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Seasonal Variation of Physico-Chemical Parameters in Surface Water in Oil-Producing Region of Nigeria

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Abstract
Water bodies support ecological activities such water generation, supply, pleasure, and beauty. This research focusses on the Niger Delta's petroleum-operating areas' physicochemical properties. Samples were taken everywhere. Umuechem, Ebocha, Ofuoma, and Ndashi in Etche, Ogba/Egbema/Ndoni, and Ughelli North LGAs of Rivers State were surveyed. The physico-chemical parameters were measured using standard methods. We calibrated the Extech EC500 meter using pH buffers of 4.0, 7.0, and 10.0 and an electrical conductivity reference solution of 1413 (µS/cm) before measuring water parameters in-situ. Measurements include temperature, conductivity, salinity, and TDS. A LaMottl 3000wi Tri-meter calibrated with 0.1.0 and 10.0 NTU standards assessed turbidity. Measurement uses a nanotransistor. The Winkler test measured oxygen. Water was added to the top of a sample container to eliminate bias. Several compounds fixed the sample's dissolved oxygen. A neutralising agent changes the colour of these compounds' acid molecules. The "endpoint," or colour change, is directly linked to dissolved oxygen in the sample. After measuring water samples using DO bottles, we incubated a 70 ml potion at 20 °C for five days. After incubation, the samples were processed as DO samples to measure dissolved oxygen. To ensure oxygen, BOD samples were diluted before incubation. We next determined the dissolved oxygen content of the diluted water. On the fifth day, the biological oxygen demand (BOD) and dissolved oxygen levels (DO) were used to define dissolved oxygen (DO), which was (A-B) times DF. Here, we can see the sample's dilution factors (DF) relative to the dilution water (A), as well as the initial and five-day incubation DOs (A and B, respectively). During the dry season, different variables are measured, including biological oxygen demand (0.88-2.05 mg/l), turbidity (3.6-27.1 NTU), pH (6.58-6.86), temperature (29.53-29.88 oC), electrical conductivity (24-79.80 µS/cm), total dissolved solids (18.27-56.0 mg/l), dissolved oxygen (5.75-6.58 mg/l), and salinity (0.01-0.04%). Both Otamiri-Oche Umuechem and Ufuoma exceeded the NPRA's 10-nanometer limit during the wet season (77.30 NTU) and the dry season (27.1% NTU) (1991). The biological oxygen demand during the rainy season exceeded the NPRA's requirement of 5 mg/L in all but one location, Ufuoma. Researchers found that rivers' physicochemical characteristics altered due to wastewater and seasonal changes. Nobody should ever consume water from a river or stream that has been polluted by oil production, and farmers shouldn't even fish in rivers that have been polluted.

Keywords: Niger Delta, Pollution, Season, Physico-Chemical Parameters, Surface Water

Introduction

Oil spills have devastated the Niger Delta, although it has a large population. Oil pollution occurs when oil pollutes air, water, or land. As recently reported in Nigeria's Niger Delta Region, oil pollution is the discharge of pollutants into the environment that might hurt or exacerbate living things (Clark, 2005). Since crude oil was found, Niger Delta inhabitants have suffered. River and agricultural pollution is a major issue. Between 1976 and 1997, 5,334 crude oil accidents spewed about 2.8 million barrels into marshes, farms, and waterways (Dublin-Green et al., 2018). According to Ite et al. (2013), soil, groundwater, surface water, and forest ecosystems have changed throughout time. Human activity contributes to Niger Delta pollution. Unicef (2006) says oil spills are risky and have consequences. Ozone-depleting pollutants include carbon dioxide, butane, propane, nitrous oxide, natural gas emissions, and hydrocarbons. These elements harm native flora and agriculture, affecting

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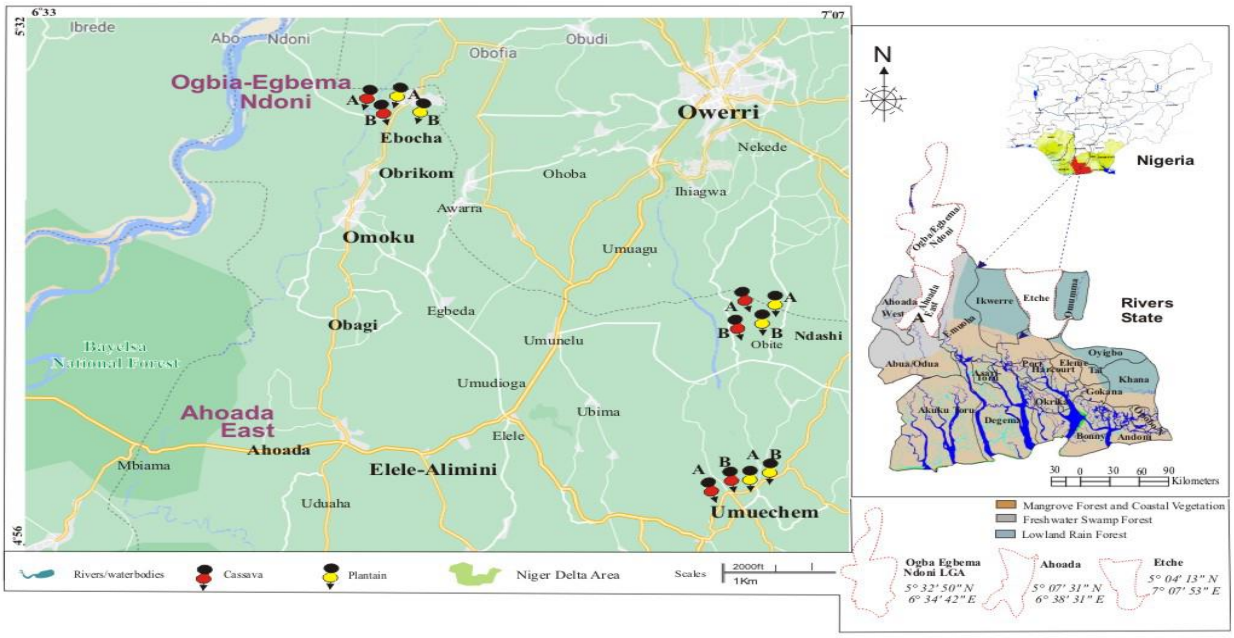
community health (Zabbey, 2004). According to Ezebuiro (2004), Niger Delta biodiversity is deteriorating. Singh et al. (2010) found metal-rich chemicals. High density and metallic composition make these materials water-inert. Bioaccumulation of non-biodegradable heavy metals in soil-plant-food and water-marine organism-food pathways may have unintended repercussions (Singh et al., 2010). Most heavy metals reach plants via their roots and pollute airborne deposits, said Elbagermi et al. (2013). Some species may be harmed by low environmental heavy metal levels (Singh et al., 2010). Farmers worry about heavy metal deposition in the soil because it reduces production and quality. These organisms threaten the ecology and human food supply, according to Osuji and Onojake (2006). Market sanitation issues, contaminated food supply chains and transportation, agricultural pollution, and irrigation with waste or filthy water are the main drivers of the alarming increase in food contamination (Singh et al., 2010).

