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EFFECTS OF DRILLING FLUID ADDITIVES ON THE ENVIRONMENT (A CASE STUDY OF A XANTHAN GUM)

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ABSTRACT

Despite its numerous benefits, the search and production of petroleum poses a lot of damage to the environment such as land, sea etc. Prominent among the sources of waste is the drilling mud which is used during drilling operations that generated the second largest amount of waste in oil and gas production activity. In this research work, an experimental method was adopted to investigate the effects of drilling mud on land by determining and comparing changes in physio-chemical properties of contaminated and uncontaminated soil sample. An area of land was mapped out and a base sample taken to determine the level of concentration of certain soil nutrients and properties like nitrogen, calcium, sodium, pH, potassium, Electrical Conductivity (EC). Thereafter, drilling mud made to the quality of spent mud by heating and adding certain salts like NaCl, was dumped on the area mapped out and after four days, the same set of experiments were carried out and repeated once in two days for two weeks. The results obtained showed increase and decrease in certain soil elements and properties (Nitrogen conc. reduced from 0.028% to 0.009 %, EC fluctuated by increasing in the early period and then decreasing as the period of soil contamination exposure increases, Cation Exchange Capacity (CEC) conc. reduced from 111 milliequivalent per 100g (111 meq/100g) to 96.54 milliequivalent per 100g (96.54 meq/100g), while Phosphorus increased from 6.50 to 7.0 pH and 0.274 milligram per litre to 1.406 milligram per litre. Degradation of the soil sample location continued to increase with time i.e. effects of the mud will continue to increase as the number of days increase. These data obtained show that xanthan gum being a very good and suitable viscosifier has adverse and continuous effects on land hence drilling mud should be treated, handled properly to prevent soil degradation..

Keywords: Drilling fluid additives, Environment, Xanthan Gum, Physio-Chemical Properties

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1.0 Introduction

In oil and gas operations especially drilling operations, the used of drilling fluids is inevitable because of its numerous functions provided for hole, the drilling fluids formed the hydrostatic pressure exerted on the formation to prevent influx of formation fluids into the wellbore, the circulation of the cuttings (rock pieces) from the bottom of the hole to the surface, cooling, cleaning and lubricating of the drill bit to prevent it from being wear-out, the provision of stability for the hole especially unconsolidated formation to prevent it from caving-in etc. However, the drilling fluid used for a particular job is selected due to their specific functions and environmental effects. Basically, drilling fluids are a mixture of slurry of clay, water and other special minerals and chemical additives. This type of drilling fluid is commonly called water base mud (WBM). Also, another very popular type of drilling fluid is called oil base mud (OBM) used for very hard and high temperature formation and it is more expensive than water base mud (WBM). OBM could be very hazardous to the environment; therefore, it is necessary to prepare it with biodegradable and environmentally friendly additives (Onuh, *et. al*, 2017).

Drilling has no doubt increased over the years; an increase in drilling operations ultimately leads to an increase in waste generation. Drilling mud is one of the major source of waste generated during drilling, when disposed into the environment usually contain radioactive materials that are harmful to human, animal, aquatic life depending on the area where it is disposed. The petroleum industry is encouraging research on drilling fluids and its additives such as non-toxic viscosity reducers and fluid loss control additives in drilling mud (Dosunmu and Joshua, 2010). Environmental regulations encourage the water base drilling fluid and its application in areas where oil base drilling fluids have been used due to their challenges (Tehrani *et al.*, 2009). In many countries engaging in offshore oil and gas exploration and production, the performance of toxicity test on drilling fluid additives and the whole of drilling mud is required before they can be disposed (Neff, *et al.*, 2000). The technical performance of drilling fluid cannot be overlook, however, the environmental impact of this mud and its additives play an important role as it determines the application of the mud. (Onuh *et al*, 2017).

