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Soil and Groundwater Quality Assessment in Oil Spill Areas of Agbura, Bayelsa State, Nigeria

Paago, J.B.[1] and Oborie, E.[1].

Abstract
An assessment of soil and groundwater quality in the oil spill affected parts of Agbura, Bayelsa State, Nigeria, was carried out to evaluate the concentration of key physicochemical parameters and determine the level of contamination in the area. Soil and groundwater samples were collected from five boreholes drilled to 6m depth at distances ranging from 100m to 500m from the primary oil spill site. Results of laboratory analysis indicate that the groundwater pH and electrical conductivity (EC) were within World Health Organisation (WHO) and Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN) limits with values ranging from 6.1 to 6.9 and 37.45to257.38µS/cm respectively. Turbidity was higher than the recommended standard, and biochemical oxygen demand (BOD) exceeded acceptable limits across all samples. Total petroleum hydrocarbon (TPH) levels varied from 0.2310 to 0.9382 mg/l, with values at the impact site significantly above regulatoryvalues. Heavy metals such as Fe and Pb were found in concentrations surpassing recommended limits in most of the samples analysed. The water quality index (WQI) revealed that thegroundwater quality deteriorated closer to the spill site, with samples from the impact site classified as "unsuitable" and"poor," while samples away from the spill site were classified as "good." Soil analysis showed TPH concentrations that ranged from 0.294 to 1.0661 mg/kg, with levels decreasing with depth and distance from the spill site. Other heavy metals showed variable contamination patterns, influenced by proximity to the spill. These findings highlight significant contamination of groundwater and soil, particularly near the spill site, emphasizing the need for continuous monitoring and remediation efforts in the study area.

***Keywords**: Physicochemical, contamination, water quality index, total petroleum hydrocarbon, heavy metals*

Introduction

Hydrocarbon contamination has a wide and direct consequence on land, aquatic, and atmospheric ecosystems. This has been a problem ever since the use of fossil fuels and the Industrial Revolution started. The era has been marked by unparalleled growth in global populations coupled with the frequent occurrence of oil spills around the world as a result of the rise in the consumption of petroleum products. These spills have threatened the lives of animals and native microbiological population on land, air, and water. In recent times, hydrocarbon contamination has become one of the major environmental problems confronting the planet.

Petroleum comprises hydrocarbons, organic compounds, and organometallic substances, with 60% to 90% being biodegradable and the remaining portion considered resistant (Alvarez and Illman, 2006). The hydrocarbons are characterized as "non-aqueous phase liquids" whose physical and chemical properties make it immiscible, with occurrence of a physical interface between two fluids that prevents the interaction and mixing of the same. Oil spills show one of the most complex and dynamic patterns of pollutant distribution and impact in both land and marine environment (Patin, 2004). Heavy metal concentrations and other physicochemical factors in soil and groundwater have a significant impact on soil and water quality, affecting human health and agricultural production.

Statistics show that more than 400,000 metric tonnes of crude oil has been spilled into the creeks and soils of the Niger Delta over the last three decades, (UNEP, 2011, Nwilo and Badejo, 2006). The spills have massively devastated biodiversity, soil, surface and groundwater of the Niger Delta. Infiltration and migration of oil from hydrocarbon spills into shallow aquifers poses severe threat to soil and groundwater quality in oil producing and pipeline host communities in the Niger Delta.

The quality of soil and groundwater in an area is usually evaluated by carrying out laboratory analysis to determine values of physical, chemical and microbial parameters. Comparing the results of the analysed parameters to stipulated standard values such as the World Health Organisation (WHO, 2011) and the Environmental Guidelines and Standards for the Petroleum Industry in Nigeria (EGASPIN, 2018), reveals the degree of contamination in the area of study. In addition, results of samples collected and analysed from locations far away from the immediate vicinity of a point source like oil spill can serve as control values at a local scale.A useful and complementary method of analysing the quality of water is to calculate the water quality index, as reported by Ramakrishnaiah et al.

✉ joypaago@gmail.com

1 Department of Geology, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.

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(2009) and Ketata-Rokbani et al. (2011).The water quality index (WQI) is a technique for measuring and expressing the overall quality of water in a specific location. It is a composite parameter that combines multiple water quality parameters into a single number.

