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Groundwater Study for the Identification of Crude Oil Pollution Sources within a Hydrocarbon Processing Facility in Niger Delta, Nigeria

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Abstract: *Hydrocarbon pollutants were physically observed to have impacted the upper aquifer based on samples taken from eight monitoring boreholes within the facility. Initial samples were taken from the monitoring bore holes (wells) before compression and analyzed to authenticate the level and types of hydrocarbons present. The results showed that all but one of the samples exceeded the Department of Petroleum Resources (DPR) intervention limit, with values ranging between 14.25 to 3,416.67 mg/l. Water samples collected one week after flushing and tested for Total Petroleum Hydrocarbon (TPH), Poly Aromatic Hydrocarbon (PAH), Total Hydrocarbon Content (THC) and other physicochemical parameters relating to hydrocarbon presence were proved positive. The possible impacts of the identified hydrocarbon pollution migration in the ground water were highlighted and recommendations made in line with preventing and possibly eliminating further future occurrence.*

Key words: *Ground water, Identification, Crude Oil Pollution Sources, Niger Delta, Nigeria.*

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I. Introduction

Niger Delta being an oil producing region is crisscrossed with a number of hydrocarbon pipelines and storage tanks that do rupture severally, sometimes as a result of corrosion or willful act to release hydrocarbon pollution into the environment. In most cases the hydrocarbon so released carry some associated toxic metals like Pb, Cd, Ni, Cr etc into the underground water as noted by Kakulu and Obibanjo, 1992; Anmar et al., 1993; Fatoki and Awofolu, 2003; Eddy and Ekop, 2007.

Several studies carried out by Amajor (1984), Mmom and Deckor (2010), Adoki (2012), Tse and Nwankwo (2013) and Giadom et al (2015) had looked at the impact of pollution on the environment of Ejama-Ebubu in Eleme (an industrial zone in the Niger Delta). This study however, is focused on the impact within the upper aquifer in the study area. Once a contaminant has escaped into the ground, it flows from pore to pore through the soil, sometimes travelling several kilometers. The manner and rate of transport of this contaminant depends on many factors, including:

- Whether the soil is saturated or unsaturated
- The type of soil
- The type of material flowing through the soil, especially its solubility in water and its specific gravity
- The velocity and direction of natural groundwater flow
- The rate of infiltration from the source

When water and contaminants flow through soil, the irregular shape of the pores and the particulate nature of the soil always cause some of the contaminants to spread out over a wide area (dispersion) than could be predicted by advection alone. These two processes dominate the transport of contaminant in permeable soils, particularly when the hydraulic gradient is high. The degree of dispersion may be defined by the hydrodynamic dispersion coefficient, (Bedient, *et al.,* 1994).

Some contaminants do form coatings around soil particles or soak into the soil particles through sorption process (adsorption and absorption). Factors that affect sorption include contaminant characteristics (water solubility, polar-ionic character, octanol-water partition coefficient) and soil characteristics (mineralogy, hydraulic conductivity, porosity, texture, homogeneity, organic carbon content, surface charge, surface area).

II. General Geology of the Area

The area of study lies within the Niger Delta region and sits on the Benin formation which is dated between the late Tertiary to Early Quaternary period. The Formation is about 200m thick with unconsolidated lithology of fine-medium-coarse-grained sands, occasionally pebbly with localized clay and shale (Igboekwe et al, 2006; Igboekwe et al, 2012, Etu-Efeotor, 1981, and Ngah, 1990).

III. Materials and Methods

Basically, the methods used in this research involved drilling monitoring boreholes and collection of underground water samples from the boreholes for laboratory analyses as to determine the level of hydrocarbon pollution within the area.

3.1 Drilling of monitoring Boreholes

Five (5) new monitoring boreholes were drilled by percussion method without any use of drilling fluids (to avoid contamination through drilling processes) in addition to four (4) already existing boreholes (figures 1&2), each to a depth of 20meters with their coordinates, ground elevation and static water levels (tables 1 and 2) taken to enable monitoring and evaluation of groundwater quality within the upper aquifer in the region. Furthermore, a topographic contour map with the distribution of boreholes is shown in figure 2while figure 3 is a fence diagram of the strata logs of the nine (9) boreholes showing their thickness and horizontal layout.