Therefore, it is important to examine the environmental standard of any mud additive according to DPR standard before it can be applied. However, the disposing of these drilling mud and its additives on the environment have one impact or the other on it. The greatest impact arises from the release of wastes into the environment in the concentration that is not naturally found in such environment (Gbadebo, *et al.*, 2010). The wastes generated during petroleum production can be broadly classified into liquid (i.e. produced water & oil) and solid (i.e. drilling mud & cuttings) (Ferrari, *et al.*, 2000). Many of the additives used in the drilling mud are believed to be toxic and should be regulated (Reis, 1988). Spent drilling fluids and cuttings account for about 2% of the total waste volume while other associated wastes like produced formation water contributed over 90% of the total waste volume (API, 1978). Since the disposal of drilling mud and cuttings has been observed to be of continuously growing concern especially to the researchers in western world due to their numerous negative effects on the health, safety and environment (HSE) (Moseley, 1983). Therefore, many investigators have published a number of papers describing the effects of drilling mud and its additives on the environment in order to understand the physical and biological properties as well as the

potential effects on plant growth (Seyle *et al.* 2002, Sahar *et al.* 2009 and Gbadebo *et al.*, 2010). In the light of this, it is necessary to identify the chemicals used in drilling fluids and those produced from active wells, as well as their behavior in soil. This study presents the effects of drilling mud additives on the environment: case study of xanthan gum.

2.0 Materials and Methodology

In the aspect of this work, the research design adopted to give proper and detail description on how the study was carried out involved five (5) different phases.

2.1 Phase 1: Equipment and Materials.

The major equipment used in this research work includes mud mixer, mud cup (baroid), pH strip, measuring cylinder, weigh balance (JA203, shengzhou), thermometer (model 4200, baroid), stirrer, lab kits MP 526 conductivity meter, Jenway 3020 pH meter, Jenway 6715 UV/VIS spectrophotometer (phosphate), bulk scientist, VGP 210. AAS (Ca & Mg), sheer wood flame photometer 410. (K & Na), Jenway 31014, orbital shaker, test tube, funnel and oven. The materials used are soil sample, 32g bentonite, 5g sodium chloride, 5g sodium hydroxide pellets, 10g xanthan gum and 500ml water.

2.2 Phase 2: Site Location

Site mapping was done by taking a measurement of a single site of about 60cm by 30cm at University of Benin premises, Benin City, Edo State, Nigeria. This was carried out to enable the collection of sand sample for analysis and also examine the contaminated and the uncontaminated soil sample.

2.2.1 Method of Soil Sample Collection

Soil samples were taken using a variety of samplers; some provide only disturbed samples, while others can provide relatively undisturbed samples. Each soil sample for this experiment was collected using an orga-grid method of collection.

2.3 Phase 3: Determination of Physio-Chemical Properties

The physio-chemical properties for the different samples were determined by the two processes enumerated in 2.3.1 and 2.3.2 below:

2.3.1 Preparation of Drilling Mud Sample

500ml of water was measured in a measuring cylinder and poured in the mud cup and was fixed to a mud mixer which was then turned on at low speed. Thereafter, 5 grams of sodium chloride (NaCl) was added to the water in the mud cup and allowed to mix for four minutes. After the four minutes, 5 grams of sodium hydroxide pellets was measured and added to the mixture and allowed to mix for another four minutes. 32 grams of bentonite was added at the end of the four minutes and allowed to mix for the next ten minutes. Thereafter, 10 grams of xanthan gum was added to the mixture while still maintaining the low speed and after another 10 minutes, the mud mixer was turned off. A pH strip was immersed in the mixture and allowed to dry for four minutes and thereafter, the pH values measured are presented in table 3. However, the mud making is the second step after selecting an area of land to contaminate. The drilling fluid

was made to have similar properties as spent drilling fluid by adding sodium hydroxide pellets (NaOH) and heating it to a temperature of 50°C. After the drilling mud was made, it was poured on the soil to contaminate or degrade it. The area of land contaminated was 60cm by 30cm as stated earlier on in phase 2 above. Thereafter, a base sample was taken for control.

