International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 10 Issue 9, September 2023

ISSN: 2394-4404

Comparative Analysis Of Physicochemical Parameters And BTEX Contamination In Effluent And Recipient Water Within Oil Mining Lease (OML) 30

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Abstract: The rapid growth of industrialization has resulted in a corresponding increase in the discharge of industrial waste into nearby water bodies. This study examined the physico-chemical and (BTEX) properties as a determinant of the effect resulting from discharge of effluent into recipient waters around an oil field. Physicochemical and BTEX properties of effluent and recipient water were conducted using standard methods of APHA (American standard for testing and materials). Results showed an increase in selected parameters at the petroleum effluent discharge point, compared to the recipient rivers. Water analysis results also showed that Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Turbidity, Total Dissolved Solid (TDS), Total Suspend Solid (TSS) was significantly increased. Results from this study indicate that the effluent quality from the sampled locations may be categorized slightly harmful with the rivers having medium risk and little effect on the aquatic biota. The effluent had little impact on the quality of the recipient water.

Keywords: BTEX, Oil fields, Effluents, Mining

I. INTRODUCTION

Water stands as one of the most inadequately regulated resources globally. Its quality has significantly deteriorated due to unsustainable practices like illegal waste disposal, improper water management, and disregard for the environment, resulting in a shortage of clean and safe drinking water, consequently impacting human health. Water is a vital element crucial for supporting terrestrial and aquatic ecosystems (Alina, 2015). Industrialization is widely regarded as a fundamental aspect of development plans, primarily due to its substantial impact on economic growth and human well-being. However, the rapid growth of industrialization has resulted in a corresponding increase in the discharge of industrial waste into nearby water bodies. As a result of inadequate adherence to sustainable regulatory measures and the inefficiency of purification systems, the effluent discharged from sewage and industrial activities into water bodies has emerged as a significant factor in water pollution. This discharge leads to an increase in oxygen demand and nutrient levels within the water bodies, consequently promoting the growth of toxic algal blooms and disrupting the equilibrium of the aquatic ecosystem (Morrison et al., 2001; Eunice et al., 2017).

Water bodies have the capability to absorb and incorporate the waste materials they receive without undergoing significant deterioration in specific quality measures. This ability is commonly referred to as their assimilative capacity (Adekunle 2009; Eunice et al. 2017). However, when water bodies receive waste beyond their assimilative capacity, it leads to the unintended accumulation of harmful substances in the surrounding environment, posing potential severe health and environmental consequences within the ecosystem (Osuoha and Nwaichi, 2019). The introduction of effluents into water bodies initially results in changes to the natural physical and chemical characteristics of the receiving water. Over time, this leads to noticeable biological degradation and microbial growth, which becomes evident through alterations in the number, diversity, and organization of living organisms within the water (Eunice et al. 2017). Wastewater discharged from petroleum and petrochemical industries is characterized by significant levels of sulfides, heavy metals, and volatile compounds such as benzene, toluene, ethylbenzene, xylene isomers (BTEX), and phenol (Fayemiwo et al. 2017; Osuoha and Nwaichi, 2019). When these hydrocarbons enter the environment, aquatic organisms absorb them through different means. Consequently, human populations are exposed to these pollutants when they consume contaminated aquatic organisms (Oyibo et al., 2018). BTEX compounds are extremely toxic environmental substances known to have carcinogenic and mutagenic effects on human health. These hazardous components can be found widely in environmental samples, including water, air, and soil, posing an elevated risk of human exposure to their harmful effects. The ubiquitous presence of BTEX compounds in various environmental media raises concerns about their potential impacts on public health and underscores the importance of monitoring and controlling their levels to safeguard human well-being (Bian et al. 2022). The consumption of these compounds has been associated with various adverse health effects, including cancer, liver lesions, drowsiness, and organ irritation (Zhang et al., 2012; Fayemiwo et al. 2017). Furthermore, Mitra and Roy, (2011) reported that prolonged human exposure to BTEX compounds can lead to skin and sensory irritation, respiratory issues, and irritation of the central nervous system. Despite the negative health implications, BTEX compounds often go unnoticed and untreated in municipal systems, thereby raising the risk of waterborne diseases through their ingestion (Fayemiwo et al. 2017). This study is aimed at determining the comparative analysis of physicochemical and BTEX in effluents water and recipient water in oil mining lease OML 30.

