled variables (independent variables). In this case, the question is how soil pH is affected by crude oil pollution at various levels in the soil during the duration of pollution.

Given n sets of measurements,

($Y_{1,}$ $X_{11,}$ $X_{21,}$ X_{31}) ---- ($Y_{n,}$ $Y_{1n,}$ $X_{2n,}$ X_{3n}), the multiple regression equation is of the form

$$Y = B_0 + B_1X_1 + B_2X_2 + B_3X_3 \ldots + B_nX_n \qquad 1.0$$

The least square estimates for B_0, B_1 and B_3 can be obtained using Panel Data Computer Software.

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The fate of soil pH over time as a result of oil pollution is now a growing concern in the Niger Delta region of Nigeria. The objective of the study is to carry out a laboratory investigation using crude oil and soil samples collected from the region to determine the effect of crude oil pollution on the soil pH over a period of time. Other authours whose publications were reviewed in respect to this research work include: Abii, et al., (2009), Akinrede, et al., (2000), Akpan, (2014), Dobermann, et al, (2002), Johnson et al., (2001), Jones, (2001), Krishnakumar, et al.,(2000) and Lewbel, (1979).

1.1 Study Area

The study area is located in Owerri, Imo State and lies between latitude $5^0 22^{'} 51.5^{"}$N and longitude $6^0 59^{'} 39^{'} 3^{"}$E, with an elevation of 61m. It is a humid tropical environment with average annual rainfall of 2400mm. The mean daily temperature is about 27^0C. The geological formation in the area shows that the soils are derived from coastal plain sands called acid sands – Benin formation (Orajaka, 1975).

2.0 Methods

The study was carried out over a period of sixteen (16) weeks using different containers measuring 17cm (height) by 18.5cm (diameter). Samples measuring 10kg polluted soil were placed in each of the containers and exposed to the same atmospheric and environmental conditions.

Table 1: Layout of experimental design

Polluted Soil Sample	A	B	C	D	E	F
Vol. of crude oil in Liters/kg of soil	0	0.05	0.10	0.15	0.2	0.25
Variable monitored for ABCDEF was:	Soil pH					

The soil used in the study was collected from the Federal University of Technology Owerri (FUTO) Research Farm from 15cm to 20cm depth with shovel. The soil was measured into containers and taken to the laboratory for treatment (greenhouse treatment).

The soil was air dried for two weeks and sieved through 2.0cm sieve. The soil samples labled B, C, D, E, F, each weighing 10kg were polluted with 0.5, 1.0, 2.0, 2.5 liters of crude oil (Bony light) respectively, and thoroughly mixed on a polythene sheet and put in a labeled container.

Sample A was not polluted and was used as the control. To maintain the moisture content of the soil, 50cl of water was sprinkled on each polluted soil sample at two weeks intervals.

The polluted samples were allowed to stay 14 days before commencement of analysis. The representative samples from (A, B, C, D, E, F) containers were taken at two weeks intervals to the soil science laboratory of Department of Crop, Soil and Pest Management, School of Agriculture and Agricultural Technology, FUTO for analysis to determine the fate of soil pH nutrient with time at various levels of pollution with crude oil. The concentration remaining after 14, 28, 42, 56, 70, 84, 98 and 112 days intervals were obtained.

For determination of soil pH twenty (20) grams air dried soil sample was put into 50ml beaker and 20ml of distilled water was added. The lump of the soil was stirred to form a homogenous slurry. The pH meter (3020 model) probe was immersed in the sample and allowed to stabilize at 25^0C. The pH value was taken and recorded. This was repeated for various levels of crude oil pollutions for the soil samples.

The Panel Data Computer Software called Stata 13 version was used to obtain the regression coefficients B_0, B_1, B_2, B_3 and B_4 and the model equation for soil pH using the data obtained from the laboratory. The model equation for the soil pH is expressed as:

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$$Y_{it} = B_0 + B_1 C_{vit} + B_2 T_{it} + B_3 T_{it}^{\ 2} + B_4 \sqrt{C_{vit}} + U_{it} \qquad (2.0)$$

Where,

Y_{it} = soil pH
B_0 B_1, B_2, B_3 and B_4 = model coefficients
T_{it} = Number of days
C_{vit} = Crude oil volume in litres
U_{it} = Random error of the model
i = crude oil pollution levels (0, 0.5, 1.0, 1.5, 2.0)
t = contact time for pollution (days)

3.0 Results and Discussions

Table 2: The Variation of soil pH values with time after pollution.

Time (days)	Pollution level (liter)/10Kg of soil					
	0	0.5	1	1.5	2	2.5
14	6.230	7.300	7.350	7.420	7.470	7.490
28	6.210	7.200	7.330	7.400	7.420	7.450
42	6.180	7.200	7.250	7.300	7.350	7.360
56	6.100	7.000	7.200	7.270	7.290	7.300
70	6.060	6.960	7.160	7.230	7.240	7.250
84	6.020	7.150	7.180	7.190	7.210	7.230
98	5.980	7.130	7.150	7.160	7.180	7.200
112	5.920	7.120	7.140	7.160	7.190	7.210

Table 2 shows the soil pH remaining in the soil after any given time (t = 14 to 112 days), for values of soil samples with crude oil pollution volume ranging from 0 to 2.5L per 10Kg of soil.