This present study attempts to analyse the physicochemical parameters of soil and groundwater in the study area, determine if the presence of contaminants in the soil and groundwater is linked to the oil spill and evaluate the WQI of samples obtained from the study area

Location of Study

Agbura is located within 15 kilometer radius from the city centre of the Bayelsa State capital, Yenagoa. It is located between latitudes 4°50' 30" and 4° 52' 0" N and longitudes 6°15' 30" and 6°17' 30" E. The study area is the host community of the 16" Nun River-Kolocreek BVS Riser - a pipeline transporting crude oil at Agbura-Otuokpoti in Yenagoa Local Government Area of Bayelsa state. A number of oil spill incidents have been reported at various sections of the pipeline on different occasions over the years but no proper remediation or cleanup have been carried out in the area.The area is characterized by tidal flats and coastal beaches, beach ridge barriers and floodplains. The broad plain is gentle-sloping and the elevation decreases downstream (Etu-Efeotor and Akpokodje, 1990). The area has an average elevation of 5m above sea level. It is drained by the Ikoli Creek, Epie Creek and the Nun River.Groundwater in the study areas occurs principally under water table conditions.

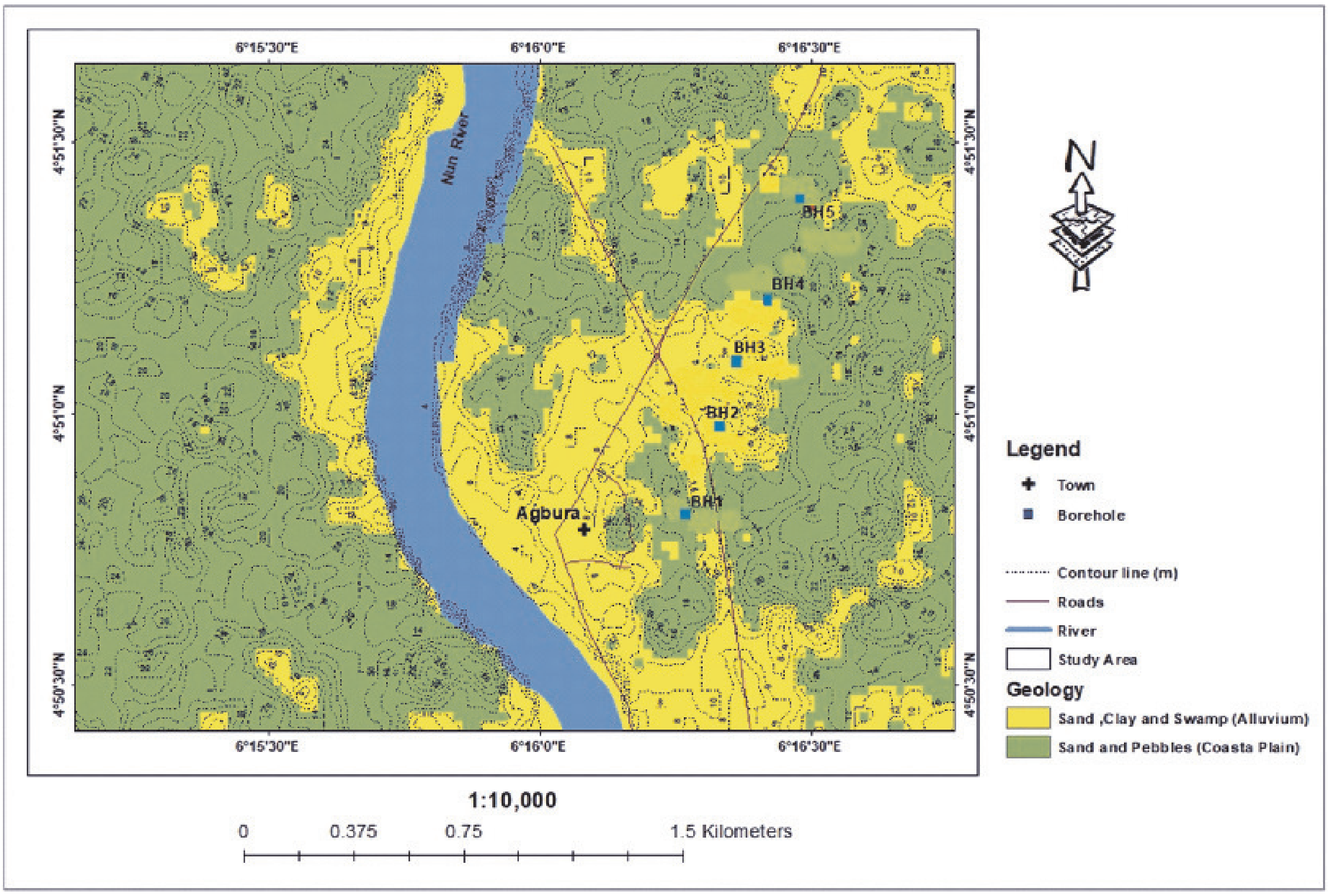

Fig. 1: The study area showing boreholes and sample points

Methodology

Soil and groundwater samples were collected from freshly drilled boreholes(herein designated BH1-BH5)positioned at specific points with respect to the primary point of impact (BH3) of the oil spill (figure 1). The borings were executed to a depth of 6m using hand auger. BH1 and BH2 were located downslope at distances of 100 and 500m with respect to BH3, while BH4 and BH5 were sited upslope of BH3 at lateral distances of 100 and 500m respectively.

Soil samples were collected at an interval of 0.5m with preliminary visual analysis and lithologic description carried out on-site. The recovered samples were put in well labelled sample bags for easy identification and preservation. In addition, soil samples obtained at depths of 0.5 and 2m in all the sample locations were selected and subjected to laboratory analysis.