II. MATERIALS AND METHOD

THE STUDY AREA

Oil Mining Lease (OML) 30 is a significant onshore oil exploration area situated in the prolific Niger Delta region of Nigeria. Covering an expansive area of 1,095 square kilometers, it is located approximately 35 kilometers east of Warri in the Delta state. This lease encompasses 11 oil fields, each contributing to the region's oil production. These fields are Afiesere, Eriemu, Evwreni, Oweh, Olomoro-Oleh, Kokori, Oroni, Uzere West, Osioka, Ofa, and Okpolo. Additionally, three of these fields, namely Osioka, Uzere, and Isoko, straddle the boundary of the license area. The oil fields were discovered between 1961 – 1966. Figure 1 shows the map of the study area. This study was conducted in Oweh, Olomoro and Oroni oil fields.

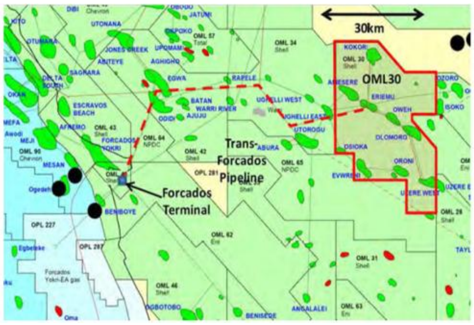

Figure 1: Map of Study Area

SAMPLE COLLECTION

Water samples were collected from a river close to the selected oil fields, while effluent was collected from effluent sampling points within the oil fields. Water Sampling, preservation, and transportation were carried out in accordance with the recommended methods as contained in APHA (2012). Sampling was carried out in May 2022. The water samples were collected in 1-liter cans and 40ml amber glass jars from the rivers and the effluent sampling points in Oweh, Olomoro, and Oroni flow stations. In situ tests of pH and Temperature were measured at the time of sampling using pH portable meters. Samples were transferred in an ice box container at 4 ºC to the Laboratory for analysis.

ANALYTICAL METHODS

pH and temperature were determined by electronic method (APHA - 4500-H+), salinity was measured by Mohr's Argentometric method, Turbidity was obtained by Nephelometric method, while TSS was measured by photometric method B. BOD was obtained by 5-day BOD test method (APHA 5210 B). COD was determined by the close reflux titrimetric method (APHA 5220C). BTEX and TPH were determined by BTEX extraction analysis using gas chromatography/flame ionization detection detector (ASTM) Method D 3328 – 78.

STATISTICAL ANALYSIS

The physicochemical parameters' results obtained in this research underwent Descriptive statistical analyses to calculate the mean and standard deviation. One-way analysis of variance (ANOVA) was utilized to identify any significant difference among the various sampling stations. Correlation Pearson correlation analysis was computed to understand the association and relationship between the different physicochemical parameters and heavy metals levels in the study areas. All statistical analysis was carried out with Microsoft Excel and Office 365.

III. RESULTS AND DISCUSSIONS

RESULTS

The findings of the physicochemical and BTEX analysis conducted on the effluents and recipient water in the study

 ISSN: 2394-4404

area are presented in Table 1 to Table 2 and Figure 1 to Figure 11. These results will be used in a comparative analysis to assess the potential impact and determine if the direct discharge of effluent into rivers has affected the quality of surface water, posing risks to aquatic life and human health.

PARAMETERS	OLOMORO FS Effluent	OLOMORO FS Recipient water	ORONI FS Effluent	ORONI FS Recipient water	OWEH FS Effluent	OWEH FS Recipient water	WHO. 2011
pH	5.91 ±0.02	6.00 ±0.02	5.67 ±0.02	6.12 ±0.03	6.19±0.04	6.76 ± 0.03	6.5 – 8.5
Temperature, ºC	27.80 ±0.07	26.40 ± 0.06	27.61 ± 0.08	26.00 ± 0.05	27.19± 0.09	25.60 ±0.04	
Salinity As Chloride mg/L	22.99 ±0-09	0.05 ±0.002	28.99 ± 0.09	0.04 ± 0.001	38.49 ± 1.00	0.02 ±0.001	
Total Suspended Solids (TSS), mg/L	29.29 ±0.09	0.00	24.11 ± 0.05	1.17 ± 0.004	434.63 ± 1	7.28 ± 0.04	50
Turbidity mg/L	67.75 ± 1	0.00	44.35 ± 1	8.62 ± 0.03	784.55 ± 1	18.13 ± 0.2	5
Biochemical Oxygen Demand (BOD), mg/L	1.80 ± 0.002	4.80 ± 0.05	1.60 ± 0.002	3.80 ± 0.03	0.00	4.00 ± 0.004	
Chemical Oxygen Demand (COD), mg/L	160 ± 1	1520 ± 1	128 ± 1	2000 ± 1	352 ± 1	2000 ± 1	
Organics							
THC,mg/L	0.03	<0.001	0.01	0.0003	0.94	<0.001	
BTEX,mg/L	0.0495	0.0551	0.1145	0.1742	0.0108	0.0085	

