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Post Impact of Hydrocarbon Spillage on Physicochemical Parameters and Heavy Metals in the Santa Barbara River, Nembe, Bayelsa State

Amararu Onyema Isukul[1], Godwin Jeremiah Udom[2], Richmond Uwanemesor Ideozu[2]

[1]Institute of Natural Resources, Environment & Sustainable Development (INRES), Port Harcourt, Nigeria
[2]Department of Geology, Faculty of Science, University of Port Harcourt, Rivers State, Nigeria
Email: richmond.ideozu@uniport.edu.ng

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Abstract

The work of the paper focused on the post impact of oil spill contamination of groundwater in Bassambiri Nembe Bayelsa State. Groundwater samples were sampled from hand dug wells from eight stations including the control point for physico-chemical investigation using sterilized glass bottles. Sampling was carried out upstream and downstream on the Santa Barbara River across the stations and the results are as follows surface water pH ranged 6.90 - 7.50, electrical conductivity 19739.41 μS/cm - 28920.64 μS/cm and Chloride 6019.63 - 9274.82 mg/l. The Total Dissolved Solids (TDS) varied from 10472.72 mg/l - 16538.19 mg/l dissolved oxygen (DO) 6.21 mg/l - 7.371 mg/l while the mean biochemical oxygen demand (BOD) 0.09 ± 0.52 mg/l - 2.4 ± 0.81 mg/l, temperature 28.04˚C - 31.79˚C while total alkalinity is 43.95 mg/L -73.87 mg/L. Calcium ion ranged 375.68 mg/l - 536.72 mg/l, Magnesium ion 88.35 - 243.24 mg/l and Potassium ion 41.27 - 121.17 mg/l. The results of the study showed that the pH, salinity, alkalinity, total suspended solids (TSS), Chlorides, Phosphates, and Nitrates are within permissible limits of the WHO, however the electrical conductivity, TDS, turbidity, DO, BOD, and hardness exceeded WHO permissible limits for drinking water. Total Petroleum Hydrocarbon (TPH) and Heavy metals had low concentrations in the Santa Barbara River across the study area suggesting that surface water is not polluted. However, the surfactants used initially to contain the oil pollution were effective based on this research.

Keywords

Post Impact, Oil Spillage, Physiochemical Parameters, Santa Barbara

1. Introduction

Oil spillage is believed to be one of the principal environmental problems associated with the petroleum industry in Nigeria, which is carried out in both onshore and offshore of the Niger Delta [1]. According to the [2] over 1500 abandoned oil spills sites are located within the Central, Western and Eastern axis of the Niger Delta. Oil spill incidents that happened between 1976 and 1996 about 4674 recorded spilling of two million three hundred and sixty-nine thousand four hundred and seventy (2369, 470) barrels of crude oil with 77% lost to the environment. Out of the lost crude oil, land spills accounted for 6%, swamps, 25% and 69% in offshore environments [3]. Pollution from oil spills and industrial effluents has the potential to harm both aquatic and terrestrial ecosystems [4]. Petroleum hydrocarbons is one of the major pollutants frequently discharged into the coastal waters, though not usually regulated as hazardous wastes [5]. Crude oil spills may result in heavy metal contamination of the vegetation and their uptake through consumption of crops threatens public health and ecosystem functions [6]. The ingestion of these heavy metals at unsafe levels could result in acute and chronic effects such as impaired growth [7]. In the Niger Delta region, low heavy metal accumulation has been reported in Elechi Creek and Lower Bonny River [8] and [9]. Anthropogenic activities may significantly increase heavy metal contamination of the environment thus posing risks to living organisms [10]. Toxic effects of metals occur when the rate of uptake exceeds the rates of physiological or biochemical detoxification and excretion [11]. Heavy metals are high priority pollutants because of their relatively high toxic and persistence in the environment thus, are used as indicators of pollution in natural settings [12]. The aim of this research is to assess the post impact of hydrocarbon spillage on the physicochemical parameters and heavy metals in Santa Barbara River, Bassambiri-Nembe, Bayelsa State. The study area, lies within South Brass and East Odiama Creeks of Nembe Southeast of Bayelsa State, Nigeria (6˚24'0"E and 6˚34'30"E, 4˚34'30"N and 4˚28'30"N). The Santa Barbara River meanders through the thick brackish mangrove forest terrain of the study area, intersected by interconnected secondary tributaries that empty into the Atlantic Ocean (**Figure 1**).

2. Materials and Methods

2.1. Sample Collection

Surface water samples were collected from Santa Barbara River using sterilized glass bottles—upstream and downstream on the Santa Barbara River. Samples were collected upstream from station 1 to 4 at intervals of 200 meters and then from station 5 to 9 with varying distances downstream, upstream and control point. Immediately after the collection of each sample, sample bottles were appropriately labeled and immediately stored in an ice chest. The samples were thereafter transported to the laboratory within 24 hours for analysis. Sample