2.3.2 Determination of Physio-Chemical Properties of the Contaminated Soil

The soil contaminated with spent drilling mud was subjected to physio-chemical analysis to determine some of its constituent which arose from the introduction of the spent drilling mud. A stepwise process of how the following physio-chemical properties were determined is described below.

- i. pH:** The pH meter was calibrated approximately using phosphate buffer 4, 7 and 9 respectively and the electrode was properly washed with distilled water and then it was inserted into the soil solution (5g of soil and 10ml of distilled water) and the readings was taken.
- ii. EC:** 0.1m of KCl was used to calibrate the EC electrode and then, the value of 5g of the soil in 10 ml of distilled water was read and recorded.
- iii. Nitrogen:** Nitrogen in the sample was determined by Kjeldahl method (Hiller *et. al.*, 1948). About 2.0g of dried powdered sample was taken in digestion flask and 15ml of conc. H₂SO₄, 7.1g of Na₂SO₄, and 0.9g of CuSO₄ were added. The flask was swirled in order to mix the contents thoroughly then it was placed on a heater to start digestion till the mixture became clear (blue green in color). The digest was cooled and transferred to 100ml volumetric flask and the volume was made up to the mark by the addition of distilled water.
- iv. Distillation:** Distillation of the digest was performed in a distillation apparatus. 10ml of digest was introduced into the distillation tube, then 10ml of 0.5N NaOH was gradually added through the same way. Distillation was continued for at least 10 minutes and NH₃ produced was collected from a conical flask containing a combination of NH₄OH and 20ml of 4% boric acid solution with few drops of screened methyl orange indicator. The distillate was titrated against standard 0.1N HCl solution till the appearance of pink colour. A blank was also run through all steps as shown above. The model for calculating the percentage of nitrogen from the mixture is shown in equation 1 below:

$$\%N = \frac{(S-B) \times N \times 0.014 \times D}{\text{Weight of Sample} \times V} \times 100 \quad (1)$$

- v. Cation Exchange Capacity (CEC):** 5g of soil sample was weighed into 250ml polypropylene bottle and 100ml NH₄OAC (ammonia acetate) solution was added and stopped. The mixture was added at 200ppm with a mechanical shaker for 1 hour. The super nutrient was filtered through Whatman No1 filter paper. The filtrate was then use to determine Mg, Na, K and Ca with AAS, and flame photometry using standards and Hollow Cathode lamp and different wavelength for the mineral elements. An estimate of CEC was then obtained by summing the Meq exchangeable base per 100g (cmol kg⁻¹) and the Meq exchangeable acidity per 100g (cmol kg⁻¹) as stated in equations 2 to 5.

$$K = \frac{\text{Instrument reading} \times 10}{390} = \text{cmol kg}^{-1} \text{ or Meq/100} \quad (2)$$

$$Ca = \frac{\text{Instrument reading} \times 10}{200} = \text{cmol kg}^{-1} \text{ or Meq/100g} \quad (3)$$

$$Mg = \frac{\text{Instrument reading} \times 10}{120} = \text{cmol kg}^{-1} \text{ or Meq/100g} \quad (4)$$

$$Na = \frac{\text{Instrument reading} \times 10}{230} = \text{cmol kg}^{-1} \text{ or Meq/100g} \quad (5)$$

Therefore $\sum Na, Mg, Ca, K = CEC$

- vi. **Phosphorus:** 2g of the soil was scooped and placed in Erlenmeyer flask, 20ml of Extracted solution was added and shook at 200rpm (Revolution Per minute) for 10 minutes at room temperature it was filtered through whatman filter paper (Number 1) and the filtration process was repeated until the filtrate was clear. 5ml of the sample Aliquot was poured into a test tube and 5ml of ammonia Molybdate solution was added and thoroughly mixed together. It was allowed to developed colour after 10 minutes. The value of the coloured solution was then read using the spectrophotometer at 882nm and the absorbance was then extrapolated from the standard curve obtained from the standards prepared at 29, 2, 4, 6, 8, 10ppm respectively.