Table 1: Mean results of the physicochemical analysis of effluent and recipient waters

EFFLUENT AND SURFACE WATER CHARACTERISTICS

pH

The pH levels observed in this study varied from 5.67 to 6.19 for the effluents, while the pH levels in the rivers that received these effluents ranged from 6.00 to 6.71. Among these, the Oweh recipient river exhibited the highest pH value of 6.71, falling within the recommended limits set by the WHO, (2011). However, the effluents from Oweh, as well as both the effluents and recipient rivers in Oroni and Olomoro, all displayed pH levels below the acceptable limits outlined by the WHO, (2011) (Figure 1).

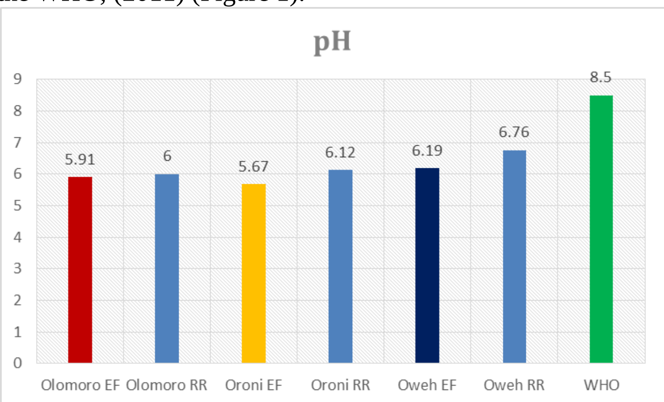

Figure 1: pH values of the Effluent Compared to pH of the Recipient Rivers and WHO, (2011)

TEMPERATURE

Temperature ranged from 27.19 – 27.80 ºC and 25.60 – 26.40 ºC for the effluent and recipient rivers in the study areas. Temperature of the effluents were generally slightly higher than temperature obtained in the recipient rivers.

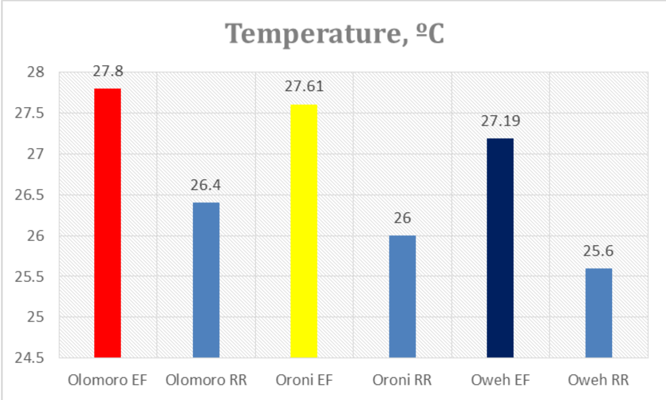

Figure 2: Temperature values of the Effluent Compared to Temperature of the Recipient Rivers

SALINITY

The effluents generally had higher salinity levels in the range of 22.99 – 38.49 mg/L for all the sampling stations. The recipient rivers had lower salinity levels in the range of 0.02 – 0.05 mg/L. Effluents from Oweh had the highest mean salinity concentration of 38.49 mg/L followed by Oroni and then Olomoro with average salinity values of 28.99 mg/L and 22.99 mg/L respectively.