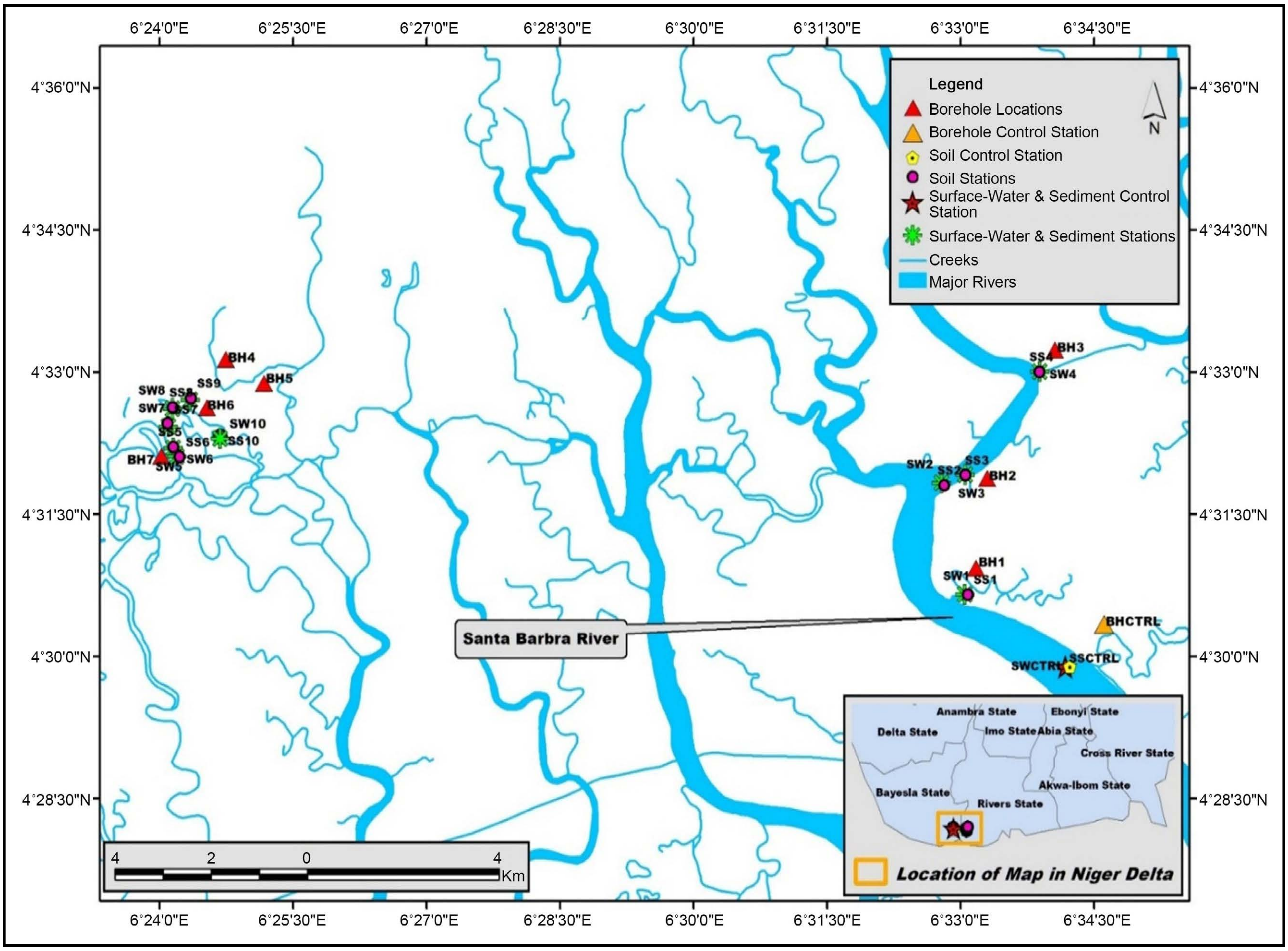


Figure 1. Location of the Study Area Showing Sample Points, Map insert (Nigeria and map indicating Bayelsa State) and Legend (after [13]).

storage was carried out according to standard laboratory practices as recommended by the American Public Health Association [14]. A total of one hundred and twenty (120) water samples in four replicates from 10 sample stations and from a control point were analyzed for the physiochemical parameters that were geo-referenced using a handheld Global Positioning System (GPS).

2.2. Analysis of Physiochemical Characteristics and Heavy Metals

The physical and chemical parameters analyzed are temperature, (pH), electrical conductivity, salinity, TDS, DO, and BOD. The methods used are as described by [14].

Turbdity

Test Method: Nephelometric Method

Standard Reference: APHA 2130B: Apparatus used: HACH 2100P Turbidimeter

Calculation:

$$\text{Nephelometric turbidity units}(\text{NTU}) = \frac{A \times (B + C)}{C}$$

where A = NTU found in the diluted ample;

B = Volume of dilution water, ml;

C = sample volume taken for dilution, ml.

TDS

Test Method: Total Dissolved Solids; Dried At 180˚C (Gravimetric Method)

Standard Reference: Apha 2540 C

Calculation:

$$\text{Total Dissolved solids}\left(\text{mg/L}\right)=\frac{\left(W_1-W_2\right)\times 1000}{\text{Sample volume}\left(\text{ml}\right)}$$

where:

W_1 = Weight of dried residue + dish;

W_2 = Weight of empty dish.

Total Suspended Solids (TSS)

Test Method: Total Suspended Solids Dried at 103˚C - 105˚C (Gravimetric method)

Standard Reference: APHA 2540 D

Calculation:

$$\text{Total Suspended solids}\left(\text{mg/L}\right)=\frac{\left(W_1-W_2\right)\times 1000}{\text{Sample volume}\left(\text{ml}\right)}$$

where:

w_1 = Weight of dried residue + dish;

w_2 = Weight of empty dish.

Alkalinity

Test Method: - Titrimetric method

Standard Reference: - APHA 2320B

Calculation:

$$\text{Phenolphthalein Alkalinity, as mg CaCO}_3/\text{L}=\frac{A\times N\times 50000}{\text{ml sample}}$$

where:

A = mL of standard acid used;

N = normality of standard acid.

Total Alkalinity

$$\text{Phenolphthalein Alkalinity, as mg CaCO}_3/\text{L}=\frac{B\times N\times 50000}{\text{ml sample}}$$

where:

B = total mL of titrant used to methyl orange or bromcresol green end point;

N = normality of standard acid.

Hardness

Standard Reference: APHA 2340C

Method: EDTA Titrimetric method

Calculation:

$$\text{Hardness}(\text{EDTA})\text{ as mg CaCO}_3/\text{L} = \frac{A \times B \times 1000}{\text{mL sample}}$$

where:

A = mL titration for sample and;

B = mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant.

Calcium

Standard Reference: APHA 3500-Ca-B

Method: EDTA Titrimetric method.