Table 3: Regression Model Coefficient for the proposed model

source	ss	df	Ms	Number of Obs = 48 F(4, 43) = 620.95 Prob > F = 0.0000 R- Squared = 0.9830 Adj R-Squared = 0.9814 Root MSE = 0.615
Model	9.393115	4	2.34828	
Residual	0.16261645	43.000	0.0037818	
Total	9.55573099	47	0.2033134	

OM	Coef	Std Err	t	P > |t|	95% Conf.	Interval
Conc	-0.7080021	0.0352156	-20.1	0	-0.779021	-0.6369832
time	-0.0062861	0.0012756	-4.93	0	-0.0088585	-0.0037137
$time^2$	2.86E-05	9.88E-06	2.89	0.006	8.67E-06	0.0000485
$conc^{1/2}$	1.857124	0.0574353	32.33	0	1.741294	1.972953
_cons	6.355381	0.0401394	158.33	0	6.274432	6.43633

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The R^2 for the determination for the proposed model is 0.9830 with a root mean square error of 0.6150 as shown in table 3. The root mean square error is small, hence the adopted model fits (Chang, 2015). The P value of 0.00 shows that there is a strong relationship between soil pH and concentration of crude oil spilled at any given time. The equation for prediction of soil pH fate in crude oil depleted soil is therefore $pH = 6.310 - 0.7080C_{vit} - 0.0063T_{it} + 2.86eT_{it}^2 + 1.857\sqrt{C_{vit}} + 0.0387$

The model was checked and adjusted using another set of experimental data. The model validation is represented in fig 1 and table 3 respectively. The values indicate closeness of the predicted values with the observed values, thus confirming the validity of the model developed (Essington, 2005).

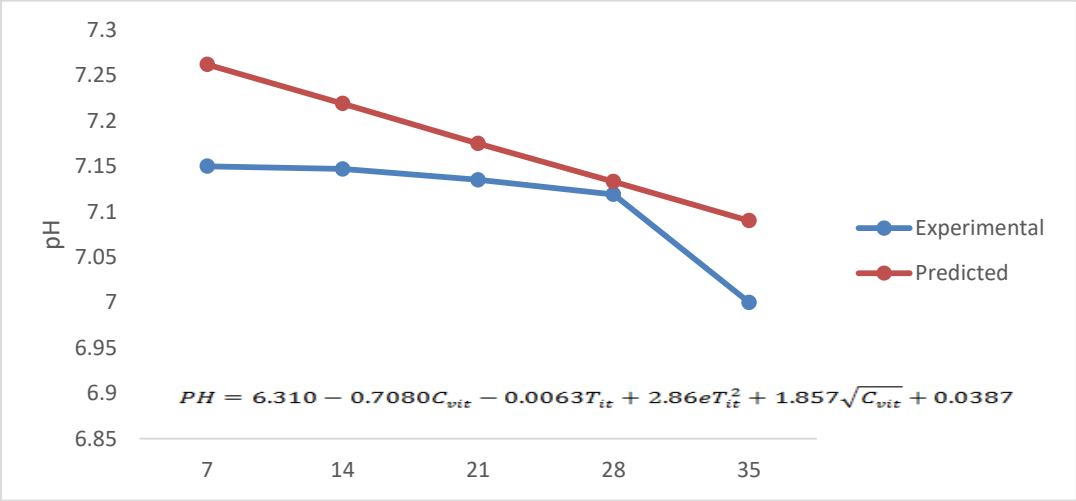

Fig 1: Experimental and predicted soil pH over time

Table 3: Experimental and Predicted Values for Soil pH over Time

Time/Day	Experimental Data (ED)	Predicted Value (PV)	Percentage Difference
7	7.15	7.262	1.5
14	7.147	7.219	1.0 (approx.)
21	7.135	7.175	0.5
28	7.119	7.133	0.19
35	7	7.09	1.3

Table 4 Experimental and Predicted Values of Soil pH at Various Pollution Levels Using Model Equation

TIME	**COV**	**ED for PH**	**PV for PH**	% Difference
14	0	6.230000019	6.272980213	-0.689890754
28	0	6.210000038	6.201789379	0.132216731
42	0	6.179999828	6.141809464	0.617967086
56	0	6.099999905	6.093039513	0.114104789
70	0	6.059999943	6.055480003	0.07458646
84	0	6.019999981	6.029130936	-0.15167699
98	0	5.980000019	6.013991833	-0.568424976
112	0	5.920000076	6.010063171	-1.521336046
14	0.5	7.300000191	7.232163906	0.929264149
28	0.5	7.199999809	7.160973549	0.542031408