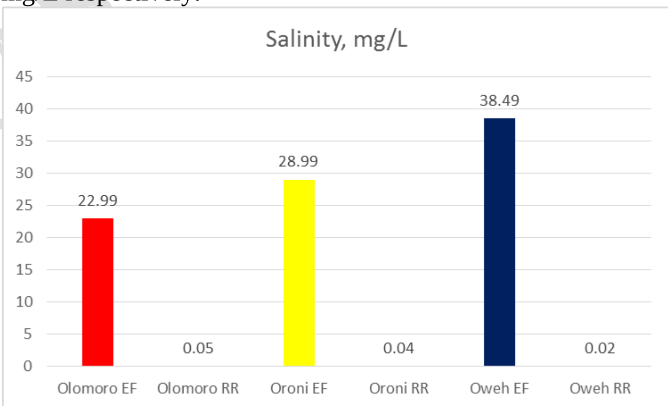

Figure 3: Salinity values of the Effluent Compared to Salinity of the Recipient Rivers

TOTAL SUSPENDED SOLIDS (TSS)

The effluents typically exhibited elevated TSS levels, ranging from 24.11 to 434.63 mg/L across all the sampling stations. In contrast, the receiving rivers displayed much lower TSS levels, ranging from 0.00 to 7.28 mg/L. Among the different sources of effluents, Oweh had the highest average TSS concentration at 434.63 mg/L, followed by Olomoro with an average of 29.29 mg/L, and then Oroni with an average TSS value of 24.11 mg/L.

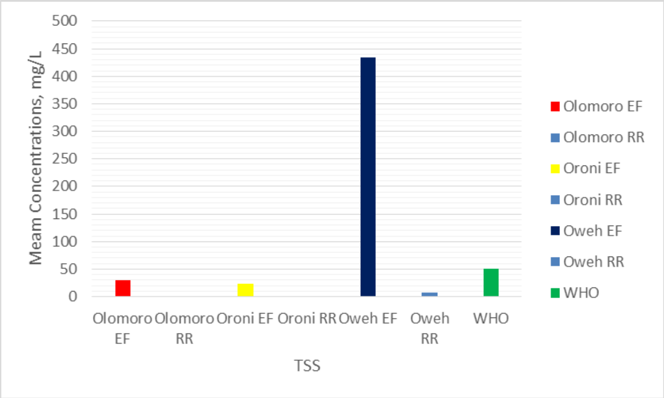

Figure 4: TSS values of the Effluent Compared to TSS of the Recipient Rivers

TURBIDITY

The effluent released had higher turbidity levels, ranging from 44.35 to 784.55 mg/L at all the sampling stations. On the other hand, the rivers that received the effluents showed significantly lower turbidity levels, ranging from 0.00 to 18.13 mg/L. Among the various sources of effluents, Oweh had the highest mean turbidity concentration of 784.55 mg/L, followed by Olomoro with an average of 67.75 mg/L, and Oroni with an average salinity value of 44.35 mg/L.

BIOLOGICAL OXYGEN DEMAND

At all the sampling stations, the effluents exhibited lower BOD values, ranging from 0.00 to 1.80 mg/L, in contrast to the BOD values found in the recipient rivers, which ranged from 3.80 to 4.80 mg/L. Among the rivers, Olomoro's river had the highest average BOD concentration of 4.80 mg/L, followed by Oweh with a mean concentration of 4.00 mg/L, and Oroni with an average of 3.80 mg/L.

CHEMICAL OXYGEN DEMAND (COD)

The effluents at all sampling stations had Lower COD values, ranging from 128.00 to 352.00 mg/L, compared to the COD values observed in the recipient rivers, which ranged from 1520 to 2000 mg/L. Oweh and Oroni recorded similar mean values of 2000.00 mg/L while Olomoro had a lower mean value of 1520.00 mg/L.

TOTAL HYDROCARBON CONTENT (THC)

The mean concentrations of Total Hydrocarbon (THC) in the effluents of Olomoro and Oweh were measured at 0.03 mg/L and 0.94 mg/L, respectively. However, the THC levels in the recipient rivers of Olomoro and Oweh were found to be below of < 0.001 mg/L. In the case of Oroni, the average THC values in both the effluents and recipient rivers were 0.01 mg/L and 0.003 mg/L, respectively.

BTEX ANALYSIS ON EFFLUENT AND RECIPIENT WATER

BTEX, which includes benzene, toluene, ethylbenzene, and the three isomers of xylene (M-xylene, O-xylene, P-xylene), exhibited varying levels in different locations. Specifically, Oloromo and Oroni effluent contained higher overall BTEX concentrations compared to the receiving river. On the other hand, the BTEX levels in Oweh recipient river were slightly higher than those in the Oweh effluent (as indicated in Table 2). Figure 5 presents the various BTEX components in all the sampling stations.