Calculation:

$$\text{mg Ca/L} = \frac{A \times B \times 400.8}{\text{mL sample}}$$

$$\text{Calcium hardness as mg CaCO}_3/\text{L} = \frac{A \times B \times 1000}{\text{mL sample}}$$

where:

A = mL titrant for sample and;

B = mg $CaCO_3$ equivalent to 1.00 mL EDTA titrant at the calcium indicator end Point.

Magnesium

Standard Reference: APHA 3500-Mg-B

Method: Calculation from total hardness and calcium.

Calculation:

mg mg/L = [total hardness (as mg $CaCO_3$/L) − calcium hardness (as mg $CaCO_3$/L)] × 0.243

Biological Oxygen Demand (BOD_5)

Standard Reference: APHA 5210 B

Test Method: 5-Day BOD Test.

Calculation:

BOD_5 (mg/L) = [DO1 − DO0]/B

where:

DO0 = initial dissolved oxygen (immediately after preparation);

DO1 = final dissolved oxygen (after 5 days of incubation);

B = Fraction of sample used.

Chemical Oxygen Demand

Standard Reference: APHA 5220 C

Test Method: Closed Reflux—Titrimetric method.

Calculation

$$\text{COD}(\text{mg/l, as O}_2) = \frac{(\text{Blank Titer} - \text{Sample Titer}) \times \text{Molarity of FAS} \times 8000}{\text{Sample Volume}}$$

where:

A = mL FAS used for blank;

B = mL FAS used for sample;

M = molarity of FAS, and;

8000 = milli equivalent weight of oxygen × 1000 mL/L.

Chloride

Test Method: Argentometric Titrimetric Method

Standard Reference: APHA 4500 Cl^- - B

Calculation:

$$\text{mg Cl}^-/\text{L} = \frac{(A - B) \times N \times 35450}{\text{mL sample}}$$

where:

A = mL titration for sample;

B = mL titration for blank;

N = normality of $AgNO_3$.

2.3. Determination of Heavy Metals

Standard Reference: APHA 3111B

Test Method: Air-acetylene Flame Atomic Absorption Spectroscopy Method. The Air-acetylene Flame Atomic Absorption Spectroscopy Method was used for heavy metal determination. Calibration analysis was carried out by diluting 1000 ppm stock solution of the individual elements (Pb, Fe, Cu, Zn, Ni, Co and Mn) while three standard working solutions were prepared from the stocks (ranging from 0.1 mg/L - 10 mg/L).

3. Results and Discussion

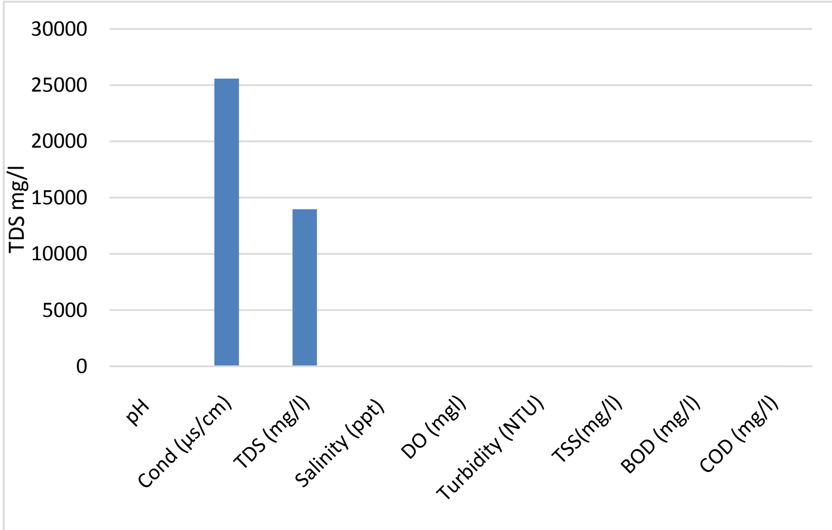
The results of the physicochemical characteristics and heavy metal analysis are presented in **Figures 2-7**.

3.1. Physicochemical Parameters of Santa Barbara River

The physicochemical parameters comprise pH, Electrical conductivity, TDS, salinity, turbidity, DO, COD, BOD.

pH: The surface water pH of Santa a River ranged between 6.90 and 7.50 across the sampling stations. The results show the water is slightly acidic to alkaline. The pH values observed in the study falls within the acceptable range for pH which ranges (6.5 - 8.5) in line with WHO Standards [15] (WHO, 2011A). However, the result shows the presence of pollutants from the hydrocarbon spill entering surface water and creating an imbalance in the pH of aquatic ecosystem, such that it fluctuates below and above the normal value of 7.

Electrical Conductivity: The mean electrical conductivity values recorded across the stations varied from 19739.41 ± 273.04 μS/cm to 28920.64 ± 290.83 μS/cm (**Figure 2**). The obtained electrical conductivity indicates brackish water. Conductivity varies according to season according to [16]-[21]. The results of electrical conductivity across the stations exceeded the WHO limit of 2500 μS/cm [22]. High values of electrical conductivity recorded in the Santa Babra River indicate the presence of dissolved substances, chemicals and minerals released from oil spillage. This shows a strong correlation between TDS and cations which is responsible for the high electrical conductivity observed across all sampled stations.