Groundwater samples were collected in clean plastic bottles of 1.5 L capacity using a weighted water bailer. All the samples were transported in ice-chest to the laboratory for analysis, in airtight plastic bottles. The groundwater samples were analysed for pH, electrical conductivity (EC), turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total petroleum hydrocarbon (TPH). Heavy metals including Fe, Cu, Pb, Zn, Ni and Mn, were also analysed.

Measurement for pH, EC and turbidity were carried out *in-situ*. The pH of each sample was measured with the Hanna pH metre Hi-1922 model. The metre was calibrated with pH buffer solution of 4.0, 7.0 and 9.0, rinsed severally with distilled water and inserted into each of the samples. The readings were taken when the digital display was stable. For EC determination, the conductivity metre was standardized with 0.01 N potassium chloride (KCl) solution. Each sample of 100 ml volume was measured into a beaker, and its conductivity was determined using Hanna 911 conductivity metre. The turbidity metre was used to measure turbidity. The cell was rinsed with distilled water and the sample poured to the cell mark and the most stable value read. BOD was determined using Winklers solutions, starch indicator, concentrated hydrochloric acid and sodium triosulphate solution. The BOD_5 was computed using Eq (1) as follows;

Water Quality Indices (WQIs) are a collection of water quality parameter data that aggregate to give a single value for water quality, reducing a large quantity of data to a simple and straightforward expression. Parameters used in the evaluation of WQI in this study include pH, EC, Turb, DO, COD, BOD, TPH, Fe, Cu, Pb, Zn, Ni and Mn. WQI values are classified into five types, excellent water, good water, poor water, very poor water and water unsuitable for drinking (Ramakrishnaiah *et al,* 2009 and Abbasi et al., 2000).

Results and Discussion

Groundwater Analysis

Results of the laboratory analysis of groundwater are graphically presented in figs 2 and 3, while the soil analysis are shown in figs 4 and 5.