The concentration of benzene within the BTEX group ranged from 0.0000 to 0.0978 mg/L. Notably, at the Oweh sampling station, the benzene levels exceeded the permissible limits for drinking water quality set by WHO in 2011. Toluene concentrations spanned from 0.0002 to 0.0096 mg/L, remaining within the WHO's 2011 standards for drinking water quality across all the sampling stations. Ethylbenzene was found to have values ranging from 0.0001 to 0.0028 mg/L, all of which fell within the permissible limits for drinking water quality outlined by WHO in 2011. The M-xylene isomer exhibited concentrations within the range of 0.000 to 0.0077 mg/L, while O-xylene levels varied between 0.0022 and 0.0187 mg/L. P-xylene concentrations ranged from 0.0008 to 0.1107 mg/L. Except for the Olomoro effluent, which displayed slightly elevated values, the total xylene levels at all study stations were within the permissible limits defined by WHO in 2011 for drinking water quality.

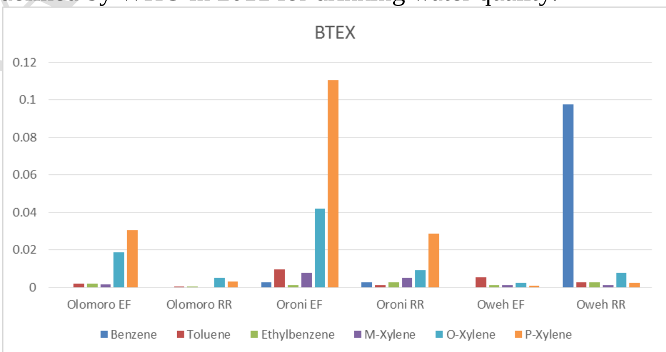

Figure 5: BTEX values of the Effluent Compared to BTEX of the Recipient Rivers

COMPONENT	OLOMORO FS Effluent	OLOMORO FS Recipient water	ORONI FS Effluent	ORONI FS Recipient water	OWEH FS Effluent	OWEH FS Recipient water	WHO, 2011
Benzene	0.0000	0.0000	0.0028	0.0027	0.0000	0.0978	0.01
Toluene	0.0020	0.0002	0.0096	0.0011	0.0053	0.0027	0.7
Ethylbenzene	0.0021	0.0001	0.0014	0.0027	0.0013	0.0028	0.3
M-Xylene	0.0016	0.0000	0.0077	0.0051	0.0012	0.0011	
O-Xylene	0.0187	0.0052	0.0419	0.0092	0.0022	0.0079	
P-Xylene	0.0307	0.0031	0.1107	0.0287	0.0008	0.0022	
Total Xylenes	0.051	0.0083	0.1603	0.043	0.0042	0.0112	0.5
Total (BTEX)	0.0551	0.0085	0.174	0.050	0.011	0.115	

Table 2: Mean results of BTEX analysis of effluent and recipient waters in studyArea

International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 10 Issue 9, September 2023

