Effects of Oil Spillage on Ground Water Quality Using Imiringi Community as A Case Study

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Abstract*—The aim of this research is to determine the effects of oil spillage on groundwater quality in Niger Delta region of Nigeria. Investigation was conducted using the spill-affected areas of Imiringi community in Ogbia Local Government Area. Groundwater samples obtained from hand dug wells in the spill-affected areas and control areas were analyzed. Water quality parameters such as temperature, pH, electrical conductivity, Total dissolved solids (TDS), Dissolved oxygen (DO), biochemical oxygen demand (BOD) and total hydrocarbon content (THC) were determined and compared with a control area that was dug 1000meters away from the well head and with available standards on the other hand. The results obtained revealed a significant increase in temperature with 28.7°C, decrease in pH of 4.26, decrease in Dissolved oxygen of 1.98of mg/L, increase in biochemical oxygen of 15.70 mg/L and increase in total hydrocarbon content of 30,000mg/L in the study area compared with the control area and the World Health Organization (WHO) standards. Therefore, the groundwater in the study area is contaminated and should be treated before use.

***Indexed Terms*— Oil, spillage, groundwater, quality, parameters, Niger Delta.**

I. INTRODUCTION

Ground water is the water present beneath the Earth's surface in soil pores spaces and in fracture of the rock formation. It is stored in and moves slowly through geologic formation of soil, sand and rock called aquifers. Crude oil is a naturally occurring complex mixture of liquids and gases, mainly of hydrocarbon contents, formed thousands of meters below the earth's crust and brought to the surface by drilling. Crude oil is accompanied by varying quantities of volatile and extraneous materials such as water, organic matters and gases. An oil spillage is the release of liquid petroleum hydrocarbon into the environment due to human activities [4].

Groundwater is a major supply of water to several communities in Nigeria. Long-lasting consumption of oil polluted groundwater has unfavorable effect on the health of the consumers. Water with elevated levels of hydrocarbon content might have adverse effect on the kidney and liver of the consumers. Some other diseases associated with oil polluted water include poor reproductive system, leukemia, increased blood pressure and reduced blood clotting. It is imperative to note that groundwater pollution from oil spill is not always responsive to total clean up. Therefore, it is safer to prevent its occurrence [1]. Nigeria recorded about 1020 incidents of oil spillage, resulting in the loss of about 1,359,715 barrels of crude oil to the waste land and water of Niger Delta region [3]. In this country, corrosion of pipelines and tankers account for 50% of all oil spills, 28% from sabotage and 21% from oil operations with 1% of the oil spills linked to inadequate or non-functional equipment [2].

II. MATERIALS AND METHODS

- MATERIALS

The materials used for this work are, water samples, PH meter, distilled water, beakers, weighing balance, filter paper, funnel, thermometer, conductivity meter, spectrometer, mechanical shaker, volumetric flask,

conical flask, spectrophotometer, pipette, Erlenmeyer flask, measuring cylinder, burette.

- SITE SELECTION, DESCRIPTION AND SAMPLING

SITE SELECTION AND DESCRIPTION

The study area used for this research work is around the vicinity of Imiringi Community in Ogbia Local Government Area, Bayelsa State, Nigeria.

Imiringi is a semi-urban community located in Ogbia Local Government Area of Bayelsa State in the Niger Delta region of Southern Nigeria.

Imiringi was chosen for the study for a number of reasons including location in the fresh water, swamp zone, easy accessibility by road from Yenagoa, the Bayelsa State Capital, which lies only about 10km away, a favorable security report – Imiringi community had a reputation for peace and stability and therefore offered an opportunity for meaningful social, health and biophysical examinations; and it is a community located within a comparatively old oil spill zone -The Kolo Creek Area [7].