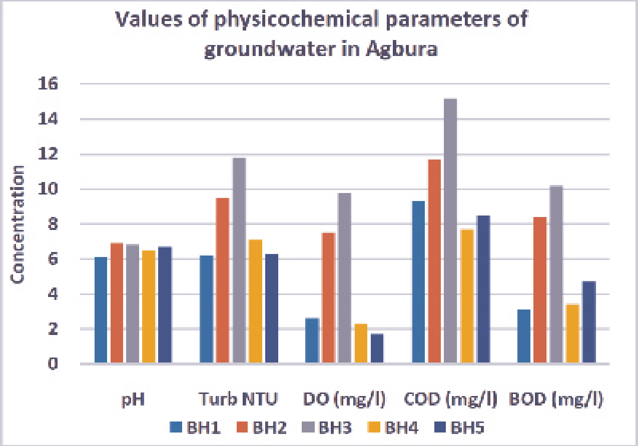

Fig. 2: Values of physicochemical parameters of groundwater samples

The recorded pH values from the laboratory analysis ranged from 6.1 to 6.9 with an average value of 6.6. This shows that the groundwater samples are slightly acidic. However, all the pH values of the sampled locations fall within the acceptable range prescribed by WHO (2011) and EGASPIN (2018).pH is regarded as a key ecological parameter and gives significant information about the state and quality of water. The EC values in Agbura ranges between 37.45-257.38 µS/cm. Based on WHO (2011) standard, the average EC is within the acceptable range for drinking water, which is 1000 µS/cm. The capacity of water to transmit electricity due to dissolved salts is measured by its electrical conductance. It is a function of the dissolved solids within the water. Turbidity values from the analysis ranged between 6.2 - 11.8 NTU, with a mean of 8.18 NTU. The recorded values exceed the prescribed permissible standard of 5 NTU. The groundwater within the sample area is therefore characterized as turbid. Turbidity in most waters is caused by colloidal and tiny particulate dispersions which is likely a result of debris, silt, and clay being eroded from host geo materials during rainfall, sewage and hydrocarbon waste discharges. The quantity of oxygen that is dissolved in the water, or the amount of oxygen that is accessible to living aquatic organisms, is measured by the term "dissolved oxygen". Results of the analysis reveals that DO values were within the WHO (2011) limit of 6.5-

8.0for samples collected from boreholes with exception of sample collected at the primary oil spill site and the sample point 100 m downslope of the spill point. COD is a measure of how much organic matter in a water sample is capable of being oxidized by a potent chemical oxidant. COD in the study area ranged between 7.7 - 15.2 mg/l. The data shows that the COD values in two boreholes exceeded WHO (2011) and EGASPIN (2018) limits of 10 mg/l. BOD measures the amount of oxygen required for waste organic matter to be eliminated from water during the process of breakdown by aerobic bacterial. The BOD values from the sample points ranged between 3.10 - 10.20 mg/l.

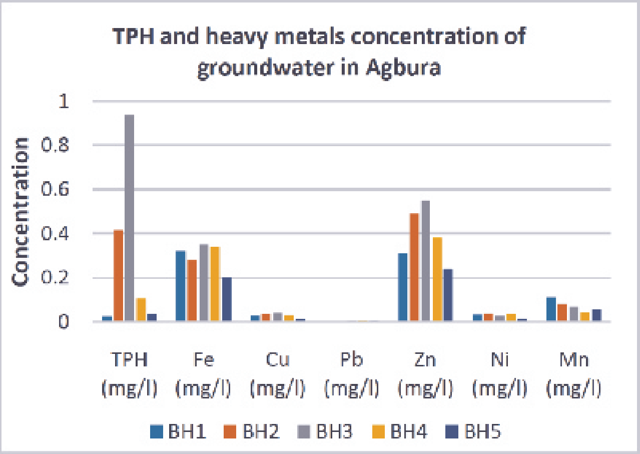

Fig. 3: TPH and heavy metals concentration of groundwater in Agbura

TPH values in the groundwater samples ranged between 0.2310 - 0.9382mg/l. The permissible limit for TPH based on EGASPIN (2018) is0.05 mg/l. The data reveals that the TPH values of groundwater samples collected at the control sites were below the EGASPIN permissible limit. However, TPH concentration of samples collected at the impact sites and within 150 m were above the limit. The results of this study show that Fe concentration was between 0.2 -0.35 mg/l. The concentrations of Fe in three sample locations exceed the WHO (2011) and EGASPIN (2018) recommended value of 0.3 mg/l. Fe contamination can present a number of problems for water filtration systems, industrial, and municipal applications (Ityel, 2011). Cu concentration in groundwater samples obtained in the study area ranged between0.01 - 0.04 mg/l. The Cu values across the study area are below WHO (2011) and EGASPIN (2018) limits of 2 mg/l. Cu is commonly found in aquatic systems as a result of both natural and anthropogenic sources. A high level of Cu in drinking water will leave a metallic or bitter taste. Concentration of Pb varied from a minimum of 0.012 mg/l to a maximum of 0.024 mg/l in the analysed samples. The concentration of Pb in 80 % of the sample points were above the permissible limit of 0.01 mg/l as per WHO (2011) and EGASPIN (2018) guidelines. Pb is a powerful neurotoxin, which means that an exposure to Pb can damage the brain (Imaseun and Egai, 2017).The concentration of Zn from results of the laboratory analysis ranged between 0.24 - 0.55 mg/l. The values are below the permissible values (5 mg/l) stipulated by the regulatory authorities (WHO 2011; EGASPIN 2018). The concentration of Ni from results of the laboratory analysis ranged between 0.02 - 0.04 mg/l. The values are below the permissible value (0.07 mg/l) stipulated by WHO (2011) and EGASPIN (2018). Ni , like Pb , causes peripheral neuropathy and brain damage (Rastogi, 1977; Tolonen, 1972). Ni is also known to cause possible carcinogenic health issues. The results of this study show Mn concentration in groundwater samples from Agbura ranged between 0.042 - 0.11 mg/. Only 20 % of the samples have concentrations of Mn above the WHO (2011) and EGASPIN (2018) recommended value of 0.01 mg/l.