The scope of the research outlined

Ofuoma in Delta State's Ughelli LG, Umuechem in Rivers State's Etche LG (the control site), and Ebocha in Rivers State's Ogba/Egbema/Ndoni area comprise Nigeria's Niger Delta. In the Niger Delta, the analysed rivers join the Niger. Rivers in Ndashi, Ebocha, Umuechem, and Delta State are utilised for leisure, residential water supply, and economic prosperity. These rivers are Ofuoma, Otamiri-Oche, Nkesir, and Ihimiri-Ama. Wetland hydrocarbons are found and retrieved. Nigeria's Niger Delta borders the Atlantic and Gulf of Guinea. A Niger River route defines it. Nigeria's Niger Delta encompasses around 70,000 square kilometres, or 70% of its territory (Frank, 2013). The largest marsh in Nigeria maintains Africa's third-largest drainage basin. The Niger Delta has coastal barrier islands, mangrove swamp forests, lowland rainforests, and freshwater wetlands. Nearly 30 million people live in Edo, Ondo, Rivers, Bayelsa, Delta, Akwa Ibom, Imo, and Abia (Frank, 2013). The Niger Delta's centre is Bayelsa, Rivers, Delta, and Akwa-Ibom, notorious for its huge oil spills and gas flaring. This Nigerian region has several oil exploration prospects. Shell maintains regional offices and is a major IOC in this area. Due to its many seaports and international airports, the Niger Delta is well-connected. Usually subtropical in the Niger Delta. Extreme heat and humidity prevail year-round. Over 70% of precipitation falls between April and August, and 22% in September and October. This region's main seasons are wet and dry. November–March are the driest months, according Ayotamuno and Gobo (2004). Delta's first three LGAs were Etche, Ogba/Egbema/Ndoni, and Ughelli North; Etche, Umuechem was the fourth. Control was at Ndashi Etche. Rivers State had two, Delta had one. High humidity is common in tropical environments. This location averages 400 mm of yearly rain. The wettest months are April–November and the driest are November–March.



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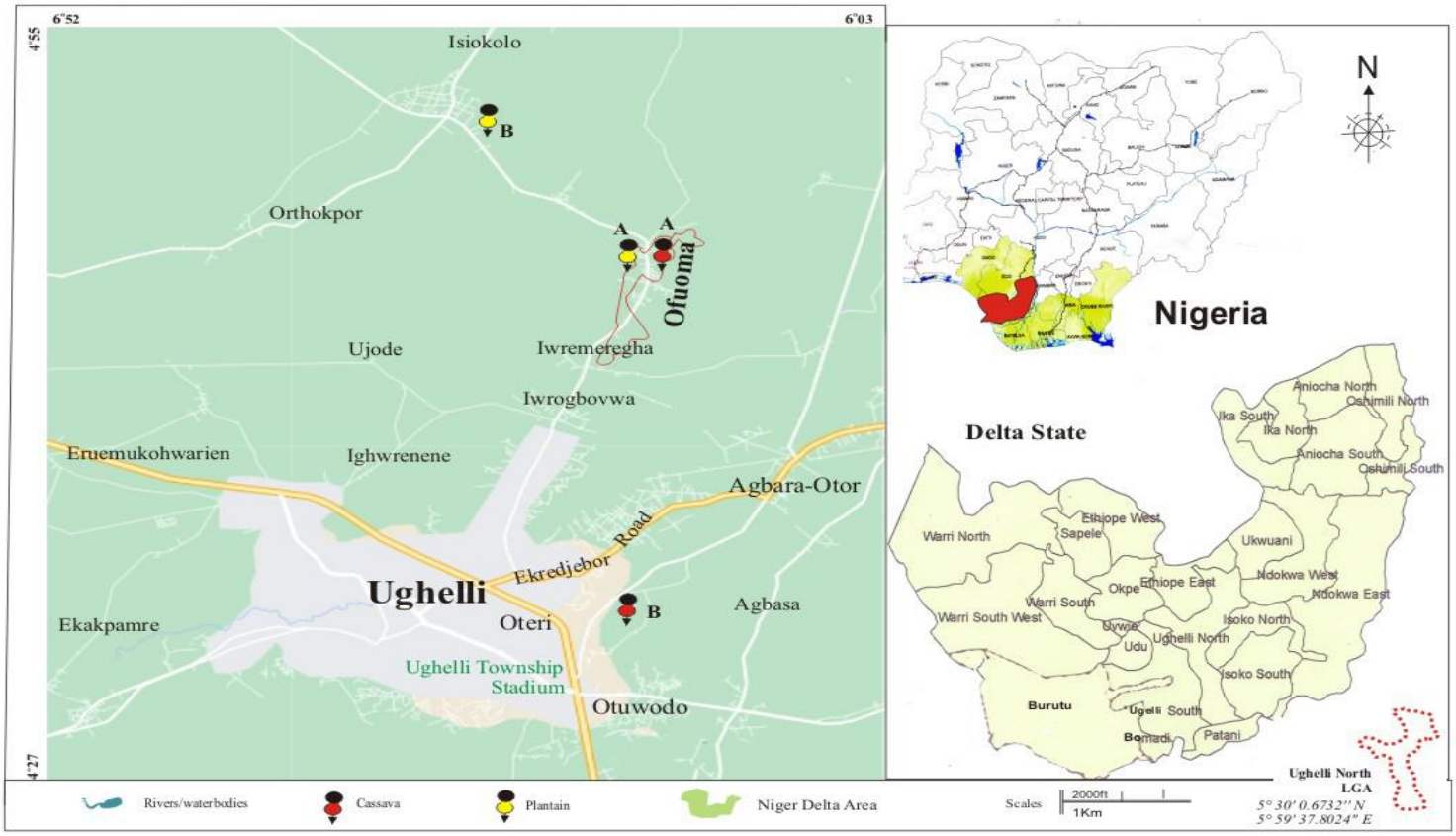

Fig. 1: Map of the study area (Source: Onwugbuta, 2023).

Materials and Method

Using pH buffers of 4.0, 7.0, and 10.0 and an electrical conductivity reference solution of 1413 (µS/cm), the Extech EC500 meter was calibrated before measurements of pH, temperature, conductivity, salinity, and total dissolved solids (TDS) of water were made in-situ. The measurement units include conductivity, salinity, temperature, and total dissolved solids (TDS). A LaMottl 3000wi Tri-meter, calibrated using 0.1.0 and 10.0 NTU standards, was used to measure the turbidity. Nanotransistor units are used as the measurement unit. The Winkler assay was used to measure the oxygen concentration. A sample container was completely filled with water to rule out any potential bias in the findings. The dissolved oxygen in the sample was fixed using a variety of substances. A color shift occurs when the acid molecule created by these reagents is titrated with a neutralizing compound. The amount of dissolved oxygen in the sample is directly correlated with the "endpoint," or point of color shift. After using DO bottles to measure the water samples, we incubated a 70 ml potion for five days at 20 °C. After the incubation period was over, the samples were processed in the same manner as the previously described DO samples to ascertain the dissolved oxygen level. To ensure the presence of oxygen, the BOD samples were diluted before incubation. Next, the dilution water's DO was determined. The DO was calculated as (A-B) x DF using the biochemical oxygen demand (BOD) and dissolved oxygen levels as determined on day five. DF is the sample's dilution factor in relation to the dilution water if A is the DO of the first dilution water and B is the DO following five days of incubation.

Results

Table 1: Temporal assessment of surface water physico-chemical characteristics across hydrological seasons.