Thereafter, the wells were developed to allow fresh water from the formation to flow in and were sampled for laboratory analyses. Again, a second phase sampling for laboratory analyses was carried out after an interval of one week.

Figure1: Drilling by Percussion Method of one of the Boreholes in Process during the study

Table 1: Co-ordinates, Elevation and Static Water Level (SWL) of Newly Drilled Boreholes (NBH)

Borehole	Co-ordinates	Ground Elevation	Static Water Level
NBH1	N04^0 45’ 41.9’’ E007^0 05’ 49.7’’	11.0 meters	10.5 meters
NBH2	N04^0 45’ 34.8’’ E007^0 05’ 53.0’’	9.0 meters	10.8 meters
NBH3	N04^0 45’ 16.7’’ E007^0 06’ 04.4’’	15.0 meters	12.1 meters
NBH4	N04^0 45’ 08.5’’ E007^0 06’ 15.1’’	15.0 meters	11.9 meters
NBH5	N04^0 45’ 50.3’’ E007^0 06’ 39.3’’	16.0 meters	9.9 meters

Source: Field Work

Table 2: Co-ordinates, Elevation and Static Water Level (SWL) of Old Boreholes (OBH)

Borehole	Co-ordinates	Ground Elevation	Static Water Level
OBH1(OIL MOVEMENT)	N04^0 45’ 33.7’’ E007^0 06’ 14.7’’	21.0 meters	11.4 meters
OBH2 (50 TK O1A)	N04^0 45’ 47.2’’ E007^0 06’ 24.9’’	13.0 meters	10.4 meters
*OBH3	N04^0 45’ 11.4’’ E007^0 06’ 13.6’’	15.0 meters	-
OBH4 (TEL)	N04^0 45’ 49.6’’ E007^0 05’ 59.3’’	16.0 meters	10.8 meters