2.4 Phase 4: Determination of Selected Metals

Firstly, the fresh soil which the oven dried at 100 degree Celsius (100⁰C) was crushed into a smaller particle size and 1g was weighed into a kjedahl flask and 10 ml of a mixed acid (HNO₃ and HCL 1:3) was introduced into fumes chamber and then was heated for 45 minutes until the brown fume gradually disappeared and became clear. The digest was filtered using whatman NO1 filter paper, and the filtrate was made to mark. Bulk scientist, VGP210.AAS (Atomic absorption spectroscopy) was used for analysis of the selected Ca and Mg respectively, with their respective hollow cathode lamps used for absorbance measurements. Wavelength, standards, slits and lamp current used for the metals were selective depend on the metals. Sheerwood flame photometer model 410 was used for analysis of K and Na.

3.0 Results and Discussion

The results for this experimental study to determine the physio-chemical properties of the contaminated soil with the spent drilling mud and its additives are tabulated as shown in table 1 below:

Table 1: Physio-Chemical Properties (PCP) of the Contaminated Soil

Days Sample Symbols for(PCP)	0	2	4	6	8	10
Ph	6.50	6.10	6.29	6.59	7.08	7.15
EC	44.51	332.00	82.81	48.28	46.05	43.25
Na		23.65	25.11	26.51	26.98	27.05

K		11.00	12.25	12.50	13.40	13.78
Ca		4.90	7.90	5.79	7.81	8.03
Mg		2.15	3.41	3.85	5.08	5.27
CEC	111.00	108.00	105.84	102.00	98.00	96.54
P	0.274	0.457	1.005	1.105	1.406	1.600
N	0.0280	0.0140	0.0140	0.012	0.010	0.009

Table 2: Cumulative Frequency Distribution for Physio-Chemical Properties Data of the Contaminated and Contaminated Soil

No of Days	Nitrogen concentration values NCV in soil samples	Cumulative frequency for NCV	Phosphorus concentration values PCV in soil samples	Cumulative frequency for PCV	CEC values in soil samples	Cumulative frequency for CEC
0	0.028	0.028	0.274	0.274	111.00	111.00
2	0.014	0.042	0.457	0.731	108.00	219.00
4	0.014	0.056	1.005	1.736	105.84	324.84
6	0.012	0.068	1.105	2.841	102.00	426.84
8	0.010	0.078	1.406	4.247	98.00	524.84
10	0.010	0.088	1.600	5.847	96.54	621.38

