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Modelling and simulation of the effects of crude oil dispersion on land

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Abstract – This research work was carried out to develop a model equation for dispersion of crude oil on land. The developed model equation in this project is $Y = 21.81 + 84.50X - 91.40X^2$. The developed equation was then simulated with the aid of MINITAB software. The experimental and model results obtained from the simulation of the model equation were plotted on the same axis against time of dispersion and distance of dispersion. The model results revealed good agreement.

Keywords: *Oil spill, modelling, simulation, pollution, dispersion*

I. Introduction

In 1956, Royal Dutch shell discovered crude oil at Oloibiri, a village in the Niger Delta, Nigeria and commercial production began in 1958. Today, there are 606 oil fields in the Niger Delta, of which 360 are on shore and 246 offshore. Nigeria is now the largest oil producer in Africa and the sixth largest in the world, producing at present 2.45 million barrels per day (bbl /d). According to the Department for petroleum resources (DPR), since in the 1980's, oil has been an important part of Nigeria's economy; the increasing demand for crude oil and petroleum products (which is due to the increasing deferent on petroleum based technology for energy and as a means of foreign exchange) has forced man to exploit all possible sources of petroleum including land and water. This has therefore contributed to the increase in the rate of occurrence of oil pollution in the world at large by oil spillage.

Pollution could be defined as the presence of chemical substances produced by man's activities and which can cause harm to man, building, marine creatures and soil. The international organization according to [4] defined oil pollution as the introduction by man, directly or indirectly substances or energy into the marine environment including (estuaries) resulting in such effects as harm to large resource hazard to human health, agricultural land and soil.

Most people living in the oil producing areas suffer from the effect of oil drilling from the petroleum industries as a result of oil spillage. This is because the effects of oil spills are very visible and sometimes very devastating. When crude and its components are released into the environment, they become degraded into simple compounds by physio–chemical or biological agencies,

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with or without human assistance and becomes relatively innocuous. But in the process, they still cause serious damage to plant and environment and this impede human exploitation of natural resources [1].

Nonetheless, in discussing these impacts, what readily strikes the mind of a common man seems to be the deleterious ones. This phenomenon appears to be more manifest in the developed countries than in the so – called developing ones, where in any case, the beneficial effects hardly makes any impression on the general level of poverty. This work examines one of the undesirable off – shoots of the petroleum industry in Nigeria, namely crude oil spills. The study is undertaken because of the magnitude and diversity of oil spill incidents in the country, and because of the public attention it has attracted recently.

Oil production in Nigeria has severe environmental and human consequences for the indigenous people who inhabit the areas surrounding oil exploration and exploitation. Spillage of different kinds has been common in recent times in the Niger – Delta. Oil spillage is associated with areas where there is oil exploration or along pipelines used for it transportation from place to another.

In this study the evaluation procedures will involve the analyses of soil samples collected from dispersed environment and the control sites which are carefully selected to enhance proper comparison of results and useful inference, suggestions and conclusions.

Since the main components of crude oil are HYDROCARBON such as Hydrogen, Carbon, Nitrogen, Potassium, Phosphorous, Magnesium, Calcium and traces of heavy metals, this work is focused on determining the change that will occur in these components in the impacted soil compared to the control environment. The contaminated soil is then known to exert adverse effect on plants by creating certain conditions which makes nutrients unavailable. As a consequence of this, oil contamination of the soil results in the soil becoming unsuitable for agricultural purpose. The causes of oil spillage can be broadly grouped as:

- Unknown
- Blow out
- Equipment failure
- Natural causes
- Engineering error

Admittedly, "equipment failure" covers quite a lot of items, however, the items or system which seem to fail under Nigerian situation include; [6]

- Burst / rupture of flow line / pipelines
- Corrosion of flow lines / pipeline
- Over pressure
- Over flow tanks
- Value failure

The study was carried out for the purpose of showing the Modeling and simulation of crude oil dispersion on land and how it effects the environment. The type of soil used for this analysis is sandy loamy and is not a suitable soil for Agricultural products.

3.0 METHODOLOGY

3.1 Experimental Procedure and Apparatus

The experimental analysis was based on the spread of samples of Nigeria crude oil on land.