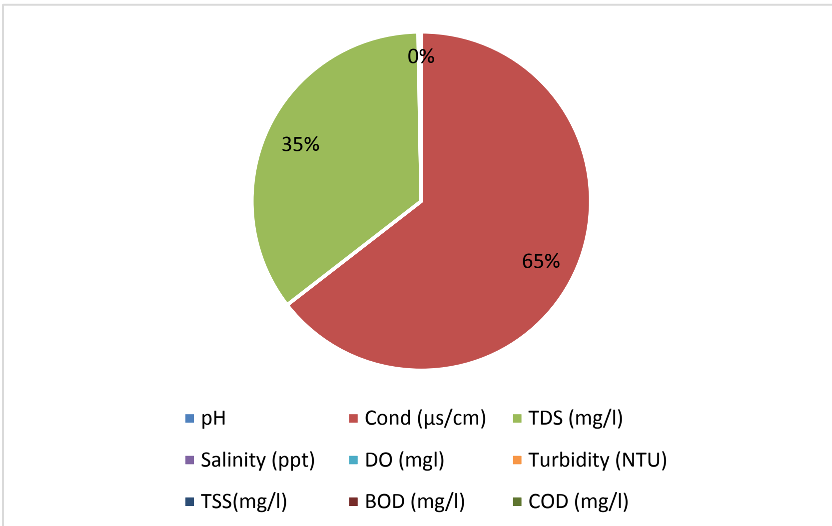
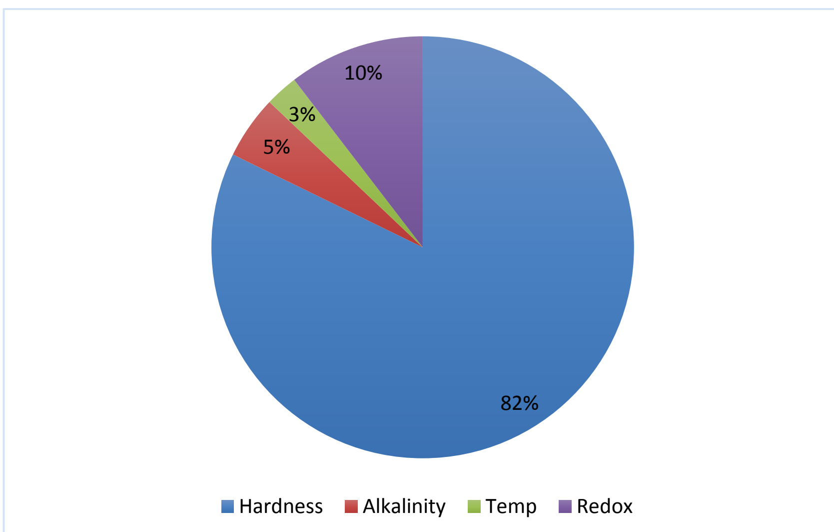


Figure 2. Physicochemical parameters in santa barbara river.



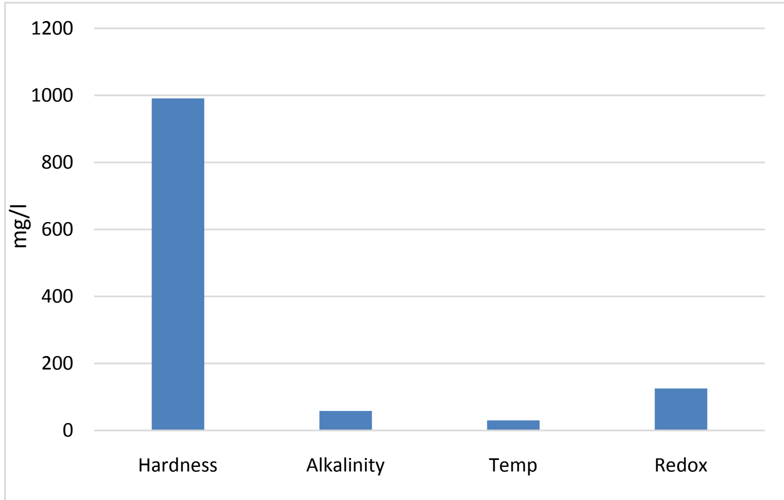


Figure 3. Hardness, alkalinity, temperature and redox physiochemical parameters in santa barbra river.

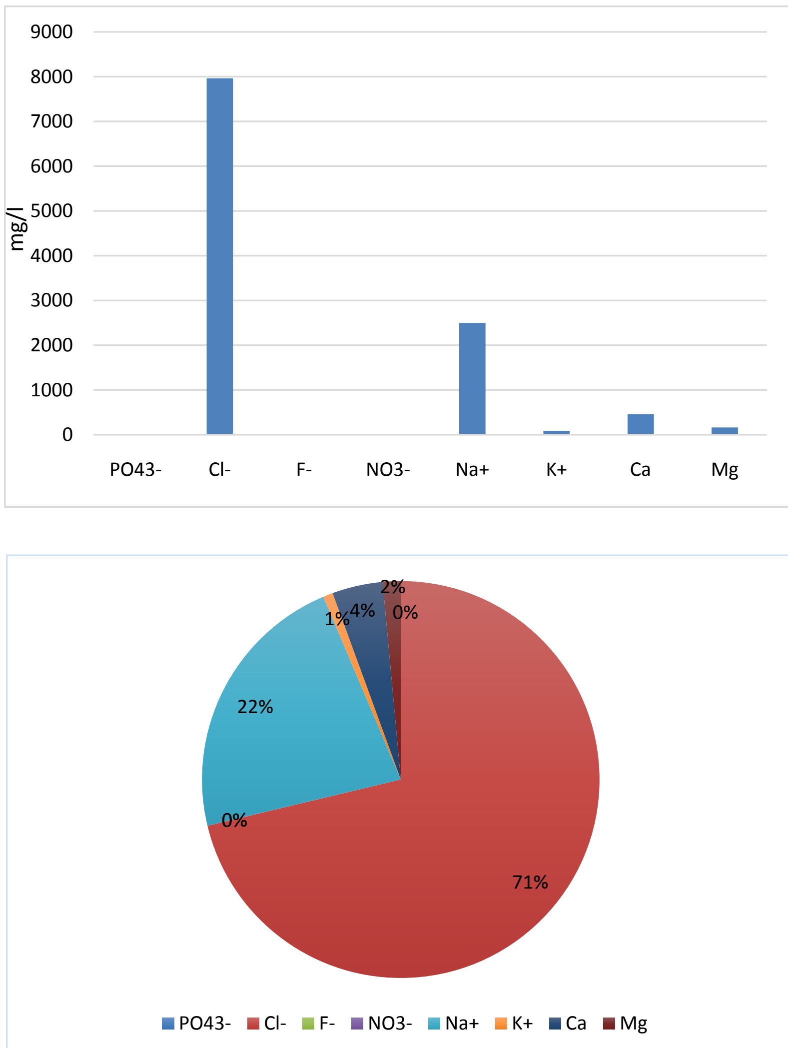
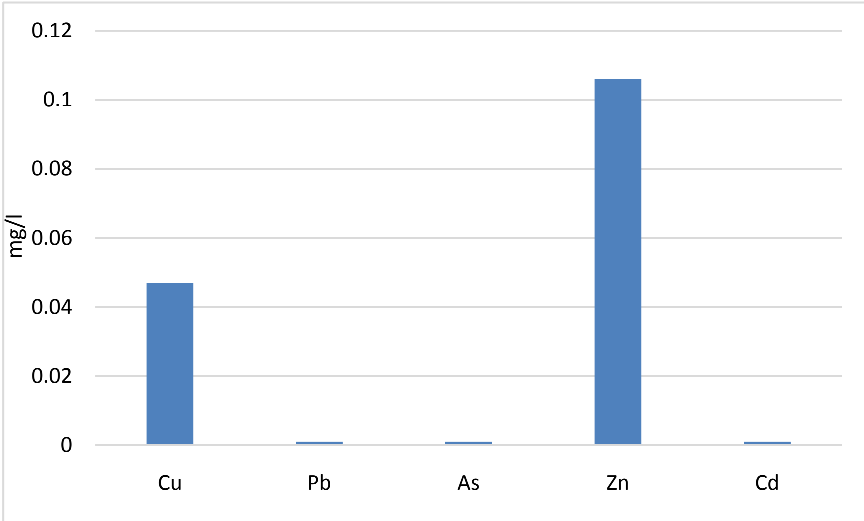