WQI of the Study Area

According to Ramakrishnaiah *et al.*(2009), WQI<50 is classified as excellent water, WQI of 50 to 100 is good water, 100 to 200 is poor water, 200 to 300 is classified as very poor water and WQI >300 is classified unsuitable water. From the results shown in Table 1 (this table should be shown below and not above), the WQI of BH3 is 309.10. It is designated "unsuitable", which implies it is highly contaminated. BH3 is located at the primary spill impact area, hence it is not surprising that it has the worst water quality status when compared to the other four borehole samples. WQI values are such that, the lower the WQI value, the better the water quality. Following a decreasing order of WQI value, BH2 is the next to BH3. WQI of BH2 is 153.15. It is designated "poor" as per its water quality status and obviously not a source of potable water. BH2 is located 100 m in the downslope direction of BH3. The poor water quality of BH2 is considered a consequence of lateral migration and infiltration of the oil spill from the BH3 site. Flow from BH3 to BH2 is made possible because of the slope which indicates that BH3 has a higher hydraulic head relative to Bh2

The next to BH2 in terms of decreasing value of WQI value is recorded in BH4. BH4 is located 100 m from BH3, just like BH2. However, it is situated in the upslope direction of BH3 (Figure 1) and apparently not significantly affected by fluid and contaminants flow from BH3. WQI of BH4 is 65.28 and it is designated

Table 1: Summary of groundwater quality indices of the study areas

Code	Water Quality Index (WQI) Value	Class of Water
BH1	52.70	Good
BH2	153.15	Poor
BH3	309.10	Unsuitable
BH4	65.28	Good
BH5	56.65	Good

"good" which implies it requires minimum treatment to become potable. BH1 and BH5 are considered as control samples. They are located 500 m downslope and upslope, respectively, from BH3. WQI of BH1 is 52.70, while WQI of BH5 IS 56.65 and are both designated "good", in accordance with Ramakrishnaiah *et al.* (2009) classification. The results show that proximity to contaminant point source and slope direction are key factors that affect contaminants transport.

Soil Analysis

From the results, TPH concentration in the soil samples ranged between 0.294 - 1.0661 mg/kg at depths of 0.5 and 2.0 m, respectively, showing a decrease with depth and lateral distances from the spill site. The systematic decrease is attributed to the inherent trapping property of soils which generally increases with decreasing soil particle size. The TPH values are significantly higher than typical background levels and exceed the limits set by environmental regulatory organisations and are strongly linked to the oil spills. Fe concentration at depths of 0.5 and 2.0m ranged between 0.26 - 0.42 mg/kg and 0.18 - 0.46 mg/kg, respectively. Analysis of the results shows that variation in concentration of iron with respect to depth did not follow any particular trend.In addition, no significant difference was noticed in values of iron in the immediate location of the spill and 100m downslope and upslope (BH3, BH2 and BH4) and samples obtained at the control sites (BH1 and BH5). This suggests that the Fe concentration in the study area is neither a function of the hydrocarbon spill, nor dependent on the depth of sampling.