- TEMPERATURE AND RAINFALL

The area lies within the rain forest belt of the Eastern Niger Delta of Nigeria. It is within the tropical wet climate classification of Koppen. The area is characterized by continual high temperatures and rainfall [6]. Average temperatures are typically greater than 18 degrees Celsius while annual precipitation is greater than 1,500mm. Precipitation takes place all year long although, there is a minute reduction in precipitation in months of August every year and between the months of December and February [5].

- SOILS, VEGETATION, RELIEF AND DRAINAGE

The Kolo Creek is characterized by tropical rainfall and fresh water swamps that are usually flooded in most parts of the year, especially between May and November. This area is characterized by periodic flooding and marsh forest vegetation continually swampy and mostly flooded by fresh water. The primary vegetation in the study area is the raffia-dominated fresh water swamp vegetation but the major soil types in the area are young shallow, poorly drained and acid sulphate soils [5]. The soils here may have been formed by the meandering of the Kolo Creek and Elebele systems which have produced silted river belt soils characterized by peaty clay water bogged soils flooded by water for most part of the year [5]. The study area is a low-lying flood plain environment with heights not exceeding 7 meters above sea level.

- SAMPLING DESIGN AND WATER COLLECTION

Water samples which were obtained from hand-dug wells were taken from three oil impacted areas and a non – impacted (control area). The contaminated areas considered are 5meters, 100meters, and 500meters around the well head, and 1000meters (control area) very far from the well head. The groundwater samples collected were transferred into sample bottles and meticulously labeled with the appropriate identification codes [8]. Before all samples were collected and transferred into sample bottles, all bottles were washed with non-ionic detergent and rinsed with de-ionized water before usage. This was conducted as part of the quality control measures. In addition, the sample bottles were rinsed three times with the groundwater samples. The samples for total hydrocarbon content (THC) were acidified with 2 ml concentrated sulfuric acid using 1-liter bottles. The labeled groundwater samples were carried to the laboratory in coolers of ice for experimental analysis within 24 hours.

- LABORATORY ANALYSIS

PH AND TEMPERATURE

PH: The basic electrometric principle method of electrometric PH measurement is determination of the activity of the hydrogen ions by potentiometric measurement using a standard glass electrode and a reference electrode. The temperature was obtained simultaneously with the PH.

Apparatus: Winlan temperature and PH meter consisting of potentiometer, a glass electrode, a reference electrode and a temperature compensating device and beakers.

Test Procedure:

- Add 50ml to distilled water into beaker.
- Measure the PH and temperature. Do not stir during measurement.
- When the reading is stable, record the sample PH and Temperature.

ELECTRICAL CONDUCTIVITY & TOTAL DISSOLVED SOLIDS

Laboratory method / Filterable method

EC/TDS: Conductivity is the measure of the ability of an aqueous solution to carry electric current. This ability depends on the presence of ions.

Apparatus:

- Self-contained conductivity meter with the capability of measuring conductivity with error not exceeding 1% or 11s/cm.
- Thermometer, capable of being read to the nearest, 0.1ºC and covering the range 23 to 27ºC..

Test Procedure:

- Add 20ml of water sample into a 50ml beaker.
- Rinse the electrode with distilled water.
- Insert the electrode of the EC meter into the water sample.
- When reading is stable, record the sample EC.

TOTAL PETROLEUM HYDROCARBON

Extraction for Soil Sediment Samples

- 10g of sample is weighed into an acid, placed in a washed and rinsed beaker.
- 25ml of 1+1 DCM and acetone were added.
- Sample is placed in a sonicator to sonicate for 20mins. A sonicator is an apparatus used to subject a sample to ultrasonic vibration so as to cause fragmentation of molecules.
- Extract is centrifuge for 10mins and solvent phase is carefully extracted through a filter paper containing 5g of anhydrous sodium sulphate and preconditioned with 1+1 DCM and acetone.
- 50ml 1+1 DCM and acetone is added to the separating funnel and extraction procedure is repeated. The extracts are combined in the Erlenmeyer flask and concentrated into 5ml syringe using rotary evaporator. The extracts are then fractionated into aliphatic and aromatic using column with hexane.