Figure 4. Anion and cation concentrations of santa barbara river surface water.



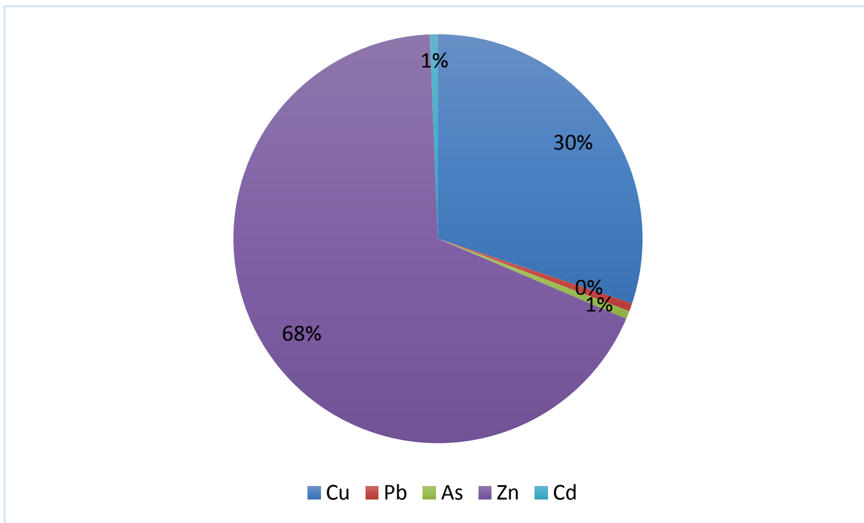
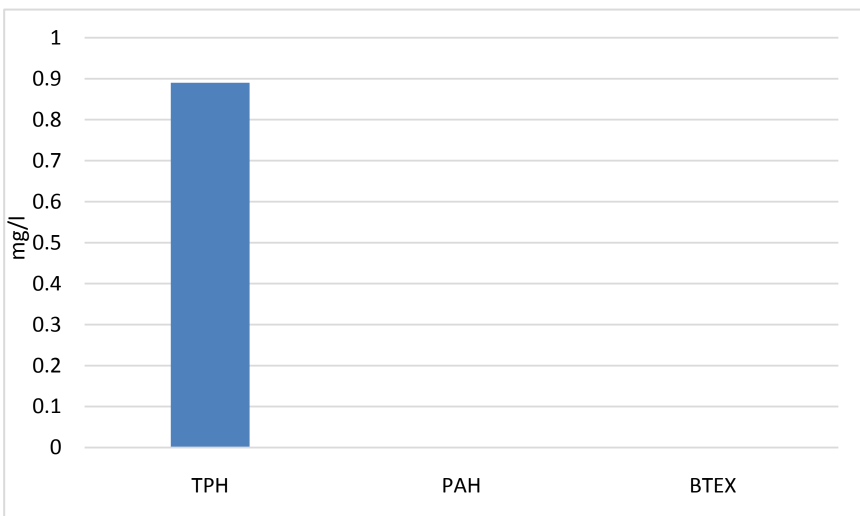


Figure 5. Heavy metals concentration in santa barbara river.



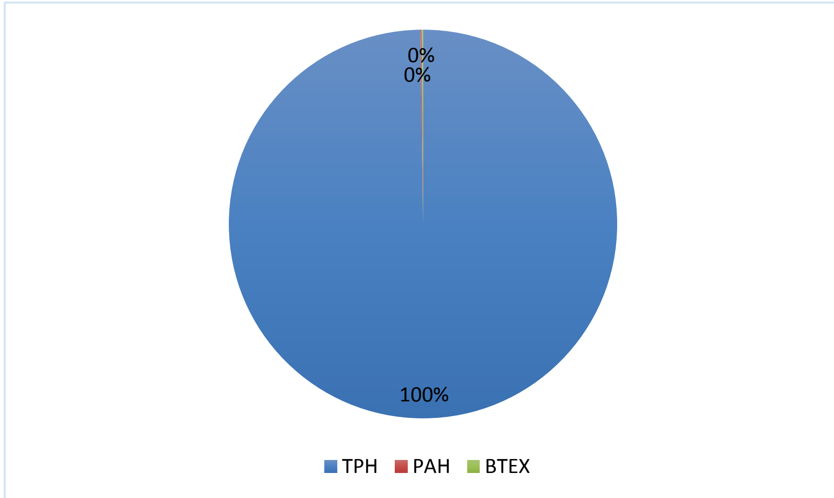


Figure 6. TPH, BTEX and PAH concentration in Santa Barbara River.