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Parameters	Otamiri-Oche Umuechem	Nkesir Ebocha	Ofuoma	Ihimiri-Ama Ndashi	Maximum Acceptable Level (NPRA, 1991)
pH					
Wet season	6.83±0.29[a]	6.91±0.33[a]	6.51±0.33 [a]	6.6±0.39 [a]	6.5-8.5
Dry season	6.81±0.06[a]	6.81±0.16 [a]	6.86±0.12 [a]	6.58±0.34 [a]	
Temp. (ºC)					
Wet season	29.07±0.26[a]	29.3±0.51[a]	29.1±0.29 [a]	28.1±29.05 [a]	35ºC
Dry season	29.88±0.25 [a]	29.85±0.1 [a]	29.80±0.2 [a]	29.53±0.22 [a]	
Electrical Cond. (µS/cm)					
Wet season	86.6±8.14 [a]	30.9±0.73[b]	28.1±5.31 [b]	30.13±4.58 [b]	400µS/cm
Dry season	79.80±0.69 [a]	24±0.4[b]	25±1.51 [b]	24.3±0.95 [b]	
Salinity (%)					
Wet season	0.04±0[a]	0.01±0 [b]	0.01±0 [b]	0.01±0 [b]	600‰
Dry season	0.04±0	0.01±0	0.01±0	0.01±0	
Turbidity (NTU)					
Wet	7.95±4.9 [a]	0.90±0.79 [a]	**77.30±39.5** [a]	1.05±0.37 [a]	10 Nephelometric
Dry	**27.1±0.51**[a]	3.7±0.12[b]	3.6±.0[b]	3.75±0.06[b]	Turbidity Unit (NTU)
Total Dissolved Solids (mg/l)					
Wet	60.8±5.68[a]	22±0[b]	20.3±3.77 [b]	21.25±2.87[b]	500 mg/l
Dry	56.00±0.82[a]	18.5±2.38[b]	20.33±2.28[b]	18.25±0[b]	
Dissolved Oxygen (mg/l)					
Wet	5.63±0.62[a]	6.2±0.09 [a]	3.7±0.17 [b]	5.93±0.43[a]	5-9.5 mg/l
Dry	6.45±0.83[a]	5.75±0.85 [a]	6.58±0.59 [a]	6.55±0.01 [a]	
Biological Oxygen Demand (mg/l)					
Wet	**5.63±1.14 [a]**	**6.18±0.32 [a]**	3.73±0.67[b]	**5.92±0.42[a]**	5 mg/l
Dry	0.90±0.35 [b]	1.75±0.57 [a]	0.88±0.35 [b]	2.05±0.05[a]	

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Big = bold, small = unbolded. Means (±) and standard deviations (SD) for four assessments are shown as results. Using ANOVA and Tukeys' test, there is a significant difference ($p<0.05$) between means with various alphabets in rows. At Umuechem, Ebocha, Ofuoma, and Ndashi, water samples were collected from the surface. Their electrical conductivity, temperature, total dissolved solids, dissolved oxygen, pH, salinity, turbidity, and biological oxygen demand (BOD) were among the physical-chemical parameters that were documented and quantified. Table 1 displays the results.

pH of surface water

A range of 6.22 to 7.04 was recorded for Ihimiriama Ndashi's pH, 6.47 to 7.08 for Otamiri-Oche Umuechem's, 6.44 to 7.15 for Nkesir Ebocha, and 6.18 to 6.84 for Ofuoma. Ebocha received a score of 7.25, while Ofuoma received a score of 6.18. The data for the mean and standard deviation are shown in Table 1: That is why Otamiri-oche Umuechem had a score of 6.83±0.29, Nkesir Ebocha 6.91±0.33, Ofuoma 6.51±0.33, and Ihimiri-Ama Ndashi 6.6±0.39. pH concentrations were from 6.78 to 6.91 at Umuechem, 6.67 to 6.95 at Ebocha, 6.68 to 6.92 at Ofuoma, and 6.01 to 6.70 at Ndashi during the dry season. Umuechem received the best score at 6.95 and Ndashi the worst at 6.01. Ndashi had the lowest pH during the dry season at 6.01 and Ebocha had the highest pH at 7.25. The average and standard deviation are as follows: Nkesir Ebocha, Ofuoma, Ihimiri-Ama Ndashi, and Otamiri-oche Umuechem achieve values of 6.81±0.06, 6.81±0.16, 6.86±0.12, and 6.58±0.34, respectively, during the wet season. The measurements for the Ebocha are 6.81±0.16, the Ofuoma are 6.86±0.12, and the Ndashi are 6.52±034 during the dry season, on the other hand. During the dry season, Ofuoma was ranked first, and during the wet season, Nkesir Ebocha was ranked first, according to Table 4.1 and Figure 1. Wet and dry seasons' pH levels were not substantially different from one another, according to the analysis of variance ($P>0.05$). A higher pH was observed during the dry season compared to the rainy season. The pH did not show any changes across time or space (Fig. 1). In terms of pH variation pattern, nothing changed..

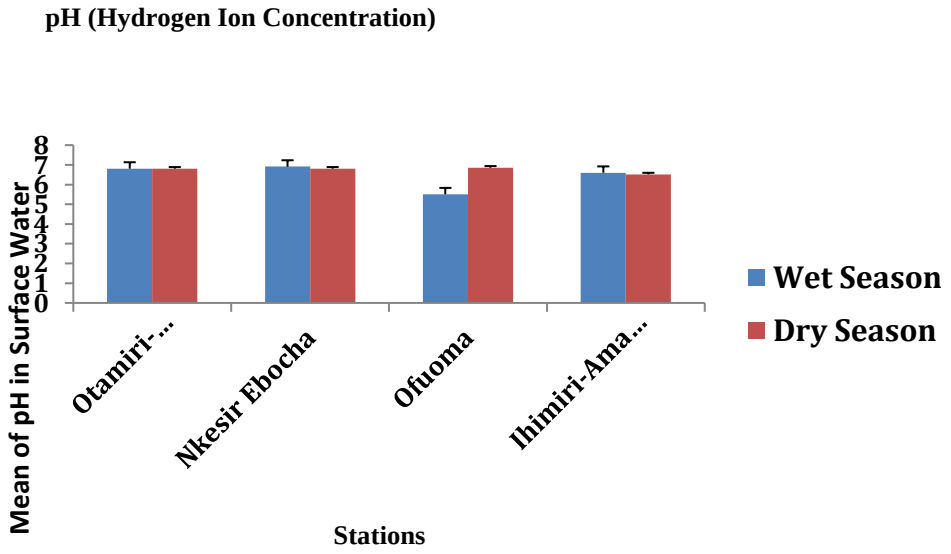

Fig. 2: Mean of pH in Surface Water from Rivers in Study Sites in Wet and Dry Seasons at the Sampled Stations.

Temperature of surface water

It was 28.8–29.3 degrees Celsius at Otamiri-Oche Umuechem. The Nkesir Ebocha temperature was 28.7–29.4. The temperature at Ofuoma was 28.9–29.5°C. It was 28.9–29.2 degrees Celsius in Ihimiri-Ama Ndashi, the control. Ofuoma was the warmest at 29.5 degrees Celsius and Ebocha the coolest at 28.7. Umuechem had dry season temperatures between 29.5 and 30.0°C, Ebocha 29.7–29.9°C, Ofuoma 29.5-29.9°C, and Ndashi 29.2–29.7°C. Umuechem was 30.0°C and Ndashi 29.2. Ebocha had the lowest rainiest season temperature (28.7) and Umuechem the highest dry season (30.0). The mean and

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standard deviation are in Table 4.1. During the wet season, temperatures at Umuechem, Ebocha, Ofuoma, and Ndashi varied from 29.7±0.26 to 29.3±0.51 oC, 29.1±0.29 oC, and 28.1±29.05 oC. In contrast, Umuechem, Ebocha, Ofuoma, and Ndashi saw dry season temperatures of 29.88±0.25oC, 29.85±0.1oC, and 29.80±0.2oC. Each site had changing temperatures. Most stations reported steady temps. Figure 2 shows a little temperature difference of 29.7±0.26 oC and 29.88±0.25 oC throughout rainy and dry seasons. Umuechem has the best dry season (Figure 2). This analysis of variance indicated no significant temperature difference between wet and dry seasons (P>0.05).