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42	0.5	7.199999809	7.100993156	1.375092437
56	0.5	7	7.052223206	-0.746045794
70	0.5	6.960000038	7.014663696	-0.785397383
84	0.5	7.150000095	6.988314629	2.261335169
98	0.5	7.130000114	6.973175526	2.199503314
112	0.5	7.119999886	6.969247341	2.117311051
14	1	7.349999905	7.422101974	-0.980980555
28	1	7.329999924	7.35091114	-0.285282632
42	1	7.25	7.290931225	-0.564568618
56	1	7.199999809	7.242161274	-0.585575914
70	1	7.159999847	7.204601765	-0.622931819
84	1	7.179999828	7.178252697	0.024333306
98	1	7.150000095	7.163113594	-0.183405574
112	1	7.139999866	7.159184933	-0.268698412
14	1.5	7.420000076	7.485479832	-0.882476479
28	1.5	7.400000095	7.414289474	-0.193099715
42	1.5	7.300000191	7.354309082	-0.743957396
56	1.5	7.269999981	7.305539608	-0.488853194
70	1.5	7.230000019	7.267980099	-0.525312304
84	1.5	7.190000057	7.241630554	-0.718087574
98	1.5	7.159999847	7.226491928	-0.928660365
112	1.5	7.159999847	7.222563267	-0.873790792
14	2	7.46999979	7.483345509	-0.178657547
28	2	7.420000076	7.412155151	0.10572675
42	2	7.349999905	7.352174759	-0.029589855
56	2	7.289999962	7.303404808	-0.183879921
70	2	7.239999771	7.265845299	-0.356982437
84	2	7.210000038	7.239496231	-0.409101148
98	2	7.179999828	7.224357605	-0.617796347
112	2	7.190000057	7.220428944	-0.423211212
14	2.5	7.489999771	7.43934536	0.676293897
28	2.5	7.449999809	7.368155003	1.098588037
42	2.5	7.360000134	7.30817461	0.70415112
56	2.5	7.300000191	7.259405136	0.556096624
70	2.5	7.25	7.221845627	0.388336182
84	2.5	7.230000019	7.195496082	0.477232872
98	2.5	7.199999809	7.180357456	0.272810466
112	2.5	7.210000038	7.176428795	0.46562057

Where

COV = Crude oil Volume

ED for P = Experimental Data for soil pH

PV for p = Predicted value for soil pH

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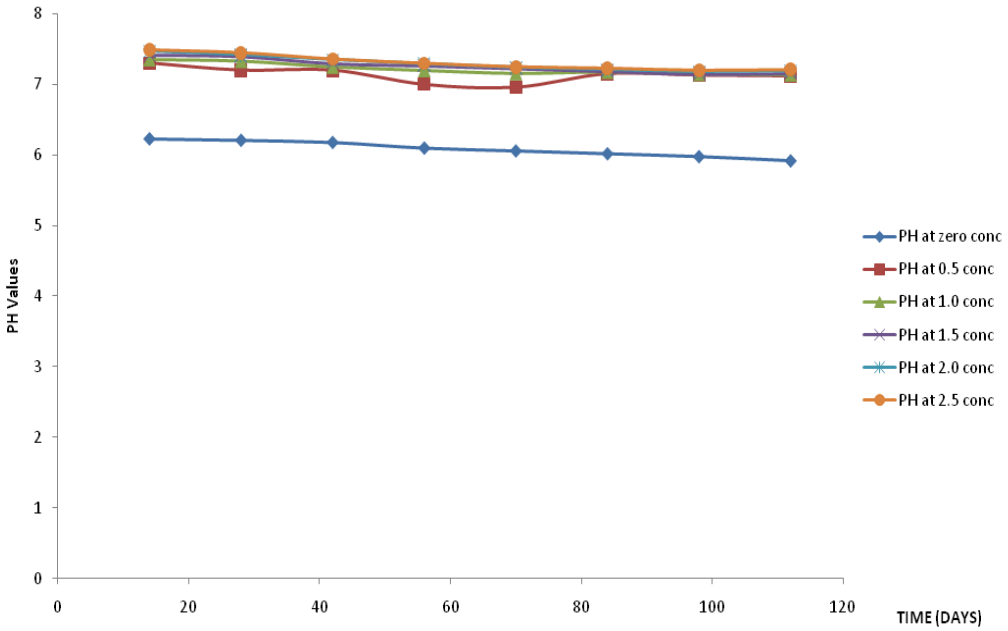

Fig 2: Soil pH at various crude oil levels with time

Figure 2 shows the graph of the control sample in comparism with the soil pH at various levels of crude oil pollution with time

The soil pH of the soil at various level of crude oil pollution varied with time of pollution as shown in Fig. 2. The soil pH is not only essential for determining the availability of many soil nutrients, but also in determining the fate of many soil pollutants, their breakdown and possible movement through the soil. In other words pH measures the acidic and alkaline condition of soil and availability of micro and macronutrients to plants. The pH value increased slightly over a period of time being lowest at 56 days after pollution for 0.5l pollution level. The increase in pH value was attributed to the alkalinity of soil as a result of the carbonaceous substances in the crude oil.

4.0 Conclusion

The impact of crude oil pollution on the physcio-chemical properties of soil in relation to soil fertility in the Niger Delta Region of Nigeria has been reviewed. Modelling of soil pH fate in crude oil contaminated soil over a period of time was carried out. The soil pH value for various crude oil levels of pollution increased with time being lowest at 56days.

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