For Aliphatic: 2ml of concentrate is introduced into the column and eluted with 10ml of hexane. The eluted solvent is concentrated into final 2ml vial which is run with the gas chromatography machine.

For Aromatic: 2ml of concentrate is added into the column and eluted with 10ml DCM. The eluted solvent is concentrated into 2ml final vial which is run into the gas chromatography machine.

DISSOLVED OXYGEN (DO)

Dissolved oxygen (DO) is the amount of oxygen that is present in water.

- Fix water samples with Winkler solution I (manganese sulphate) and Winkler solution II (potassium iodide and sodium azide).
- Add 50% sulphuric acid (4 ml) to the precipitate formed on fixing with Winkler solution I and II.
- Titrate the solution with standard 0.0125 M thiosulphate ($Na_2S_2O_3.5H_2O$) to a light-yellow colored solution.
- Add two drops of starch indicator to the light-yellow colored solution and it will become blue.
- Continue titration until the blue color becomes colorless.
- Calculate DO using the following equation:
  DO (mg/l) = Volume of b0.0125 M $Na_2S_2O_3.5H_2O$ used.

BIOCHEMICAL OXYGEN DEMANDS (BOD)

Biochemical oxygen demand (BOD) is the amount of dissolved oxygen (DO) needed by aerobic biological organisms to break down organic materials present in a given sample at certain temperature over a specific time period.

- Determine the DO of the groundwater samples.
- Incubate the water samples in the dark at 20 °C for five days determine the DO for each day.
- Calculate the BOD using the following Equation:
  $BOD_5 = DO_1 – DO_5$

Where DO_1 = DO at day one (before incubation) and DO_5 = DO at the fifth day of incubation.

III. DATA ANALYSIS AND RESULTS

A. Results of the water analyses at the crude oil contaminated area-5 metres from well head.

Table 1: Soil Contaminated Area (5 meters from well head) Water Parameter values from three trials

WATER PARAMETER	TRIAL 1	TRIAL 2	TRIAL 3	MEAN VALUE
PH	4.10	4.25	4.50	4.28
Temperature (ºC)	27.7	29.5	28.6	28.6
Electrical Conductivity (EC)	284	292	294	290
Total Dissolved Solids (TDS)	142	146	147	145
Total Petroleum Hydrocarbon (TPH)	29,990	30,000	30,010	30,000
Dissolved Oxygen (DO)	2.4	2.3	2.5	2.4
Biochemical oxygen demand (BOD)	15.6	15.7	15.8	15.7

3.2: Results of the water analyses at the crude oil contaminated area - 100 metres from well head.

Table 2: Soil Contaminated Area (100 meters from well head) Water Parameter values from three Trials.

WATER PARAMETER	TRIAL 1	TRIAL 2	TRIAL 3	MEAN VALUE
PH	5.10	5.01	5.19	5.1
Temperature (ºC)	28.9	28.6	28.0	28.5
Electrical Conductivity (EC)	261	268	269	266
Total Dissolved Solids (TDS)	133	132	134	133
Total Petroleum Hydrocarbon (TPH)	11,994	12,003	12,003	12,000
Dissolved Oxygen (DO)	2.80	2.65	2.70	2.72
Biochemical oxygen demand (BOD)	12.50	12.55	12.35	12.47

B. Results of the water analyses at the crude oil contaminated area- 500 metres from well head

Table 3: Soil Contaminated Area (500 meters from well head) Water Parameter values from three trials

WATER PARAMETER	TRIAL 1	TRIAL 2	TRIAL 3	MEAN VALUE
PH	7.62	7.64	7.74	7.67
Temperature (ºC)	27.7	29.5	28.6	28.6
Electrical Conductivity (EC)	240	245	247	244
Total Dissolved Solids (TDS)	122	124	120	122
Total Petroleum Hydrocarbon (TPH)	2,997	3,001	3,002	3000
Dissolved Oxygen (DO)	2.0	1.98	1.96	1.98
Biochemical oxygen demand (BOD)	11.5	11.4	11.6	11.5