Temperature of Surface Water

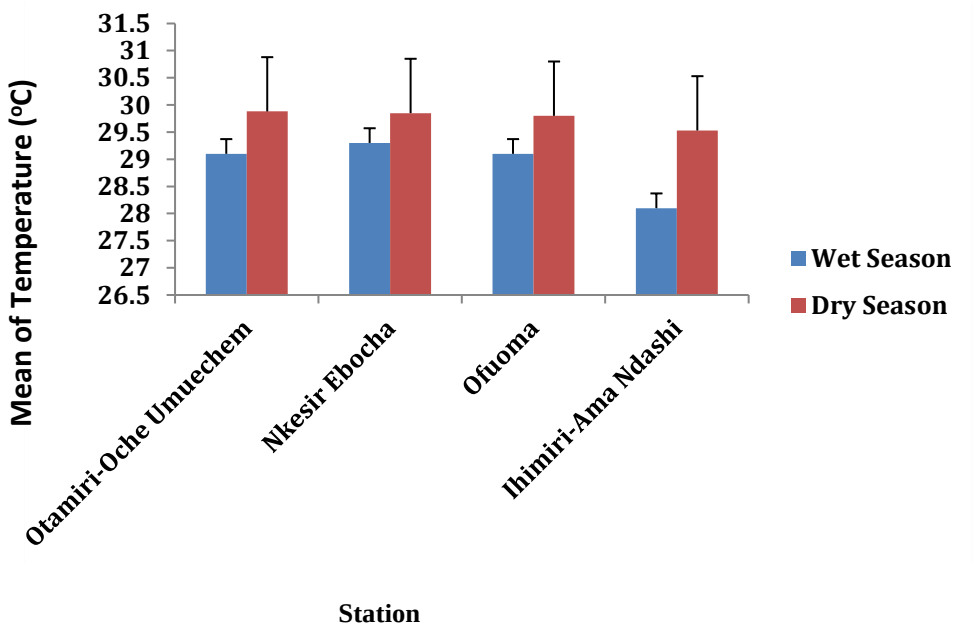

Fig. 3: Mean Temperature of Surface Water from Rivers in Petroleum and Non Petroleum Sites in Wet and Dry Seasons at the Sampled Stations.

In Otamiri-Oche Umuechem, temperatures ranged from 28.8 to 29.3 degrees Celsius. The temperature in Nkesir Ebocha was 28.7–29.4°C. At Ofuoma, temperatures were 28.9–29.5 degrees Celsius. Ihimiri-Ama Ndashi, the control location, averaged 28.9–29.2 degrees Celsius. The lowest temperature was 28.7 degrees Celsius in Ebocha and the highest in Ofuoma. Ofuoma had 29.5-29.9°C, Umuechem 29.5–30.0°C, Ebocha 29.7–29.9°C, and the control location, Ndashi, 29.2–29.7°C. It was 30.0 degrees Celsius in Umuechem and 29.2 in Ndashi. Umuechem had the hottest season at 30.0 degrees and Ebocha the wettest at 28.7 degrees. The right side of Table 4.1 displays the mean and standard deviation: Umuechem reported temperatures of 29.7±0.26 oC, 29.3±0.51 oC, 29.1±0.29 oC, and 28.1±29.05 oC during the rainy season, in that sequence. Temperatures at Umuechem, Ebocha, Ofuoma, and Ndashi were 29.88±0.25oC, 29.85±0.1oC, and 29.80±0.2oC during the dry season. Any area might be becoming colder or warmer. Most weather stations reported consistent temperatures all day. Figure 2 shows a temperature difference of 29.7±0.26 oC during the wet season and 29.88±0.25 oC during the dry season. Figure 2 shows Umuechem had the greatest dry season tally. Analysis of variance showed no significant temperature variation between dry and rainy seasons (P>0.05)..

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Electrical Conductivity of Surface Water

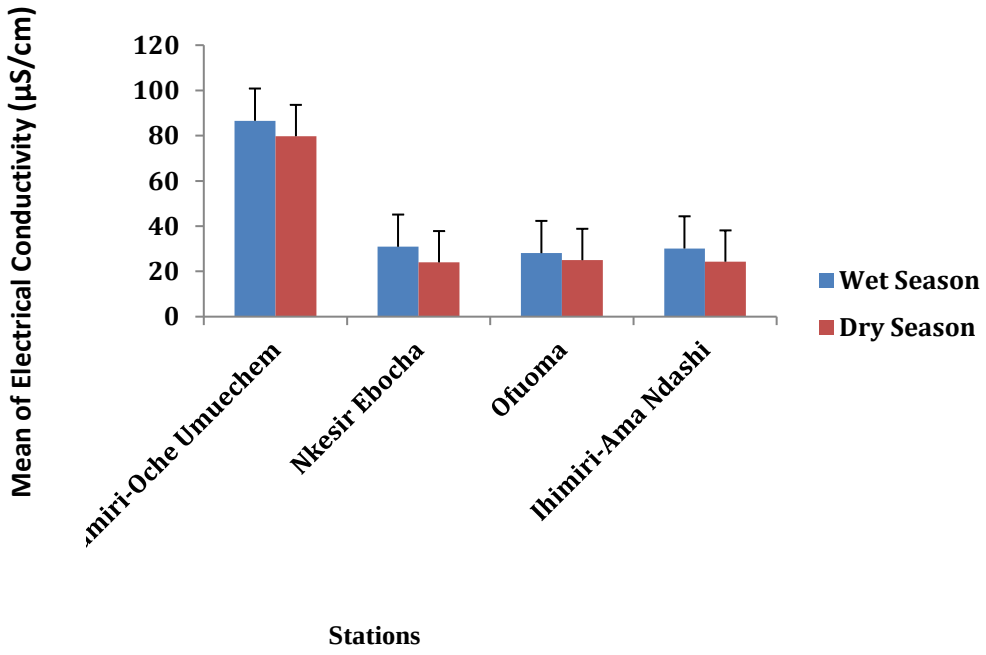

Fig. 4: Mean of Electrical Conductivity in Surface Water from Rivers in Petroleum and Non-Petroleum Sites in Wet and Dry Seasons at the Sampled Stations.

Salinity of Surface Water

During the wet season, salinity levels in Ofuoma, Ebocha, Ndashi, and Umuechem were recorded at 0.01 to 0.01 mg/l, 0.01 to 0.01 mg/l, and 0.04 to 0.04 mg/l, respectively. During the rainy season, Umuechem demonstrated the highest concentration at 0.04 mg/l, while Ebocha, Ofuoma, and Ndashi showed the lowest levels at 0.01 mg/l. During the dry season, the salinity levels measured for Umuechem, Ebocha, Ofuoma, and Ndashi were 0.04-0.04 mg/l, 0.01–0.01 mg/l, and 0.01–0.01 mg/l, respectively. During the rainy season, Umuechem demonstrated the lowest concentration at 0.04 mg/l, whereas Ebocha, Ofuoma, and Ndashi displayed the highest concentration at 0.01 mg/l. Throughout the wet and dry seasons, Umuechem demonstrated the highest concentration at 0.04 mg/l, whereas the three locations of Ebocha, Ofuoma, and Ndashi showed the lowest levels at 0.01 mg/l. The recorded mean and standard deviation of salinity in Umuechem, Ebocha, Ofuoma, and Ndashi during the wet season were 0.04±0 mg/l, 0.01±0 mg/l, 0.01±0 mg/l, and 0.01±0 mg/l, respectively. In contrast, the dry season exhibited a uniform value of 0.01±0 mg/l, suggesting a stable freshwater environment. Otamiri-Oche Umuechem demonstrated higher salinity levels when compared to Nkesir Ebocha, Ofuoma, and Ihimiri-Ama Ndashi, as shown in Figure 4. The Otamiri-Oche Umuechem station, in conjunction with other stations, recorded increasing salinity levels, indicating some regional differences in addition to a general trend. During the wet and dry seasons, salinity levels remained relatively stable, measured at 0.01±0 mg/l and 0.04±0 mg/l, respectively (Fig. 3). The ANOVA results demonstrate that salinity exhibited a consistent pattern across the rainy and dry seasons, with no significant variations detected (P>0.05).