Cu concentration in the soil ranged between 0.28 - 0.0.56 mg/kg and 0.22 - 0.47 mg/kg. Analysis of the results show that the concentration decreased downslope with respect to the spill impact site and also decreased with depth, suggesting the values of the copper may have been influenced by the spill. Theconcentration of Pb in the soil ranged between 0.0044 - 0.0058 mg/kg and 0.0036 - 0.0051 mg/kg at depths of 0.5 and 0.2 m, respectively. Analysis of the results show that the concentration decreased downslope with respect to the spill impact site and also decreased with depth, suggesting the values of the lead may have been influenced by the spill. According Udoetok et al. (2009), Pb, Ni , V , Zn and Cd are the most often post oil spills heavy metals.

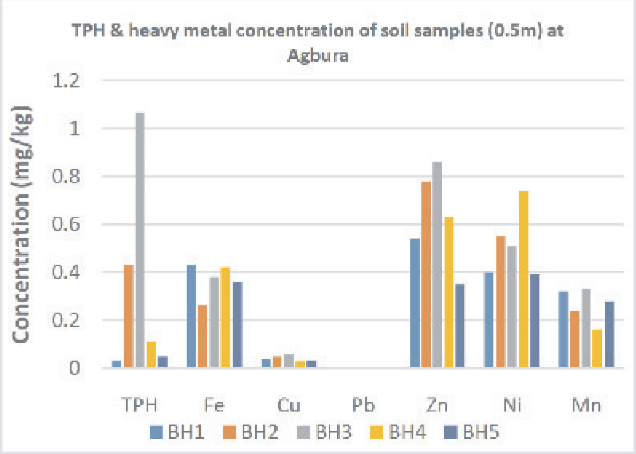

Fig. 4: TPH and heavy metals concentration of soil at 0.5m in Agbura

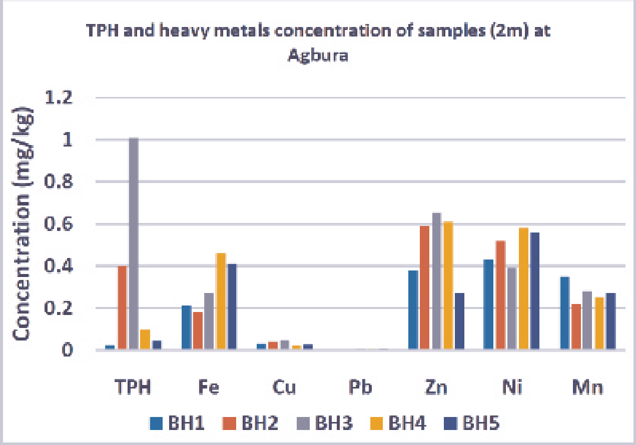

Fig. 5: TPH and heavy metals concentration of soil at 2.0m in Agbura

The concentration of Zn obtained at a depth of 0.5 m decreased from 0.86 mg/l at the primary spill point to 0.54 mg/l at a lateral distance of 500 m downslope. The concentration of zinc was 0.35 mg/l at a lateral distance of 500 m upslope. Comparatively, the concentration of Zn decreased with depth. Ni concentration also showed a decrease with depth and lateral distance from the primary spill point. The results show that Ni concentration at the spill point was 0.61 mg/l at a depth of 0.5 m and 0.39 mg/l at a depth of 2 m. The concentration of Mn relatively decreased with depth but did not show consistent decrease or increase in both downslope and upslope directions. The concentration of Mn was 0.33 mg/l at the depth of 0.5 m and 0.28 mg/l at the 2 m depth.

Conclusion and Recommendations

The assessment of soil and groundwater quality in Agbura, Bayelsa State, Nigeria, reveals significant contamination linked to oil spills. Soil and groundwater analysis showed that pH and EC values where within acceptable limits of international and local regulatory organizations, while turbidity was notably high, exceeding the permissible threshold. DO, COD and BOD levels were satisfactory except at the primary spill site and 100m downslope of the spill site. Heavy metals and TPH concentrations varied across the study area with values at the impact site significantly higher than background values recorded at the control sites. Proximity to the spill site, depth of sampling and flow direction with respect to the position of the contaminant's source were seen as the most critical factors which affectedthe soil and groundwater quality in this study. Proactive measures should be put in place to prevent incessant occurrence of oil spills, while rapid response to cases of spill is strongly advocated to mitigate widespread contamination of soil and water resources of the study area.

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