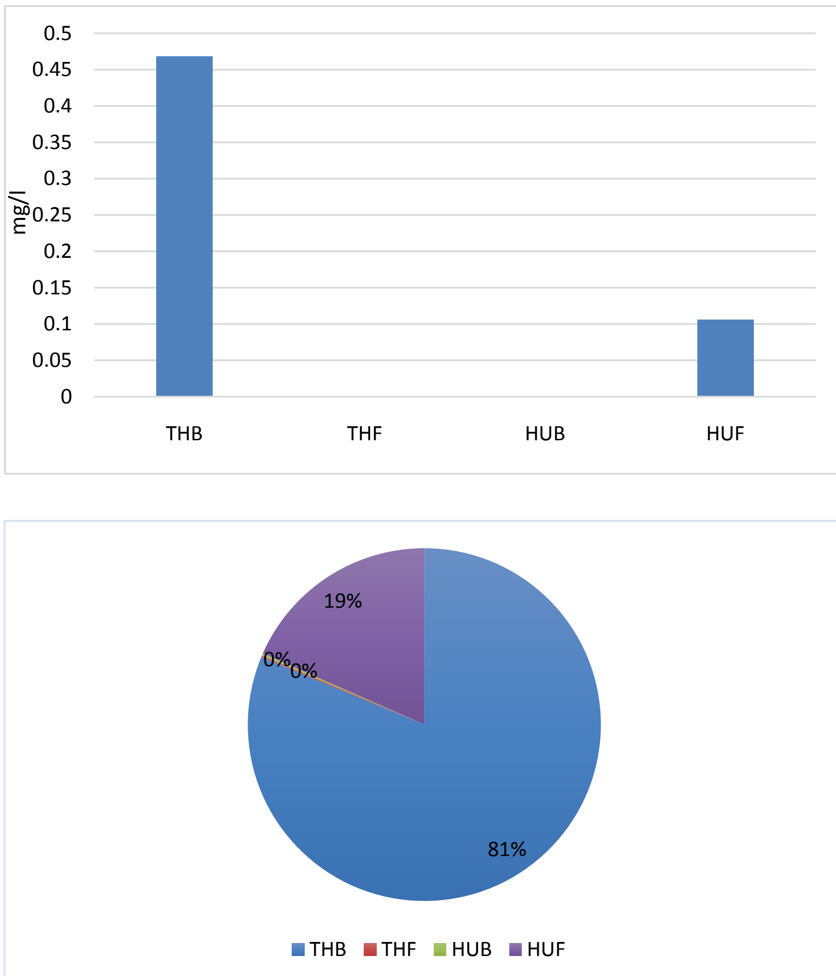


Figure 7. Microbial Population in the Santa Barbara River.

TDS: The mean TDS values ranged 10472.72 ± 1034.95 mg/l - 16538.19 ± 1253.63 mg/l across the stations. The maximum permissible value of 1000 mg/l for TDS was exceeded in all the stations [23]. The result of TDS was below the range of 1235 - 19846 mg/l reported for brackish Elechi Creek in Port-Harcourt Nigeria [8]. All values recorded were above the acceptable limits. The TDS is related to the electrical conductivity and salinity of the water. The high TDS values in this study is attributed the hydrocarbon spill contamination.

Salinity: The results of salinity recorded across stations was 13.29 ± 0.72 ppt - 17.30 ± 1.24^{a} ppt. Salinity was low for all the sampling stations and the maximum permissible limit of 200 g/l was not exceeded. Changes in salinity are the direct cause of some species disappearing and others occurring [24]. Variations in salinity can also contribute indirectly to food shortages and, consequently, they impact zooplankton abundance [25].

Turbidity: Turbidity ranged 7.10 - 37.48 NTU with mean varying significantly from 2.53 ± 0.46 to 35.42 ± 5.63 NTU across the stations (**Figure 2**). The WHO limit of 5 NTU for turbidity was exceeded across the stations for surface water samples analyzed ([23and [15]). At $P < 0.05$ level of significance, this research observed significant difference in turbidity across the station for surface water. The high turbidity could be attributed to the discharge of crude oil waste or bunkering activities within the study area. [26] reported turbidities in natural waters rarely surpass 20000 mg/l and even muddy waters usually have less than 2000 mg/l. The observed turbidity level in the study area is within 2 NTU - 47 NTU for the turbidity of Nigerian water bodies [27]. High turbidity waters have been linked to microbial contamination [28].

DO: The DO across the stations ranged 6.21 mg/l - 7.371 mg/l. Elevated oxygen levels in surface water range from 6.3 - 8.3 mg/l [29]. The acceptable value of 5 mg/l was exceeded in all the stations for surface water samples thereby making the water oxygenated sufficiently to sustain aquatic life. Similarly, the dissolved oxygen level in the Santa Barbara River exceeded the maximum permissible limit of 6 mg/l [15] [23]. DO is a useful indicator of water quality, ecological standing, efficiency, and health of a river [30]. [31] recorded higher values of DO early rainy season compared to dry season because increased rainfall and river runoffs result to increase in water current flow and high mixing rate. The concentration of DO in aquatic environment at any point in time is influenced by the biological activity of flora and fauna, BOD degradation process, sediment oxygen demand and oxidation process [32] and [33]. Temperature and salinity also affect solubility and availability of oxygen in aquatic environment. [34] [35] argued that solubility of oxygen decreases as temperature and salinity increase and is more dependent on temperature variation than on salinity variation.

Chemical Oxygen Demand (COD): The COD across the stations ranged 49.72 mg/l - 90.03 mg/l. According to [36] COD is an important index for evaluating of water pollution. COD provides information about the readily oxidized fraction of the organic load or reduced compounds in waters, indicating the degree of water pollution [37].