Table 3: pH values for the control soil site

No. of Days	0	4	6	8	10
pH Values	6.50	6.10	6.29	6.59	7.08

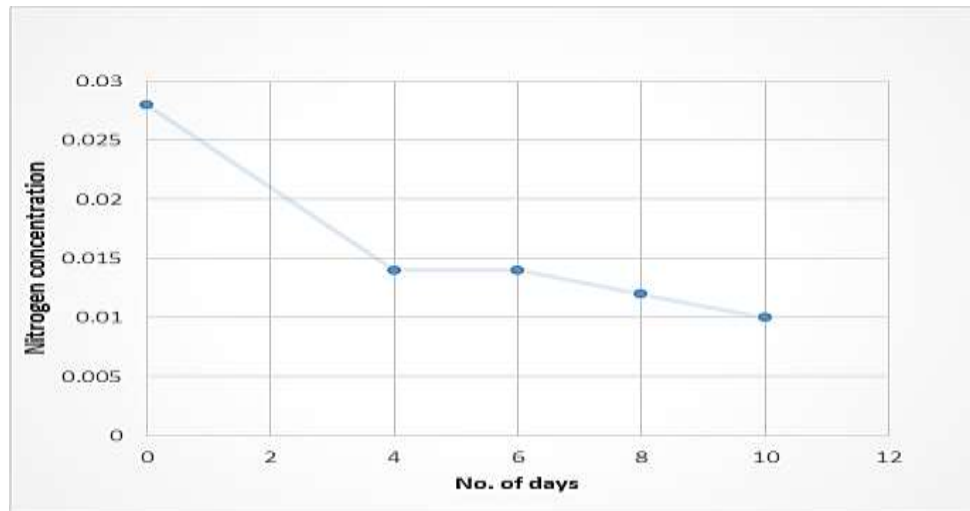


Figure 1: The Effect of Nitrogen Concentration on Soil Degradation

Table 1, 2, 3 above shows the experimental measurement of physio-chemical properties of contaminated and uncontaminated soil samples for specific number of days. The cumulative frequency curves are statistical technique adopted to exhibit the changes in physio-chemical properties of the chosen site for the experiment. These changes were caused by the influence of the spent drilling mud and its additives dumped on the site. The mean pH value of soil samples in the study area and control site ranged from 6.5 – 7.0 which indicates that soil samples are acidic and it increases further after contamination with mud. The major effect of soil acidity on plants growth includes subsurface restriction of plant roots to water and nutrients due pH values below 4.2, increased concentration of metallic ions in solution, especially that of aluminium, copper and manganese, which may be toxic for range of pH value below 5.5.

The nitrogen value over time reduces continuously as shown in figure 1 and table 2 as it decreases from 0.028 to 0.009 % due to the effect of spent mud and its additives dumped on the site. The effect of the spent drilling fluid and its additives may cause leaching, erosion and runoff due change in soil structure which will result to the loss of nitrate (NO_3^-) in the soil. The loss of nitrogen affects the growth of the plants, the symptoms include; reduction in chlorophyll content of the plant leaves which results in pale yellow colour. Older leaves turn completely yellow. Flowering, fruiting, protein, starch contents are also reduced. Cation Exchange Capacity (CEC) is a measure of the soil's ability to hold positively charged ions. It is a very important soil property influencing soil structure stability, nutrient availability, soil pH and soil reaction to fertilizers, as it indicates the capacity of the soil to retain several nutrient elements such as Na^+ , K^+ , Ca^{2+} , Mg^{2+} etc. for plant required form. Therefore, larger values of CEC indicate soil has a greater capacity to hold cations. For this particular work, the CEC keep reducing overtime which implies that the spent drilling mud as well as its additives has negative effects on the soil capacity to retain nutrients. In this study, as the day increases, the concentration of phosphorus increases showing that the drilling mud and its additives can serve as a means of replenishing the soil nutrients. However, phosphorus is an essential element which is classified as one of the macronutrients because of the relative large amount of it required by plants. Phosphorus is one of the three elements which are used to make fertilizers that are added to the soil to improve its nutritious value to plants. One of its functions in living

organisms is the transfer of energy. Adequate availability phosphorus for plants stimulates early plant growth and hastens maturity. Again, drilling mud additive can pose threat to water quality due the supply of large amount phosphorus which may pollute it which then gives rise to the excessive growth of algae resulting in reduction in water clarity and decrease in available dissolved oxygen as the algae decays, conditions that can be very detrimental to game fish populations.

4.0 Conclusions

This study shows that drilling mud additives are sources of pollution to the environment and have adverse effects on it due to the increasing and decreasing concentration of certain elements in the contaminated soil sample when compared with the uncontaminated soil sample. However, within the period of two weeks, the soil sample was able to react to changes such as continuous increase in pH, phosphorus, electrical conductivity, some macronutrient elements and decrease in nitrogen and CEC. Based on theoretical and practical observations made from this research work, the following deductions and conclusions were made:

1. The effects of drilling wastes on the environment play a critical role in managing the drilling process as well as the associated waste and should be monitored always.
2. The selection of the optimum drilling waste management must always be subjected to environmental, technical and economic analyses which are the major drivers.

5.0 Acknowledgement

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Nomenclature

- B - Concentration x Volume of Standardized NaOH Solution
D - Density of Nitrogen in the Evolved Ammonia (g/ml)
%N - Percentage of Nitrogen in the Sample.
N - Normality of the Standard Solution of Acid
RPM - Revolution per Minute (RPM)
S - Concentration and Volume of Standard Acid used to Trap Ammonia,
V - Volume of Standard Acid (ml)

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