Apparatus

- Soil samples
- Stirrer
- Oven
- Measuring Cylinder
- Crude oil
- Filter paper
- Plunger
- Measuring ruler
- Petroleum ether solvent
- Beaker
- Soxhlet extractor
- Calcium Chloride($CaCl_2$)
- Petrish dish
- Distilled water
- Weighing balance
- PH meter
- Round Bottom flask
- Stop watch etc.
- Sodium Hexaphosphate $(NaPO_3)_6$

3.2 Samples Collection and Method

Determination of Dispersion of Crude Oil

The experiment apparatus consist of a portion of land; length of 20cm. Prior to the commencement of the experiment, the portion of land was first cleaned to ensure that its surface is clean. Afterwards, crude oil was poured on the 20 cm portion of cleared surface land in order to allow the crude oil to disperse into the soil for about one week particular days or there about. After a week, collection of soil samples was done at a depth interval of 1cm using ruler to measure each depth for seven days at a particular time within at an interval for 24 hours.

The soil samples collected for 7days at a time interval of 24hours for each depth of 1cm were then air dried, sieved and analyzed for pH, soil texture, moisture content and lipid content. Two replicates were run for each analysis; the following analytical procedures were used.

3.2.1To Determine the Moisture Content

Moisture content was determined by weighing the petrish dish on the weighing balance. 2 g of each 7 soil samples were put inside the oven, to remove water from the soil. The oven was then switched on to 105^0C for 24 hours. After 24hours, the samples were removed from the oven and weighed immediately. Then the percentage moisture contents were measured.

3.2.2To Determine the Lipid Content

Lipid content was determined by weighing the filter paper, because filter paper has different weights. 1g of each soil sample was taken and put in the already weighed filter paper and folded, put in equipment called Soxhlet extractor. Petroleum ether was the solvent used for the extraction and it was put inside the round bottom flask, and 150 ml of petroleum ether was used to extract lipid from the samples for 6 hours.

Temperature was set at 40– 60^0C. After 6hours of extraction, the sample was removed from the Soxhlet extractor and in dried in the oven for at least 10minutes. The individual samples was then weighed, the percentage lipid was then measured. Finally, the solvent was evaporated until the petroleum ether escaped fully, to get final oil.

3.2.3To determine the pH for Soil Samples.

pH was determined by ensuring that the soil samples were dried, then sieved to fine particles. 10g of 2 mm sieved soil samples were weighed twice and poured in to pH cups. First weighing was represented with cups 1w, 2w, 3w 4w, 5w, 6w and 7w while second weighing represented 1, 2, 3, 4, 5, 6, and 7. 25ml of distilled water was pipetted and transferred into 10g of 2mm sieved soil which was then weighed and poured in into pH cups: 1w, 2w, 3w, 4w, 5w, 6w and 7w. After pipetting 25ml of $CaCl_2$ into 1, 2, 3, 4, 5, 6, and 7, pH cups and pipetting 25ml of distilled water into 1w, 2w, 3w, 4w, 5w, 6w and 7w, a stirrer was then used to stir the solution for at least 2-5 minutes and then left for 30minutes. Thereafter the pH meter was calibrated with buffer 4 and buffer 7, in order to standardize the pH meter. The pH meter (electron) was then dipped into each soil samples of $CaCl_2$ and distilled water. Readings were then taking for every $CaCl_2$ and distilled water.

3.2.4 To determine Particle Size (Textural Class) of Soil Samples.

Soil texture is the term used to describe the particle size distribution of a soil. The determination of soil texture "by feel" depends on an individual's ability to feel sand grains at one extreme of particles size and plasticity, and to determine the stickiness of clays at the other extreme of particles size. This ability requires a great deal of practice. Accurate particles – size distributions are usually performed in the laboratory. Textural classes are formed by grouping various size factions, for example.

Silt clay loam - 55% silt, 35% clay, and 10% sand

- 40% silt, 20% clay, and 40% sand.

Procedure

2mm sieved soil was transferred into a plastic bottle, 50ml of Carbon (Sodium hexameta phosphate) $(NaPO_3)_6$ was added, 10ml of distilled water also added. Mechanical shaker was then used to shave for 2 - 3hours. After shaking, each of the seven soil samples was then transferred into a measuring cylinder and marked with distilled water, before 40seconds. Temperature readings were then taken at every 40 seconds with the aid of a set of stop watch.

4.0 RESULTS AND DISCUSSION OF RESULTS

4.1 Results

(See appendix)

Regression Equation

The regression equation for the modeled result is obtained as follows;

$$Y = 21.81 + 84.50X1 - 91.40X2 \qquad (1)$$

The significant P-value or α-value is 0.05; any value greater than this is regarded as insignificant and can be neglected.

From the above regression model result, it shows that the coefficients for all the factors are significant (i.e. $p < 0.05$) since the p-value of the factors are all greater than 0.05 which is the standard significant value. Also the coefficient of distance has negative value and this would have a negative effect on the rate of dispersion. This implies that the reduced first-order regression equation (1) remains unchanged.