ISSN: 2394-4404

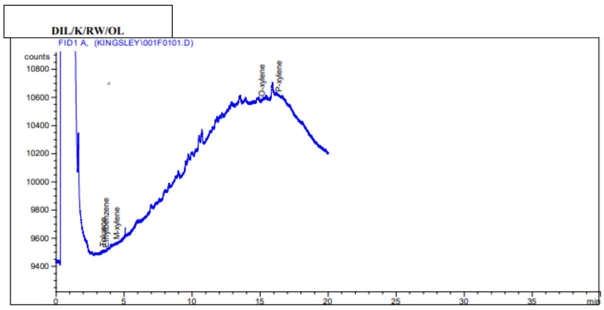

Figure 6: Chromatographic Results of BTEX in Olomoro Recipient Rivers

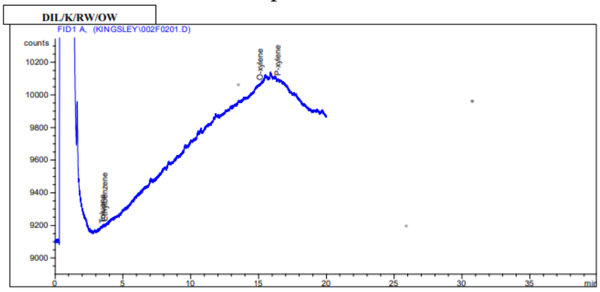

Figure 7: Chromatographic Results of BTEX in Oweh Recipient Rivers

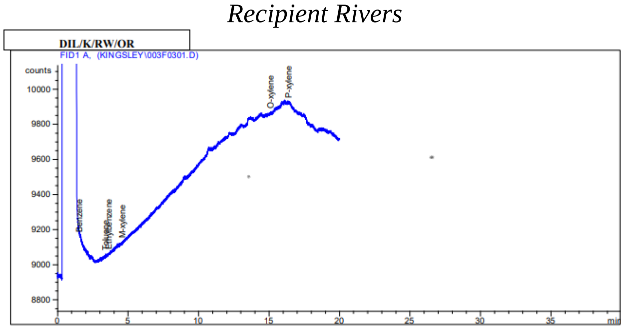

Figure 8: Chromatographic Results of BTEX in Oroni Recipient Rivers

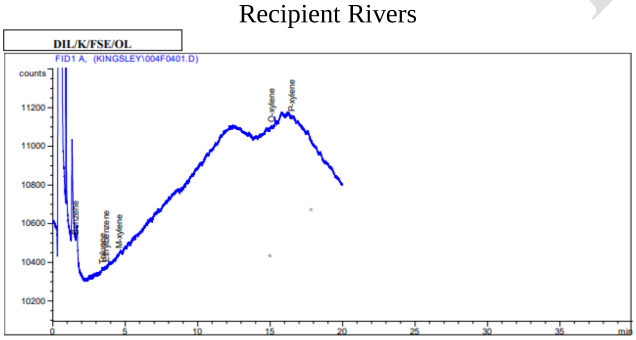

Figure 9: Chromatographic Results of BTEX in Olomoro Effluent

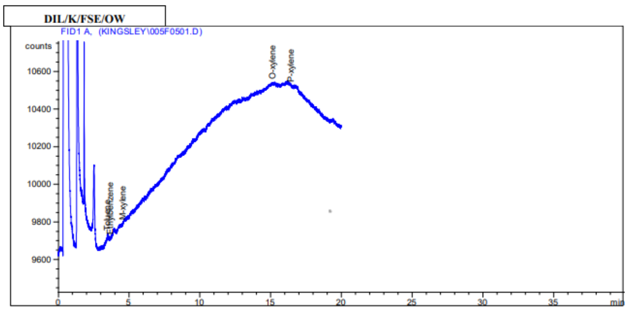

Figure 10: Chromatographic Results of BTEX in Oweh Effluent

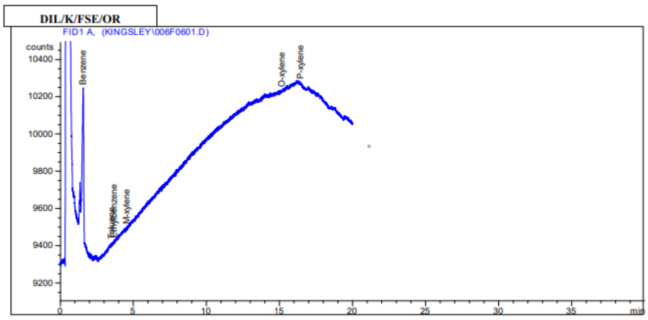

Figure 11: Chromatographic Results of BTEX in Oroni Effluent

IV. DISCUSSION

Temperature is a vital factor among the environmental variables that exerts influence over metabolic processes, developmental rates, nourishment intake, reproductive patterns, spatial dispersion, and the migratory tendencies of aquatic life forms. Additionally, it plays a role in the dissolving capacity of gases within the water, with gas solubility decreasing as temperature rises (Makinde et al. 2015). The temperature recorded in this study aligns with the temperature findings reported in comparable studies conducted within the Niger Delta sub-region in Nigeria (Makinde et al. 2015; Vincent-Akpu and Nwachukwu, (2016); Seiyaboh et al. 2016; Wokoma and Njoku, 2017). The pH recorded in this study ranged from acidic to near neutral. Except for the Oweh receiving river, which adhered to the acceptable limits outlined by WHO in 2011, the remaining recipient rivers and all samples from the effluent stations exceeded the permissible limits set by WHO, (2011). The recipient rivers demonstrated levels below the WHO, (2011) allowable thresholds, as indicated in Table 1. Total suspended solids (TSS) refer to tiny particles and matter that remain suspended in water rather than settling to the bottom. These particles can vary widely in size and composition, including silt, clay, organic matter, and other debris. The concentration of these suspended particles has a significant impact on the optical properties and overall health of aquatic systems (Fanela et al. 2019). TSS observed in all the sampling stations were within WHO, (2011) stipulated limits for drinking water quality. Turbidity serves as an indicator of the transparency or opaqueness of water, as noted by Edori et al. (2019). Elevated levels of turbidity result from the presence of particles suspended and dissolved within the water, consequently impeding the penetration of light into the aquatic environment. This, in turn, hinders photosynthetic processes, as highlighted by Puyate and Rim-Rukeh, (2008) and Edori et al. (2019). The measured turbidity at all sampling locations surpassed the standards set by WHO (2011), suggesting a notable accumulation of suspended and dissolved particles within the water, indicative of a substantial particle load. Salinity plays a crucial role in the well-being of aquatic life and the maintenance of various environmental factors, as it signifies the level of salt concentration within water. Salinity values observed in this present study correspond to the low salinity values of 31.63 mg/l reported by Ogbonna et al. (2021).