Biological Oxygen Demand (BOD): The BOD varies from 1.11 mg/l - 2.71 mg/l across the stations. The maximum permissible value of 1.9 mg/l for BOD was exceeded in the study area [23]. High values of BOD signify high concentrations of organic contaminants and relatively high biological activities (microbial and faunal activities) resulting in the reduction of oxygen content in the water body. Unpolluted waters typically have BOD values of 2 $mg \cdot L^{-1}$ or less, whereas water bodies receiving wastewater may have BOD values up to 10 $mg \cdot L^{-1}$ or more at proximities to discharge points [38]. According to [39] BOD values 2 mg/l - 4 mg/l indicate unpolluted whereas those above 5 mg/L are indicative of severe pollution. This result suggests the surfactants used after the hydrocarbon pollution was effective.

Temperature: Temperature ranged 28.04˚C - 31.79˚C across stations. The observed temperature values in the area are in agreement with that of the Niger Delta. [39] reported temperature ranges of 25˚C - 35˚C. The temperature of this current research agrees with previous works carried out in the Niger Delta [40] [41] and [42]. Temperature fluctuations occur seasonally often higher in the dry season months compared to wet season months, typical of tropical African inland water systems [43]. Seasonal variations in water temperature suggest surface water temperatures closely follow ambient air temperature [44] also temperature is inversely proportional to DO [45].

Alkalinity: The total alkalinity across the stations was 43.95 mg/L - 73.87 mg/L and the measured values were below the WHO limit of 120 mg/L. Alkalinity is the water's ability to resist changes in pH and is a measure of the total concentration of bases including carbonates, bicarbonates, hydroxides, phosphates, and borates [46]. Reactions between bases and neutralize acids, buffers changes in pH of aquatic media [46]. Higher alkalinity levels in surface water cushions acid rain effects and other acidic wastes thereby preventing pH changes that are harmful to aquatic life.

Total Hardness: The values of total hardness concentrations recorded in the water samples across the stations in the study area ranged between 794.80 mg/L and 1129.32 mg/L (**Figure 3**). Total hardness concentrations observed in the study were above the maximum allowable limit of 300 mg/L by WHO for fresh and portable water [47]. The total hardness also exceeded WHO revised maximum permissible limit of 500 mg/l [15]. Hardness of water may be caused by the occurrence of dissolved polyvalent metallic ions, mostly calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}).

TSS: The TSS concentrations ranged 1.33 mh/l - 5.13 mg/l. It was observed that the levels of TSS in the sample points were below 50 mg/L WHO limit for the protection of fisheries and aquatic life [48]. TSS in water is detrimental since they decrease water transparency, inhibit photosynthesis, increase sediments, smoothen breeding bed of aquatic organisms and eventually lead to an increase in sediments which contributes to the decrease in water depth [49].

Anions: The **c**oncentration of phosphates ranged 0.06 - 0.07 mg/l. The sources of phosphates in surface and groundwater vary and may include atmospheric deposition, natural decomposition of rocks and minerals, weathering of soluble inorganic materials, decaying biomass, runoff, and sedimentation [50]. Excess phosphorus in water is considered a pollutant [51] and may be due to enrichment from allochthonous phosphorus-containing substances rather than oil exploration and production activities [52]. Chloride concentrations ranged 6019 mg/l - 9274.82 mg/l. Brackish waters often have chloride concentrations ranging from 500 - 5000 mg/l [53]. According to the [54] the use of road salt (sodium chloride) for deicing in road construction is a major man-made source for surface and groundwater. Run off during rains and storms aids in cycling road salt to rivers streams and groundwater reservoirs. The high chloride levels in the Santa Barbara River Nembe may be due to its unique estuarine environment where it mixes with salt water from the Atlantic Ocean. The WHO limit for chloride is 250 mg/l and chloride in the study area exceeds 250 mg/l however high chloride content is not known to cause any health risk or hazard. Fluoride levels in the Santa Barbara River Nembe ranged from 0.03 mg/l - 0.10 mg/l and were below the WHO limit of 1.5 mg/l for domestic purposes [55]. Fluoride concentrations in fresh water may be less than 1.0 mg/l and in natural waters its concentrations may exceed 50.0 mg/l [56]. The concentration of nitrates ranged from 1.7 mg/l - 1.6 mg/l. Nitrates are available in the aquatic system because of run off, dissolution of nitrogen rich geological deposits, N^2 fixation of cyanobacteria and biodegradation of organic matter [57] and [58].

Cations: The concentration of calcium ion level 375.68 mg/l - 536.72 mg/l. Calcium ion is a metallic cation often present in fresh surface water bodies [59]. Cation concentration for sodium and potassium in Osioma River ranged from 1.35 mg/l - 1.43 mg/l and mean 0.25 mg/l respectively [60]. Magnesium ion levels ranged 88.35 mg/l - 243.24 mg/l. The values of calcium and magnesium ions recorded in the study indicated that all the samples were above the acceptable limits (50 mg/l) for human consumption [61]. Sodium ion concentration in the sampled river system was relatively high but varied from 1833 - 2755 mg/l across the stations. Increase in sodium ion concentration has been linked to crude oil leakage [62]. The potassium ion level across the stations ranged between; 41.27 - 121.17 mg/l across stations. Potassium ion was above the WHO limit.