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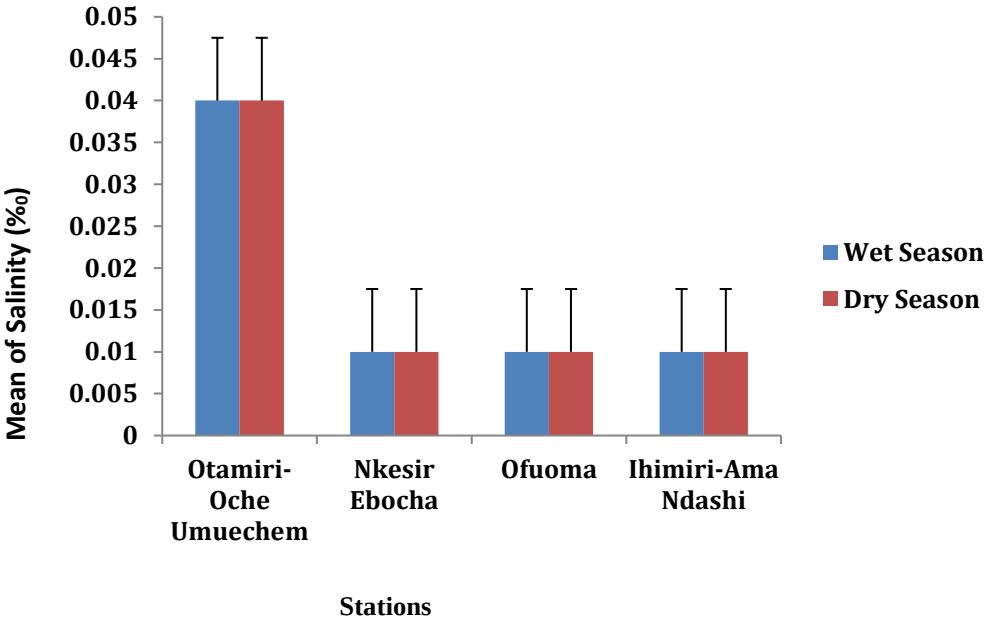

Fig. 5: Mean of Salinity in Surface Water from Rivers in Petroleum and Non Petroleum Site (Wet and Dry Seasons) at the Sampled Stations

Turbidity of Surface Water

Umuechem had 3.8 to 15.1 NTU wet season turbidity, Ebocha 0.2 to 0.9, Ofuoma 1.2 to 187.0, and Ndashi, the control site, 0.7 to 1.5. Highest was 187.0 at Ofuoma, lowest 0.2 at Ebocha.Umuechem experienced 18–36.2 NTU dry season turbidity (Appendices 12 and 14). Ofuoma had 3.5–3.6 NTUs, whereas Ebocha had 3.6–3.8. Control site Ndashi had 3.7–3.8 NTU turbidity. Umuechem at 36.2 NTU was highest and Ebocha at 3.5 NTU lowest. Ofuoma got the highest rainy season reading at 187.0 NTU and Ebocha the lowest at 0.2 NTU. The wet season turbidity mean and standard deviations were 7.95±4.9 NTU, 0.90±0.79 NTU, 77.30±39.5 NTU, and 1.05±0.37 NTU. In the dry season, Umuechem, Ebocha, Ofuoma, and Ndashi recorded NTU values of 27.1±0.51, 3.7±0.12, 3.6±0, and 3.75±0.06. In the rainy season, Ofuoma had a greater turbidity level (77.30±39.5 NTU) compared to other stations (see Table 1 and Fig. 5). The ANOVA revealed substantial turbidity differences between wet and dry seasons ($P<0.05$).

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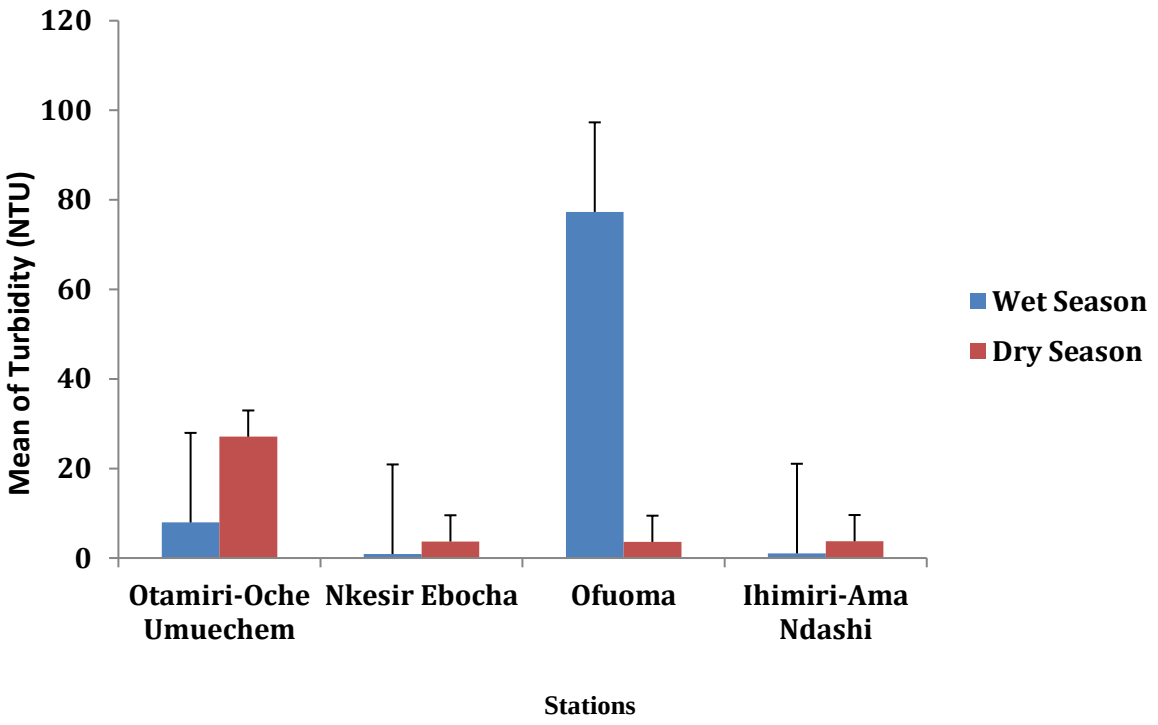

Fig. 6: Mean of Turbidity in Surface Water from Rivers in Petroleum and Non-Petroleum Sites (Wet and Dry Seasons) at the Sampled Stations.