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Biological oxygen demand (BOD5) or chemical oxygen demand (COD) analysis is extensively employed to assess the presence of organic contaminants (Lee et al. 2016). Biological oxygen demand refers to the quantification of the oxygen required by microorganisms to biologically break down organic substances present within the aquatic environment (Ngah et al. 2017). According to Ioryue et al. (2018), natural aquatic ecosystems exhibiting a Biological Oxygen Demand (BOD) value of < 5 mg/L are classified as uncontaminated environments. The BOD values observed in the effluents and recipient rivers were found to be less than 5, suggesting a relatively low demand for dissolved oxygen by microbial activity. Chemical oxygen demand serves as an estimate of the quantity of oxygen required for the oxidation process of susceptible organic substances within the aquatic environment (Sharma and Walia 2015). In surface waters, the range of COD values can span from 20 mg/L or lower in uncontaminated aquatic ecosystems to exceeding 200 mg/L in bodies of water affected by pollution, as outlined by Chapman (1996). The COD values observed in the effluents and recipient rivers surpassing 200 mg/L signify a substantial presence of oxidizable organic matter, pointing towards a notable pollution load within the water bodies. BTEX compounds, even at concentrations lower than established reference levels considered safe, are potentially associated with endocrine-disrupting characteristics and these substances have the potential to negatively impact the reproductive system and reproductive capacity by generating reactive oxygen species, which are recognized triggers of apoptosis in diverse types of cells (Sirotkin, 2019). benzene, toluene, ethylbenzene, *m*/*p*-xylene, and *o*-xylene were detected in all sampling stations but benzene in Oweh recipient water exceeded WHO, (2011) permissible limits in water bodies. Total petroleum hydrocarbons (TPH) are a term employed to characterize hydrocarbons of petroleum origin present in crude oil, which can be quantified in natural surroundings. When TPHs are introduced into aquatic ecosystems, they can inflict significant damage on organisms, displaying a range of toxic effects from immediate to prolonged (Owhonda et al. 2021). TPHs have the potential to accumulate in larger organisms through the transfer of energy up the food chain, either by consuming smaller organisms or by directly ingesting them through the attachment of hydrocarbons to organic substances (Quintana-Rizzo et al., 2015). Ighariemu et al. (2019) reported similar TPH values in a similar study.

V. CONCLUSION

This study investigates the physicochemical characteristics of rivers in the proximity of OLM 30 to ascertain the influence of effluents from the oil field on the water quality of the river. The physicochemical characteristic results suggests that certain parameters, such as pH, turbidity, COD, and high levels of turbidity, raise concerns about water quality and potential ecological impacts. These results could serve as valuable insights for policymakers, environmental regulators, and researchers to devise strategies for the sustainable management and protection of aquatic ecosystems in the Niger Delta sub-region and beyond. Further studies and monitoring efforts are recommended to gain a comprehensive understanding of the long-term trends and potential mitigations for the observed environmental issues.

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