3.2. Heavy Metal in Santa Barbara River

Average arsenic concentration across all sampled stations was 0.001 mg/l (**Figure 4**). Arsenic concentration in the study area is below the WHO limit of 0.01 mg/l [22] for drinking water. High levels of arsenic in environmental media are of great concern as it is linked to adverse health issues. Several studies suggest a strong association between arsenic exposure and increased risks of both carcinogenic and systemic health risks [63]. The average concentration of cadmium was 0.001 mg/l across all the sampled stations and below the WHO acceptable limit of 0.01 mg/l [15]. The cadmium levels in the surface water in Santa Barbara River presents no danger or health concern as the background levels are below acceptable limits. Cadmium is present in the environment at low concentrations and increased levels linked to anthropogenic activities [64]. High cadmium levels in the environment are of global concern because of adverse effects resulting from human exposure, flora, and fauna. Major anthropogenic sources of cadmium are mining and smelting as well as refining of non-ferrous metal [65] other sources include fossil combustion and incineration of cadmium batteries in addition to plastics ([66] [67]). Studies suggest cadmium exerts toxic effects on the kidney, the skeletal system and the respiratory system and is classified as a human carcinogen ([68] [69] [70] [71]). Lead concentration across all stations was 0.001 mg/l. The lead levels in the surface water samples analyzed were lower than the WHO acceptable limit of 0.01 mg/l. Lead levels in the Santa Babra River Nembe are low and present no health effect or impact. The impact of lead in the environment is well known. Anthropogenic activities accounts for extensive environmental contamination from lead globally particularly mining, smelting, manufacturing, and recycling activities and use in a wide range of products [72]. Lead exposure accounts for 21.7 million persons having disability and death globally due to long-term effects on their health, with 30% idiopathic intellectual disability, 4.6% cardiovascular disease and 3% chronic kidney diseases [70]. The concentration of copper ranged from 0.03 mg/l - 0.07 mg/l while the mean concentration of copper was below 2 mg/l [73]. The concentration of zinc ranged from 0.08 - 0.16 mg/l while the average zinc levels were below 3 mg/l [71]. The low levels of heavy metal observed suggest the surface water in not polluted and the initial clean-up was effective. In the Niger Delta low heavy metal accumulation has been reported in Elechi Creek and Lower Bonny River, Benin River ([8] [9]). When anthropogenic activities increase significantly heavy metal contamination in the environment it causes harm to living organisms [10]. Toxicity of heavy metals occur when the rate of uptake exceeds the rates of physiological or biochemical detoxification and excretion [11]. Heavy metals are high priority pollutants because of their relatively high toxic and persistent nature in the environment [12]. Thus, heavy metals may be used as indicators of pollution in the study area.

3.3. TPH, PAH and BTEX in the Santa Barbara River

Results of the TPH, PAH and BTEX concentration s in the study area shows that the TPH concentration ranged 0.37 - 1.41 g/L (**Figure 6**) while the average level of TPH in surface water from this study is 1.41 μg/L (**Figure 5**). The highest concentration was observed at station 9 BA/SW9 which had 1.41, followed by SUN/SW4 with 1.23 and the least was recorded at the control station. The result shows a significant difference ($P < 0.05$) across the sample stations. Higher concentrations of TPH were observed in areas that were more severely impacted that others within the study area. There was a decrease in trend in TPH a distance further downstream from the hydrocarbon spill site. There was spatial variation in the distribution of TPH across sampled stations. The spatial variation in the distribution of TPH across sampled stations suggests introduction of petroleum hydrocarbons to the study was because of the Santa Barbara hydrocarbon spill incident resulting in high level of petroleum hydrocarbons. The total mean concentration of TPH from all sample stations were lower than the [74] acceptable standard limit for petroleum hydrocarbons (300 μg/L) in river and basin water. Although clean-up activities were carried out remedial levels of hydrocarbons were detected in the analyzed sample. Inappropriate clean-up of hydrocarbon spill sites accounts for the higher concentration of TPH in sampling stations in the study area. According to [75] TPH of 168.33 μg/L was recorded in the Qua Iboe River Ibeno Akwa Ibom when hydrocarbon was spilled. Polluted sites with higher TPH levels of 73500 μg/l have recorded in surface water of Ubeji Riverin Warri, Niger Delta [76]. The total mean concentration of TPH from all sampled stations were lower than the [72] acceptable standard limit for petroleum hydrocarbons (300 μg/L) in rivers and basin water. The average level of TPH in surface water from this research is 1.41 μg/L which is significantly lower ($P < 0.05$) compared to values reported in other Niger Delta regions. The results for the PAH and BTEX show both values are <0.001 which is below the maximum contaminant level of 5 ppb for drinking water set by the [72] [77] and PAH was not observed in the surface water. The results suggest that the clean-up activities carried out on remedial levels of hydrocarbons were successful.

Microbial Population: The Total Heterotrophic Bacteria (THB) ranged from 2.58 CFU/ml to 6.17 CFU/ml (**Figure 6**). Total Heterotrophic Fungi population (THF) ranged from 2.59 CFU/ml to 4.17 CFU/ml. Hydrocarbon Utilizing Bacteria (HUB) population ranged between 0.24 CFU/ml and 1.27 CFU/ml. Hydrocarbon Utilizing Fungi (HUF) ranged between 0.16 CFU/ml to 1.01 CFU/ml. The result shows that the quality of surface water deteriorated because of bacterial population. The maximum permissible value of total coliforms in drinking water is 1 per 100 ml [78] and 10 per 100 ml [79]. The surface water is highly contaminated and portends potential public health hazards. The bacterial contamination in the surface water may be due to hydrocarbon spillage and sewage disposal as well as indiscriminate defecation into the water way [80] (see **Figure 7**).

4. Conclusion

The post assessment of oil spill in the Santa Barbara River revealed that oil spills in the area impacted the ecological integrity of the area as evidenced in the variability of the physiochemical parameters of surface water. The presence of oil in the surface water influenced the buildup of specific bacterial population that depleted the oxygen content of the water thereby inducing the release of toxin into the water as well as utilize the oxygen content which increased the biological oxygen demand of the water system. The presence of trace metals such as lead in the Santa Barbara River indicates the introduction of heavy metals into surface water due to hydrocarbon spills. Pollutant load in surface water may increase if not identified, checked, and closely monitored. There is need for periodic surveillance to ascertain the quality of water resources for human and animal consumption as well as recreation purposes. Bioaccumulation and magnification along the trophic level are eminent if contamination and pollution persist.

Acknowledgements

This work is an extract of the PhD thesis of Mr. Isukul supervised by Professor G. J. Udom and Dr. R. U. Ideozu and titled Post impact assessment of oil spill contamination of soils and water resources in Nembe Bayelsa state.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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