Total Dissolved Solid (TDS) of Surface Water

During the rainy season, TDS levels ranged from 55 to 67 mg/l in Umuechem, 22 to 22 in Ebocha, 15 to 23 in Ofuoma, and 17 to 23 in Ndashi (the control site). Umuechem had 67 mg/l, whereas Ofuoma had 15. TDS ranged from 55 to 57 mg/l in Umuechem, 16 to 20 in Ebocha, 9.1 to 23.2 in Ofuoma, and 16 to 21 in Ndashi, the control site, during the dry season. Umuechem had 57 mg/l, whereas Ofuoma had 9.1 mg/l. The wet season had the highest concentration (67 mg/l) in Umuechem and the dry season the lowest (9.1 mg/l) in Ofuoma. During the rainy season, Umuechem, Ebocha, Ofuoma, and Ndashi had average TDS levels of 60.8±5.68 mg/l, 22±0 mg/l, 20.3±3.77 mg/l, and 21.3±2.87 mg/l, respectively. The dry season readings are 56±0.82 mg/l, 18.5±2.38 mg/l, 20.33±2.28 mg/l, and 18.25±0 mg/l. Table 1 and Fig. 6 show that Otamiri-Oche Umuechem had the greatest TDS during the rainy season (60.8±5.68 mg/l). ANOVA showed that TDS was substantially different ($P>0.05$) in both wet and dry seasons.

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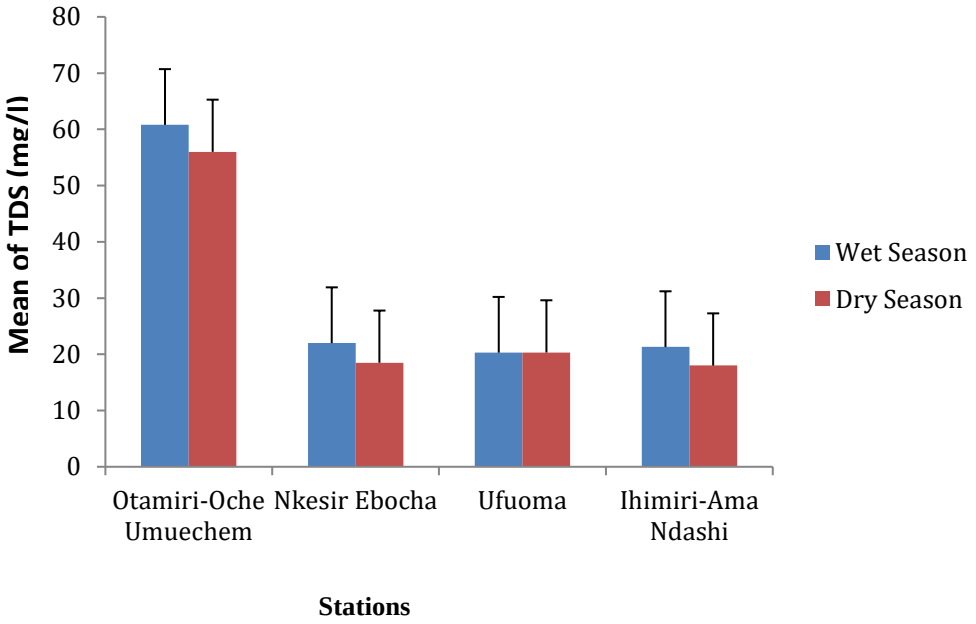

Fig. 7: Mean of TDS in Surface Water from Rivers in Petroleum and Non-Petroleum Sites in Wet and Dry Seasons at the Study Sites.

Dissolved Oxygen (DO)

Wet-season dissolved oxygen results indicate that Umuechem recorded levels ranging from 5.1 to 6.3 mg/l, Ebocha showed values between 3.5 and 3.9 mg/l, Ofuoma had measurements from 5.8 to 6.4 mg/l, and Ndashi presented a level of 6.4 mg/l. In the dry season, the observed values for Ebocha ranged from 4.9 to 6.6 mg/l, while Ofuoma and Ndashi, the control site, both exhibited values between 6.5 and 6.6 mg/l. Appendices 12 and 14 indicate that Umuechem recorded a concentration of 6.8 mg/l during the dry season, while Ebocha showed a concentration of 4.9 mg/l. Umuechem exhibits a higher concentration during the dry season, measuring 6.8 mg/l, in contrast to Ebocha's 3.5 mg/l. Table 4.1 and Fig. 4.7 present the wet season mean and standard deviation values as follows: 5.63±0.62, 6.2±0.09, 3.7±0.17, and 5.93±0.43, respectively. During the dry season, the recorded values across all locations were 6.45±0.83, 5.75±0.85, 6.58±0.59, and 6.55±0.01. Ofuoma's dissolved oxygen levels (3.7±0.17) exhibited reduced variability during the dry season. ANOVA indicated that there was no significant difference in DO between the wet and dry seasons (P>0.05).Wet-season dissolved oxygen results indicate that Umuechem recorded levels ranging from 5.1 to 6.3 mg/l, Ebocha showed values between 3.5 and 3.9 mg/l, Ofuoma had results from 5.8 to 6.4 mg/l, and Ndashi measured at 6.4 mg/l. In the dry season, Ebocha recorded values ranging from 4.9 to 6.6 mg/l, while Ofuoma and Ndashi, the control site, both exhibited values between 6.5 and 6.6 mg/l. Appendices 12 and 14 indicate that Umuechem recorded a concentration of 6.8 mg/l during the dry season, while Ebocha showed a concentration of 4.9 mg/l. Umuechem exhibits a higher concentration during the dry season at 6.8 mg/l, in contrast to Ebocha, which has a concentration of 3.5 mg/l. Table 4.1 and Fig. 4.7 present the wet season mean and standard deviation values as follows: 5.63±0.62, 6.2±0.09, 3.7±0.17, and 5.93±0.43, respectively. During the dry season, the recorded values at all locations were 6.45±0.83, 5.75±0.85, 6.58±0.59, and 6.55±0.01. Ofuoma's dissolved oxygen levels (3.7±017) exhibited reduced variability during the dry season. ANOVA indicated that there was no significant difference in DO between the wet and dry seasons (P>0.05)..

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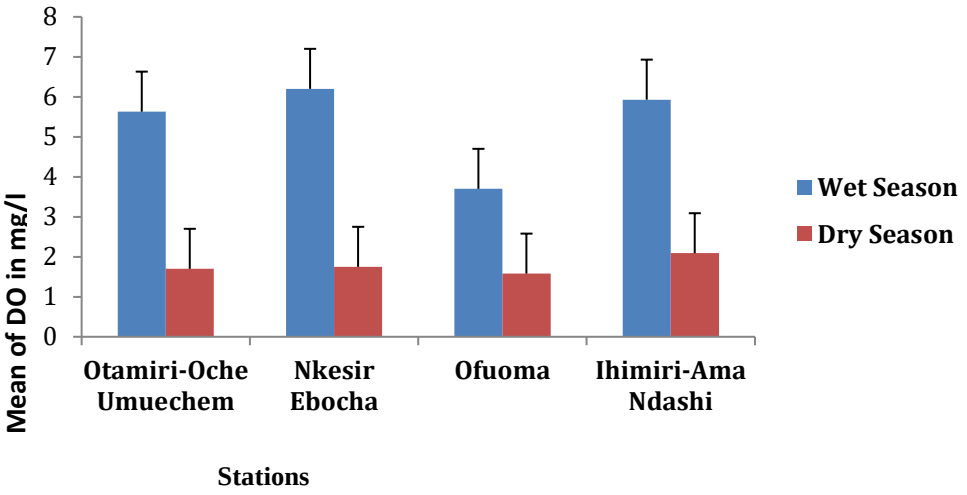

Fig. 8: Mean of DO in Surface Water from Rivers in Petroleum and Non-Petroleum Sites in Wet and Dry Seasons at the Sampled Stations

Biological Oxygen Demand (BOD)