Source: Field Work

**OBH3 – This well collapsed so it was not productive*

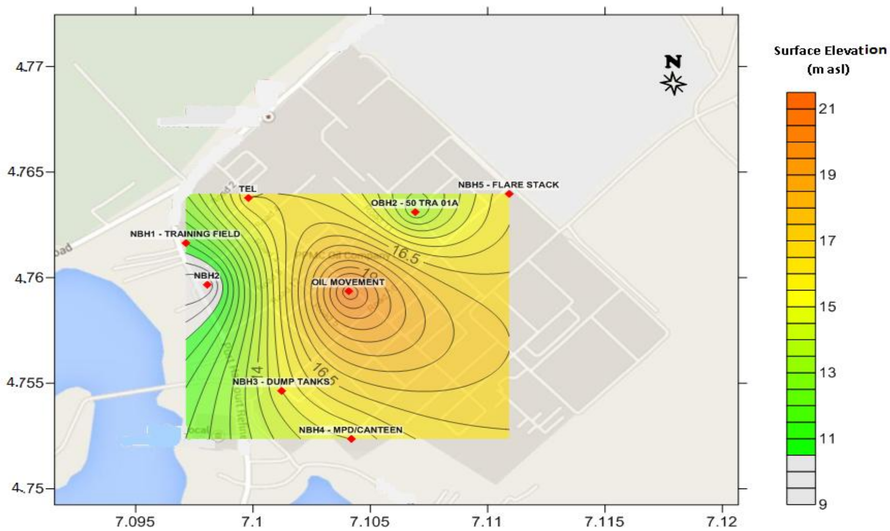

Figure 2: Ground Surface Elevation around the Borehole Points

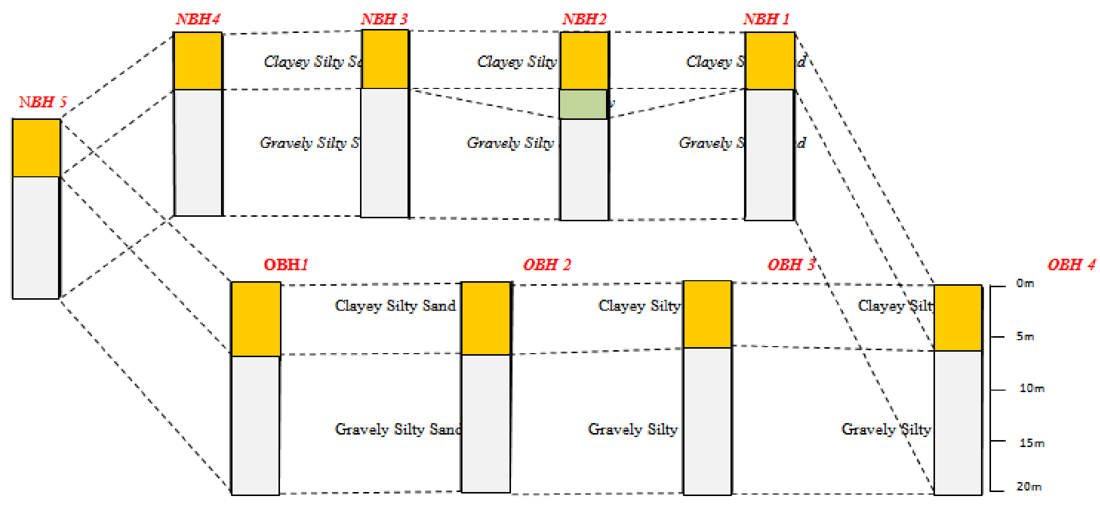

***Figure 3*: Fence Diagram of the 9 Monitoring Boreholes**

IV. Results and Discussions

The results of pre-compressed water analyses from NBH 1, NBH 2, NBH 3, NBH 5, OBH 1 and OBH 4 with static water levels of 10.5m, 10.8m, 12.1m, 9.9m, 11.4m and 10.8m respectively showed contamination levels exceeding the Department of Petroleum Resources (DPR) intervention limit, with values ranging between 14.25mg/l in OBH 4 to 3,416.67mg/l in NBH 2 as contained in tables 3 and 4.

Table 3: Pre-Compression Results of Specified Physico Chemical Parameters Analyses

S/ N	Sample ID	PAH (mg/l)	THC (mg/l)	Cu (mg/l)	Zn (mg/l)	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)	Ni (mg/l)	Mn (mg/l)	Fe (mg/l)	Hg (m/gl)
1	NBH 5	0.019	29.37	0.005	0.052	<0.001	<0.001	<0.001	<0.001	0.032	16.741	<0.001
2	NBH 4	<0.001	1.44	0.019	0.038	<0.001	<0.001	<0.001	<0.001	0.171	3.373	<0.001
3	NBH 3	0.045	82.90	<0.001	0.008	<0.001	<0.001	<0.001	<0.001	0.048	0.232	<0.001
4	NBH 2	2.050	3,416.6	0.098	0.279	1.487	0.031	0.006	0.124	0.192	22.285	<0.001

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5	NBH 1	0.022	36.75	0.085	0.325	0.219	0.063	0.008	0.225	0.817	24.109	<0.001

Analyses of results in table 3 for PAH, THC and the heavy metals from the newly drilled boreholes (NBH 1, 2, 3, 4 and 5) showed concentration above the threshold values for Pb (in NBH 1 and 2), Cd (in the five NBH), Fe (in the five NBH) and THC (in all except NBH4 that serves as a control).