C. Results of the Water Analyses at the Control Area -1000 meters from well head.

Table 4: Control Area (1000 meters from well head) Water Parameter Values from three trials

WATER PARAMETER	TRIAL 1	TRIAL 2	TRIAL 3	MEAN VALUE
PH	7.97	8.05	7.98	8.0
Temperature (ºC)	28.5	28.4	29.2	28.7
Electrical Conductivity (EC)	169	172.5	173.0	171.5
Total Dissolved Solids (TDS)	85	85.8	86.6	85.8
Total Petroleum Hydrocarbon (TPH)	1.10	1.60	1.80	1.5
Dissolved Oxygen (DO)	2.25	2.20	2.15	2.2
Biochemical oxygen demand (BOD)	10.2	10.8	10.5	10.5

The mean values of the water parameters refer to the average values of the water parameter gotten from three trials for the cases of water collected from 5meters, 100 meters, 500 meters from the well head and water collected at the control area (1000 meters). These values were compared to the WHO standards.

Table 5: Result of Water Parameter Mean Values from the Study Areas Compared to World Health Organization Standards.

Parameters	5 meters from well head	100 meters from well head	500 meters from well head	Control area	W.H.O Guideline
PH	4.28	5.10	7.67	8.0	6.5-8.5
Temperature (ºC)	28.6	28.5	28.6	28.7	25
Electrical conductivity (µs/cm)	290	266	244	171.5	1000
Total dissolved solids (mg/L)	145	133	122	85.8	600-1000
Total petroleum hydrocarbon (mg/L)	30,000	12,000	3,000	1.50	0.05
Dissolved oxygen (mg/L)	2.40	2.72	1.98	2.20	<3
Biochemical oxygen demand (mg/L)	15.70	12.47	11.5	10.5	10

IV. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

The temperature readings of the groundwater samples in the study area varied between 28.6°C and 28.7 °C with a mean value of 28.65 while that of the control area was 25.7 which is slightly higher than the World Health Organization (WHO) standard of 25ºC. The increase in temperature in the study area could be due to increased rate of chemical reaction resulting from the presence of oil in the groundwater. The pH values in the study area ranged from 4.26 to 7.66 which is basic, while the pH value in the control area was 8.0. The low pH values observed in the study area indicates contamination of the groundwater due to oil spillage.

The dissolved oxygen in the study area ranged from 1.98mg/L to 2.65mg/L in the study area and 2.20 in the control area. The low levels of DO in the study area imply that the groundwater is polluted with organic materials whose breakdown is gradually depleting the available oxygen. The biochemical oxygen demand (BOD) in the study area ranged from 11.5 mg/L to 15.7 mg/L which is greater than the recommended WHO standard of 10 mg/L, while that

of the control area was 10.5 which is just slightly higher than the recommended WHO standard. Thus, it can be said that the groundwater in the study area is contaminated with organic pollutants.

The total hydrocarbon content (THC) in the study area ranged from 12,000 mg/L to 30,000 mg/L which is greater than the WHO standards of 0.05 mg/L. The THC in the control area was slightly higher than the WHO standard. This result is a clear indication of hydrocarbon pollution of groundwater in the study area and accounts for the high BOD recorded in the study area.

This will have negative impact on the health of the indigenes depending on the extent of consumption and their previous health history. If treatment is not considered as soon as possible, there is no doubt that these health problems may cause low life expectancy and affect the productivity of the study area.

B. RECOMMENDATIONS

Detailed medical test should be carried out in the affected area to ascertain the health of the people. Thorough groundwater investigations should be carried out and adequate treatment should be implemented. Cleanup exercises should be conducted by the government immediately there is oil spillage in order to prevent infiltration of oil into the groundwater thereby causing pollution. Oil spill prevention, containment and countermeasures should be set up.

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