4.4 Discussion of Results

The model equation obtained in this work is as shown in equation (1); it represents the distance of dispersion as a function of time. It is obvious from table 4.1, that the distance traveled by the crude oil decreased due to its negative effect on the rate of dispersion, which implies that a decrement in distance and the coefficient of time has positive effect on the rate of dispersion. Table 4.2.1 shows the mathematical model of time, lipid content and distance; it represents the estimated Regression coefficient for the dispersion of crude oil. The factors affecting rate of dispersion are time of dispersion(X1) and distance of dispersion (X2).The coefficient for the first order factorial design were obtained as 21.81, 84.50, and 91.40. The significant predicted value (p-value) is 0.005, any value greater than this value is insignificant and can be neglected. From the above regression model, it shows that the coefficients for all the factors are significant that is p- value is less than ($p<0.05$). This implies that the reduced first order regression equation (1) remains unchanged, since it is not a normal factorial, custom factorial degree was used.

It can be observed from table 4.4, that the rate of dispersion (Y) increases as both distance of dispersion (X_2) and also the time of dispersion (X_1) Increases. From figure 4.3.1, it can be observed from the graph that there Y increases with an increase in X2. There is a strong dependence of Y on X as depicted on figure 4.3.2; it has shown that Y increases as X increases also. From figure 4.3.3, Y against X_1 and X_2 = X- data, It was shown that X_2 is represented with broken line, that is [----------], increases more faster than X_1 represent with a thick line, [.__________ .].The graphs show how well the model equation represents the crude oil dispersion phenomenon, with respect to time and distance.

5.0 Conclusions

A model equation which represents the dispersion of crude oil in terms of distance and time has been developed, and simulated with the aid of computer software known as MINITAB software. The coefficient and R^2 values show high level of accuracy. This shows how well the model equation represents the dispersion of crude oil on land with respect to time and distance.

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PhD (Chemical Engineering) from the University of Nottingham, United Kingdom (2008-Till date)
He is a member Institution of Engineers and Technology (MIET)

APPENDIX

TABLE 4.1 Results of analysis

Sample days	% moisture	% lipid C-D/B X100%	pH ($CaCl_2$)	Depth of (cm) Dispersed	Time (HRS)	Particles Size Analysis
1	22. 00	28. 11	6. 71	1cm	11	30.88
2	6. 50	16.00	6. 48	2cm	24	28.88
3	10. 00	16. 00	6. 72	3cm	48	32.88
4	8. 50	10. 00	6. 78	4cm	72	36.88
5	7. 50	16. 00	6. 80	5cm	96	34.88
6	8. 50	16. 00	6. 83	6cm	120	32.88
7	6.00	15. 00	6. 71	7cm	144	32.88

4.2 Model Results

This result was analyzed using Minitab software. The analysis was done using coded units.

Table 4.2.1 Regression Coefficients

Estimated Regression Coefficients for LIPID CONTENT

Term	Coef	SE Coef	T	P
Constant	21.81	1.657	13.163	0.000
TIME	84.50	22.170	3.811	0.019
DISTANCE	-91.40	22.876	-3.995	0.016

S = 2.684 R-Sq = 85.1% R-Sq (adj) = 77.7%

Table 4.2.2 Analysis of Variance for Lipid Content

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Regression	2	165.067	165.067	82.5337	11.46	0.022
Linear	2	165.067	165.067	82.5337	11.46	0.022
Residual Error	4	28.819	28.819	7.2048		
Total	6	193.886				