Table 4: Pre-Compression-Results of Specified Physico Chemical Parameters Analyses

S/N	PARAMETER(S)	OBH 1 (OIL MOVT)	OBH 2 (50 TK O1A)	OBH 4 (TEL)	DPR Target Value(S)
1.	pH	5.40	7.00	6.20	*6.5-8.5*
2.	Cond. (µS/cm)	168	41	150	*NS*
3.	Chloride (mg/l)	18	8	14	*600*
4.	Temperature (^{0}C)	29.9	29.8	29.9	*25*
5.	TDS (mg/l)	85	21	76	*2,000*
6.	SO_4^{2-} (mg/l)	<0.1	7	16	*NS*
7.	PO_4^{3-} (mg/l)	0.17	4.80	<0.1	*NS*
8.	Cu (mg/l)	0.044	0.198	1.234	*1.5*
9.	Pb (mg/l)	0.428	3.870	4.848	*0.05*
10.	Zn (mg/l)	0.347	1.442	1.615	*1.0*
11.	Fe (mg/l)	12.902	88.746	356.052	*1.0*
12.	Cd (mg/l)	0.025	0.024	0.029	*0.0004*
13.	Cr (mg/l)	0.038	0.074	0.897	*0.03*
14.	Mn (mg/l)	0.602	0.539	3.999	*NS*
15.	THC (mg/l)	21.45	2.02	14.25	*10*
16.	TPH (mg/l)	0.550	1.111	7.840	*NS*
17.	PAH (mg/l)	0.001	0.002	0.017	*0.0001*

Similarly, results of analyses of samples from old boreholes (OBH1, 2 and 4) as shown in table 4 indicated that both temperature of the water, Pb content, Zn content, THC content (except in OBH2) and PAH content are all above the DPR target values.

Table 5: Post-Compression Results of Specified Physico Chemical Parameter Analyses

S/N	PARAMETER(S)	NBH 1	NBH 2	NBH 3	NBH 4	NBH 5	OBH 2 (50 TK)	OBH 4 (TEL)	DPR Target Value(s)
1.	pH	6.2	5.7	6.0	6.7	5.7	5.9	6.4	*6.5-8.5*
2.	Cond. (µS/cm)	123	135	47	178	53	102	418	*NS*
3.	Chloride (mg/l)	8	8	4	6	6	8	10	*600*
4.	Temperature (^{0}C)	30.1	30.0	30.0	30.0	30.3	30.0	30.0	*25*
5.	TDS (mg/l)	60	68	24	89	27	51	209	*2,000*
6.	SO_4^{2-} (mg/l)	2	2	1	3	1	2	7	*NS*
7.	PO_4^{3-} (mg/l)	0.03	0.03	<0.1	0.04	<0.1	0.02	0.06	*NS*
8.	Cu (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	*1.5*
9.	Pb (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	*0.05*
10.	Zn (mg/l)	0.034	0.018	0.032	0.037	0.021	0.016	0.030	*1.0*
11.	Fe (mg/l)	6.228	4.124	0.229	7.423	0.036	1.263	11.540	*1.0*
12.	Cd (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	*0.0004*
13.	Cr (mg/l)	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	*0.03*
14.	Mn (mg/l)	0.398	0.104	0.007	0.147	0.041	0.273	0.042	*NS*
15.	THC (mg/l)	<0.01	16.98	7.41	<0.01	<0.01	<0.01	4.80	*10*
16.	TPH (mg/l)	<0.001	7.98	3.19	<0.001	<0.001	<0.001	2.15	*NS*
17.	PAH (mg/l)	<0.001	0.011	0.005	<0.001	<0.001	<0.001	0.004	*0.0001*

A post compression result analyses of these boreholes (both old and newly drilled) in table 5 still showed high concentration of some of these elements. The slight difference in concentration between the pre and post compression results may be attributed to lag time in plume flow which eventually builds up over time.