In the rainy season, the recorded biological oxygen demand (BOD) levels in Umuechem, Ebocha, Ofuoma, and Ndashi were as follows: Umuechem showed values ranging from 0.7 to 2.9 mg/l, whereas Ebocha presented a range of 2.1 to 2.9 mg/l. Ofuoma exhibited concentrations ranging from 0.6 to 1.9 mg/l, while Ndashi showed values between 1.5 and 2.4 mg/l. Ofuoma recorded the minimum value at 0.6 mg/l, while both Umuechem and Ofuoma exhibited the maximum value of 2.9 mg/l. In the dry season, the biological oxygen demand (BOD) for Umuechem ranged from 0.6 to 1.2 mg/l, while Ebocha showed a variation between 0.6 and 1.9 mg/l. Ofuoma exhibited BOD levels varying from 0.7 to 1.4 mg/l, whereas Ndashi demonstrated values ranging from 2.0 to 2.1 mg/l. Ofuoma demonstrated the highest concentration at 0.7 mg/l, while Umuechem showed the lowest concentration at 0.6 mg/l. In the dry season, Umuechem recorded a minimum concentration of 0.6 mg/l, while in the rainy season, it reached a maximum of 2.9 mg/l. The mean and standard deviation values recorded for the wet season were 5.63±1.14, 6.18±0.32, 3.73±0.67, and 5.92±0.42. The dry season displayed values of 0.90±0.35, 1.75±0.57, 0.88±0.35, and 2.05±0.05. The data indicates an absence of significant seasonal or temporal variations in the biochemical oxygen demand across all stations (refer to Table 4.1 and Fig. 4.8). The ANOVA results indicated that BOD was significant during the wet season ($P>0.05$), whereas it lacked significance in the dry season.

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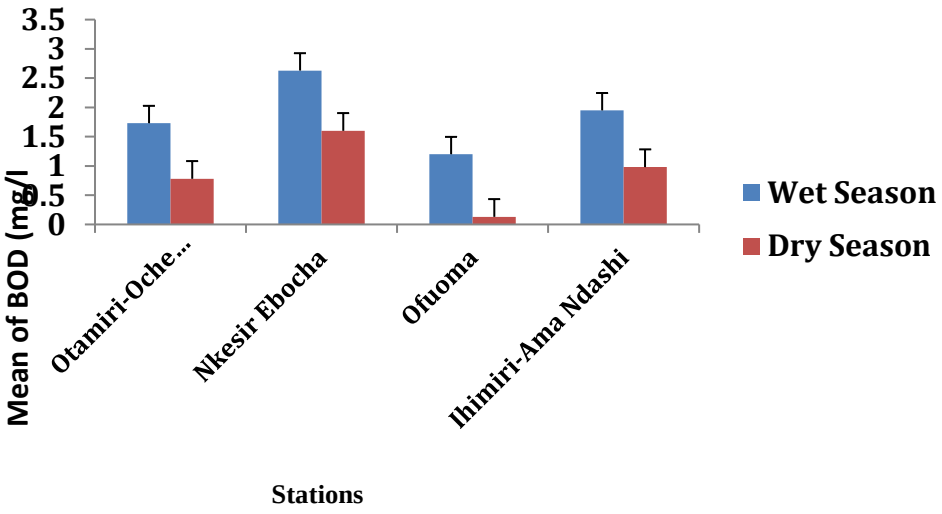

Fig. 9: Mean of BOD in Surface Water from Rivers in Petroleum and Non-Petroleum Sites (Wet and Dry Seasons) at the Sampled Stations.

Discussion

During the wet season, the study found that Nkesir Ebocha's subsurface pH increased to 6.91. Both the wet and dry seasons showed that the average values at Otamiri-Oche Umuechem, Nkesir Ebocha, Ofuoma, and Ihimirir-Ama Ndashi fulfilled the standards set out by NPRA (1991). While the EU has self-protection rules ranging from 6 to 9, the World Health Organisation (2004) suggests a pH range of 6.5 to 8.5 for fisheries and aquatic life. This backs up the Ona River study conducted by Andem et al. in 2012. Abija et al. (2018) reports that the pH of the alkaline surface water of the Farcados River in the Western Niger Delta of Nigeria ranges from 7.66 to 8.31 during the rainy season to 6.2 to 6.3 during the dry season. The pH range of Okpoka Creek in the Niger Delta of Nigeria is 6.68±0.07 to 7.03±0.05, as reported by Abowei and George (2009). The pH remained constant along the course of both space and time. From 6.81±0.367 during the rainy season to 6.97±0.044 during the dry season, the pH varied greatly. It was previously found in Bonny River by Dublin-Green (1990) that pH levels were lowest during the late wet season and highest during the dry season; the current analysis supported these findings. Identical patterns were found in the Andoni flats and the New Calabar River by Ansa (2005) and Ekeh and Sikoki (2003) in the Niger Delta. ANOVA did not reveal a statistically significant change in pH between the rainy and dry seasons ($P>0.05$). pH Both in terms of time and space, the pH remained rather constant (Fig. 1). The change in pH was expected.

Temperature (oC) is significant because it influences numerous water-related variables. Temperatures peak at 29.880 degrees Celsius during Umuechem's dry season, according to the research. All year round, all of the station readings were lower than the fresh water restriction set by the NPRA (1991) of 35°C. Since 29.90C is considered normal for water fishing, these temps are just fine. Many studies have found comparable temperatures: Braide et al. (2004), Ansa (2005), Hart and Zabbey (2005), Sikoki and Zabbey (2006), Dibia (2006), and Chindah et al. (1999). Temperatures fluctuated often. The study suggests irrigating with the water since most of the metrics were within the ranges allowed by the FAO. The physicochemical properties and nutritional load of river sediment in Ibadan City, Nigeria, might vary with the seasons, according to research by Adeyemo et al. (2008). Scientists found that the physicochemical quality of the water was declining in the region under investigation. The physicochemical properties of the surface water of the Elelenwo River in Rivers State, Niger Delta, Nigeria were investigated by Edori et al. (2020). According to the World Health Organisation, the readings were normal for surface water. This analysis is in line with previous research on the Niger Delta river. Among them are the following studies: Research into the Niger Delta's Upper Bonny River revealed temperature fluctuations in the following studies: A study conducted by Chindah et al. (1999) found temperatures ranging from 26 to 30.5°C, another by Zabbey (2002) from 26.3 to 30.4°C, a study by Braide et al. (2004) from 26.64 ± 1.18°C to 30.83 ± 1.47°C, and a study by Ansa (2005) from 25.9 to 32.4°C. Temperatures

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ranging from 25.8 to 30.4°C were recorded by Hart and Zabbey (2005), 26 to 27.8°C by Sikoki and Zabbey (2006), 25 to 27.8°C by Dibia (2006), and 27 to 30°C by Jamabo (2008). The average dry season temperature at Otamiri-Oche Umuechem was 29.88±0.25oC, which was higher than the other three stations, because of its shallow depth. Surface and bottom water mix and circulate due to the lack of stratification and shallowness. Changes in the seasons impacted the weather. The dry season is characterised by hot weather. Between the rainy and dry seasons, there was no statistically significant variation in temperature ($P>0.05$).