TABLE 4.3 Simulation Result Analyses

X_1	X_2	Y
11	1	859.91
24	2	1867.0
48	3	3804.0
72	4	5740.0
96	5	7677.0
120	6	9613.0
144	7	11550.0

4.3 Graphical Results

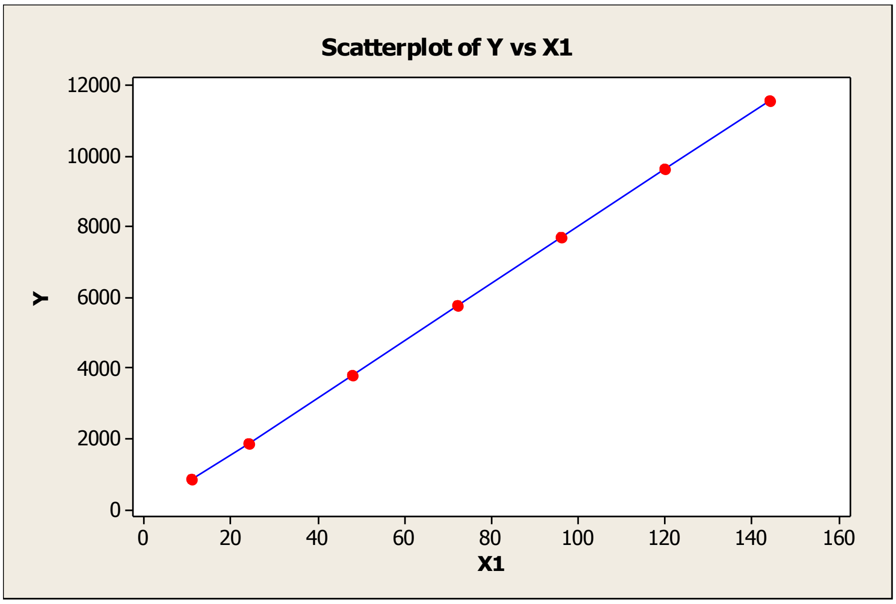

Figure 4.3.1: A graph of Y against X1

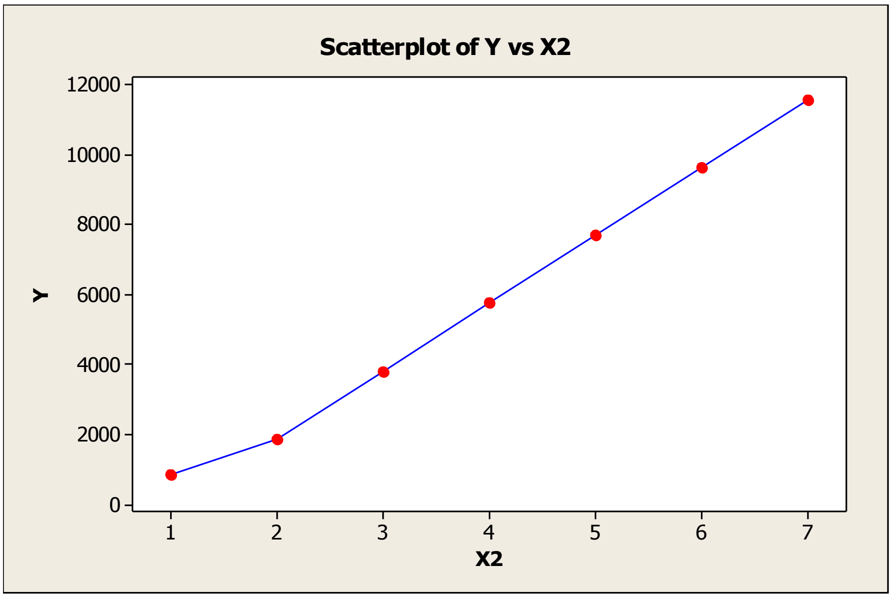

Figure 4.3.2: A graph of Y against X_2

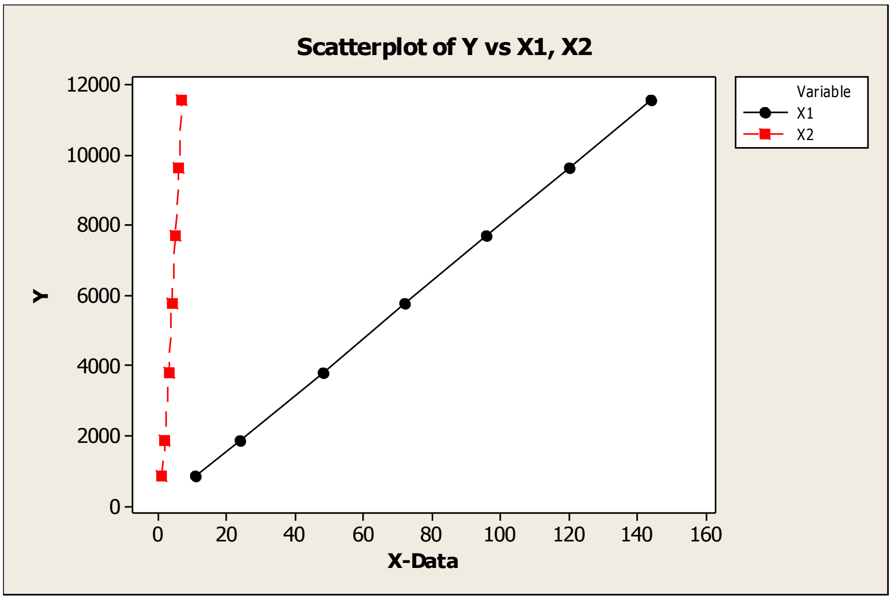

Figure 4.3.3: A graph of Y against X_1 and X_2