Table 6: Laboratory Test Results of PMS from Monitoring Borehole (OBH 1)

PARAMETERS	METHOD OF TEST	RESULTS

Density @15^{0}C	ASTM D 1298-12b	0.7782kg/l
Relative Density @ 60/60^{0}F	ASTM D 1298-12b	0.7785(50.25^0 API gravity)
Distillation, Atmospheric	ASTM D 86-12	^{0} C
IBP	Same	45 ^{0} C
5% Recovered	‘’	64 ^{0} C
10% Recovered	‘’	75 ^{0} C
20% Recovered	‘’	89 ^{0} C
30% Recovered	‘’	102 ^{0} C
40% Recovered	‘’	114 ^{0} C
50% Recovered	‘’	125 ^{0} C
60% Recovered	‘’	137 ^{0} C
70% Recovered	‘’	147 ^{0} C
80% Recovered	‘’	158 ^{0} C
90% Recovered	‘’	177 ^{0} C
95% Recovered	‘’	194 ^{0} C
FBP	‘’	232 ^{0} C
Total Recovery	‘’	99 % vol
Residue	‘’	0.5 % vol
Loss	‘’	0.5 % vol
Recovery @ 70^0 C	‘’	8 % vol
Recovery @ 125^0 C	‘’	50 % vol
Recovery @ 180^0 C	‘’	89 % vol

A representative sample was taken from OBH1 for PMS laboratory test to determine the Specific gravity (SG) of the hydrocarbon as to ascertain its density and Atmospheric distillation to mark differences in the Initial Boiling Point (IBP), Final Boiling Point (FBP) and recoveries at various percentages (see table 6). The average Specific gravity value, 0.7785 (50.25) of the samples is found to be within the range of The American Petroleum Institute gravity values of 0.75 to 0.79 (57.98–47.95) API gravity, which suggests that the sample is neither too heavy nor too light (ATSDR, 1995). The result of 10%recovery is put at 75 °C which is above the standard of70 °C as recommended by ASTM (1979) for PMS (gasoline). Again, the standard specified that the limit for 50% recovery and Final Boiling Point should not exceed a maximum of 125 °C and 205°Crespectively, but the FBP in this result is 232 °C, suggesting that the hydrocarbon must have been adulterated along the plume course.

V. Conclusion

It is clear from the post-compression results in table 5 that the values for both THC, TPH and PAH were not obliterated one week after compressing the wells but were merely reduced, showing migratory tendency. So, given enough time the value will again build up.

Again, result of laboratory test of PMS obtained from OBH 1(table 6) shows that the sample has relative density and atmospheric distillation of PMS which proves the fact that there is an infiltration of PMS from underground sources within the area. The implication of this result is in various facets;

- First, the identified crude oil pollutant on the ground water has the potential of affecting the surrounding aquifer to the facility over a short and long term period due to its migratory attribute. If continuously fed from source unhindered, this has the capacity to pollute various sources of domestic borehole water supply in the adjourning residential areas, making them unsafe for human consumption.
- Within the locality of this study; underground water are often harnessed and applied for aquaculture such as fish culture and sometimes for irrigation purposes. This means that the hydrocarbon pollutants such as heavy metals can become introduced into the food chain and ultimately find their way into humans through bio-accumulation and bio-magnification processes.
- Due to persistent nature of hydrocarbon pollutants, the saturated underground water with polluted hydrocarbon can significantly affect surface water and other terrestrial environment during aquifer recharge. This has severe adverse environmental consequences, leading to the reduced and non-usability of otherwise useful aquatic/land based resources due to the underground water pollution impact.

VI. Recommendations

Based on the findings of this study, the following are recommended as a means of abating or eliminating the ground water hydrocarbon pollution of typical crude handling facilities within the Niger Delta region.

- Periodic monitoring of the ground water in target facilities, as a means of constantly identifying real and potential sources of hydrocarbon pollution of underground water.

- Carrying out routine random testing of borehole water sources within the adjourning environments and neighbourhoods to determine the extent of spread of such pollutants through ground water flows whereby the preceding recommendation results turns out positive.
- Ensuring through the appropriate Agencies that the facilities handling any form of crude oil activity applies the best global practices to ensure the ground water and the environment in general does not get polluted either accidentally or intentionally.
- Constant monitoring of equipment and processes that leads to hydrocarbon pollution to avoid the occurrence of either or both phenomenon.

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