Surface water samples from both oil-operating and non-oil-operating locations exhibited electrical conductivities below 1000 U/L drinking water, according to the Nigerian Petroleum Resources Authority (1991). A peak of 86.6±8.14µS/cm was achieved by Otamiri-Oche Umuechem during the dry season. Regardless of the season, NPRA (1991) discovered that every site maintained readings below 400µS/cm. This study's result was lower than the average conductivity value of 3752 µS/cm found in the New Calabar River by Agbugui and Deekae (2014). In the rainy season, the Forcado River's electrical conductivity varied between 17.0 and 26.0 µS/cm, whereas in the dry season, it reached 68.5 µS/cm, as reported by Abija et al. (2018). (Dublin-Green, 2000; major Bonny River; King and Nkanta 2001: rain forest pond, Nigeria; Mallin et al. 2009; Dibia, 2006; Mini-Chinidah stream Port Harcourt, Niger Delta; Davies et al. 2008, Trans-Amadi (Woji) creek) Research in the Niger Delta lends credence to this assertion. Dublin-Green (2000) and Zabbey (2002) found the same thing in their Woji stream investigations, and the Bonny River investigation proved it. According to Figure 3, electrical conductivity fluctuated by 86.6% while it was raining and by 70.78% when it was dry. Both salinity and conductivity showed comparable trends. Conductivity fluctuated throughout the trial since there was no discernible shift between the rainy and dry seasons ($P>0.05$).

It is possible that an oil leak was the cause of the above-average samples at Otamiri-oche, Umuechem (0.01). Throughout the wet and dry seasons, the freshwater ecosystem was preserved by a maximum salinity of 0.04%. The NPRA's criterion for freshwater aquatic horticulture, which is 600 ppt, was not met in any of the measurements (1991). In line with previous studies, Abija et al. (2018) found that during the dry season, the freshwater levels in the Farcados River, Western Niger Delta, Nigeria, were 4.4 mg/l with a mean of 0.01 and that during the rainy season, they increased to 8.0 mg/l. In 2015, Vincent-Akpu et al. evaluated the physicochemical characteristics of the water from Bodo Creek. It was found that the salinity range in the Niger Delta is normal. The amounts of salt rose sharply when the dry season commenced. The salinity levels were consistently 0.01±0 mg/l and 0.04±0 mg/l throughout the wet and dry seasons, respectively (Fig. 3). Salinity did not alter significantly ($P>0.05$) during the rainy and dry seasons, according to ANOVA.

The amount of each component influences the turbidity of the water, according to research by Oboh and Agbala (2017). Outside of Nkesir and the control site Ndashi, turbidity levels at Otamiri-Oche Umuechem (27.1±0.51) and Ofuoma (77.30±39.5) were found to be over the 10NTU recommended limit during both the dry and rainy seasons, according to NPRA (1991). According to Chinda and Braide et al. (2011), this could have been influenced by petroleum contamination of surface water that is accessible to the public. This could be due to petroleum particulate matter in aquatic environments, wastewater from farms or urban households that exceeds the NPRA's 10NTU limit (1991). In 2008, Arain et al. examined how Manchar Lake in Pakistan stacked up against other lakes in terms of their physicochemical characteristics. All of the physicochemical parameters that were tested fell below the upper limit set by the World Health Organisation (WHO) when compared to the water quality evaluation of the Uttarakhand River in India. Bhadra and Nayal (2008) state that the sole criterion that were disregarded were turbidity and BOD. In 2011, Simpi et al. investigated the water quality of Shimoga, Karnataka's Hosahali Tank. Every one of the physicochemical characteristics came back inside the acceptable range. The physicochemical properties of the surface water of the Elelenwo River in Rivers State, Niger Delta, Nigeria were investigated by Edori et al. (2020). The results demonstrated that the water was unsafe according to WHO guidelines for conductivity and turbidity. During the rainy season, Ofuoma had a higher turbidity (77.30±39.5 NTU) than the other stations, as shown in Table 1 and Fig. 5. Nevertheless, the results of the ANOVA showed that there was a significant difference ($P<0.05$) in the levels of turbidity during the rainy and dry seasons. Water turbidity may be increased during dry seasons because to riverbank and other silt, which reduces this effect. Aside from the control site (Ihimiri-Ama Ndashi), Otamiri-Oche Umuechem, Nkesir Ebocha, and Ofuoma all had TDS levels lower than the NPRA's 500 mg/l standard (1991). The physical and chemical characteristics of Bodo Creek were investigated by Vincent-Akpu et al. (2015). The Niger Delta's total dissolved solids were within the usual range. In Umuechem, the mean and standard deviation for TDS during the dry season are 60.8±5.68 mg/l, in

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Ebocha, 22±0, in Ofuoma, 20.3±3.77, and in Ndashi, 21.3±2.87. Table 1 and Figure 6 show that during the rainy season, Otamiri-Oche Umuechem had the highest total dissolved solids (TDS), at 60.8±5.68 mg/l. Both the rainy and dry seasons had significantly different TDS values (P>0.05), according to the ANOVA.

Soluble oxygen levels never exceeded the NPRA (1991) 5-9.5 mg/l limit, even during wet season. The physical and chemical characteristics of Bodo Creek were investigated by Vincent-Akpu et al. (2015). Nigeria had average DO levels that were higher than what is considered safe for household use (NPRA, 2002). During the rainy season, oxygen solubility increases at lower temperatures, in contrast to earlier findings (Plimmer, 2008; McNeely et al., 2009). Conversely, during the dry season, it decreases at higher temperatures. Because aquatic plants have a shorter photoperiod and produce less oxygen during photosynthesis, dissolved oxygen levels were found to be lower (4.48 mg/l) than in the dry season (5.14 mg/l) according to Davies et al. (2008). According to Egborge (2001), mean dissolved oxygen concentrations are lower during the tropical wet season compared to the dry season. The yearly decrease in mean dissolved oxygen could be explained by water turbidity caused by runoff and the decomposition of organic molecules. Research on Miniweja Creek's water quality was conducted in 2004 by Braide et al. in Nigeria's Eastern Niger Delta.

(Clair et al., 2003) Bacterial oxygen demand (BOD) is the amount of oxygen required to decompose organic compounds in one litre of water. Water pollution assessment is the goal. Ofuoma had the lowest mean BOD levels and Ebocha had the highest, according to NPRA (1991). All sites had BOD levels over the 5 mg/l standard. Although this study found an average BOD of 405.57 mg/l in the Ona River, Andem et al. (2012) found a higher value. With a range of 19.20 to 28.40 mg/l, biological oxygen demand averages 32 mg/l during the wettest months (Abija et al., 2018). Nonetheless, it falls below the detection limit in all samples during the dry season, falling below 1.0 mg/l. The physical and chemical characteristics of Bodo Creek were investigated by Vincent-Akpu et al. (2015). There was a higher than recommended amount of biological oxygen demand (BOD), according to Nigeria's National Petroleum Resources Agency (2002). Pure water has a BOD level below 1.0 to 2.0 mg/l, according to Moore and Moore (2006). Our results are at odds with that criterion. In the absence of 3.0 mg/l, the water is considered pure; in the presence of 5.0 mg/l, it is questionable; and in the presence of 10.0 mg/l, it is considerably polluted. Similarly, Braide et al. (2004) found organic contamination indicators in the Miniweja stream water quality analysis in the Eastern Niger Delta, proving that BOD levels can be used to identify such contamination. Ofuoma kept its dissolved oxygen concentration at 3.7±017 during the dry season. Statistical analysis revealed no significant variation in DO between the rainy and dry seasons (P>0.05).

Conclusion

When comparing the wet and dry seasons, turbidity and dissolved oxygen were found to be the parameters most impacted by seasonal variation. The concentrations of most physicochemical parameters were much higher during the dry season than during the rainy season. Based on a detailed examination of the physicochemical characteristics of the water samples collected from every station and the NPRA standard, the water can be described as a good, stable, and healthy aquatic ecosystem during the wet season as opposed to the dry season when debris and other substances are deposited into the water. As human activity in the area expands, it will be necessary to regularly assess the physicochemical parameters.

Recommendation

It is recommended that monitoring, education, and cleaning should be carried out in Niger Delta region to avoid further residential, industrial, and agricultural pollution and oil spills.

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