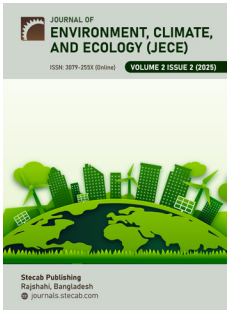

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Research Article

Seasonal Variation in Some Physicochemical Parameters of Water from Douglas Creek, Ibeno LGA, Akwa Ibom State

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About Article

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ABSTRACT

This study evaluated the seasonal variation of physicochemical parameters in Douglas Creek, Ibeno LGA, Akwa Ibom State, to determine water quality status and ecological implications. A comparative cross-sectional study was conducted during the wet (July–September 2023) and dry (January–March 2024) seasons, with water samples analyzed using standard methods. Parameters such as pH, conductivity, salinity, dissolved oxygen, temperature, turbidity, nitrate, phosphate, sulphate, chloride, total suspended solids, chemical oxygen demand (COD), cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}), and total petroleum hydrocarbons were determined using appropriate analytical instruments. The results revealed pronounced seasonal differences, with electrical conductivity rising from 278.67 µS/cm in the wet season to 30,344.67 µS/cm in the dry season (P = .009), chloride from 20.02 mg/L to 15,881.00 mg/L (P = .018), salinity from 175.33 mg/L to 23,028.67 mg/L (P = .004), and turbidity from 5.33 NTU to 306.67 NTU (P = .014), while calcium and potassium concentrations also increased significantly in the dry season. These changes, driven by reduced dilution, saline intrusion, and evaporation, led to elevated mineral and salt loads that exceeded World Health Organization (WHO) limits, thereby posing risks to aquatic biodiversity and public health. The findings underscore the urgent need for continuous monitoring and stricter environmental management to safeguard water quality in Douglas Creek.

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1. INTRODUCTION

Water is a vital natural resource that supports all life forms and plays a significant role in socio-economic activities (Nyantakyi *et al*., 2019). However, water quality is increasingly threatened by pollutants, which has become a growing global concern (Benson *et al*., 2017). Seasonal variation in the physicochemical parameters of water is a critical aspect of understanding the ecological dynamics of aquatic systems, particularly in regions impacted by industrial activities. Monitoring these parameters is essential to assess the extent of pollution and its effects on both the ecosystem and the local communities that rely on the creek for fishing and other activities. Elevated concentrations of toxic substances, such as lead, cadmium, and chromium, pose serious health risks to aquatic organisms and humans alike (Nriagu *et al*., 2016). Furthermore, alterations in parameters such as pH and dissolved oxygen (DO) can lead to biodiversity loss, thereby threatening the sustainability of the ecosystem (Ugochukwu & Ertel, 2008).

In the Niger Delta region of Nigeria, where the study area is located, extensive oil exploration activities have had adverse effects on the ecosystem (Ubong *et al*., 2020). Oil exploration and production are major contributors to environmental pollution, particularly in this region, where spills, leaks, and industrial effluent discharges are common (Nwilo & Badejo, 2005). Douglas Creek (900 m long and 8 m deep) is one of the estuaries of the Qua Iboe River in Ibeno Local Government Area, Akwa Ibom State. The creek empties into the Qua Iboe River, which connects directly to the Atlantic Ocean. Two oil and gas flare stacks are located a few meters from this creek (Anarado *et al.* 2023). Despite this, the area supports settlements and markets for fishermen, traders, timber dealers, and other human activities. In such a region, where the economy and livelihoods of residents are closely tied to the aquatic environment, regular assessment of water quality is vital for safety, sustainable development, and environmental management (Okpoji *et al* 2025).

Considering these activities, the physicochemical parameters of water and sediment in Douglas Creek may experience significant seasonal variations that could affect the ecological balance and overall health of the aquatic system (Nyantakyi *et al*., 2019). This research therefore seeks to determine the physicochemical parameters of Douglas Creek and examine their seasonal changes, with emphasis on their potential impacts on aquatic life.

2. LITERATURE REVIEW

Seasonal variation in water quality has been widely documented across aquatic ecosystems, with marked differences in physicochemical parameters between wet and dry periods. In West Africa, Nyantakyi *et al.* (2019) observed significant seasonal fluctuations in heavy metals in the River Tano, attributing changes to rainfall-driven dilution and concentration effects during the dry season. Similar patterns of seasonal variability in suburban rivers of the Democratic Republic of Congo were reported by Nienie *et al.* (2017), who found that physicochemical indices and trace metals were strongly influenced by hydrological cycles (Okpoji *et al.* 2025). Within the Niger Delta, oil exploration and industrial effluents have compounded natural seasonal changes, often resulting in elevated contaminant levels that threaten aquatic biodiversity and public health (Nriagu *et al*., 2016; Ugochukwu & Ertel, 2008). Research has also highlighted the impacts of specific physicochemical parameters (Udo *et al*., 2020). Chloride levels, for instance, have been shown to increase substantially during dry seasons due to evaporation and saline intrusion, as reported in arid and semi-arid urban creeks (Breen & Maguire, 2020; Evans *et al*., 2018). Salinity fluctuations are a major concern in freshwater systems exposed to seasonal hydrological shifts, with elevated dry-season values stressing aquatic organisms and reducing biodiversity (Williams, 2018). Other studies have emphasized the role of sulphates and phosphates, where anthropogenic inputs and reduced dilution can lead to water quality deterioration and potential eutrophication risks (Ma *et al*., 2016; Zhu & Ma, 2020).

In addition, studies on chemical oxygen demand (COD) reveal seasonal dynamics linked to organic matter inputs. Elevated COD levels during wet seasons often result from surface runoff transporting organic debris, while dry-season values may reflect evaporation-driven concentration or localized human activity (Rodriguez & Tockner, 2020; Bai, 2019; Hassett, 2021). Turbidity and sediment dynamics also follow seasonal patterns, with low-flow conditions in the dry season promoting sediment resuspension and higher particulate concentrations (Foster & Brooks, 2018; Schlesinger, 2019).

Although these studies provide valuable insights into seasonal water quality variation, few have focused specifically on creeks in the Niger Delta. Douglas Creek, located within a region of intense oil exploration, presents a unique case where industrial activities coincide with natural seasonal changes, amplifying risks to water quality and ecosystem health.

3. METHODOLOGY

3.1. Study area

This research was conducted on water samples collected from Douglas Creek, located in Ibeno, a coastal area within Akwa Ibom State, Nigeria. Ibeno lies along the Atlantic coast and forms part of the Niger Delta region, which is renowned for its rich oil deposits. Douglas Creek is situated close to petroleum exploration and production zones, where oil-related activities are intense and continuous. The creek is geographically located at approximately Latitude 4.5500° N and Longitude 7.9500° E, positioning it near the Atlantic Ocean within the Niger Delta, an area characterized by extensive oil and gas operations. Sampling sites were selected based on the intensity of anthropogenic activities in the vicinity, including fishing, trading, and industrial discharges. Douglas Creek, a vital estuarine ecosystem, serves both ecological and socio-economic functions for surrounding communities. Figures 3a and 3b present the map of the study area and photographs of the sampling stations.

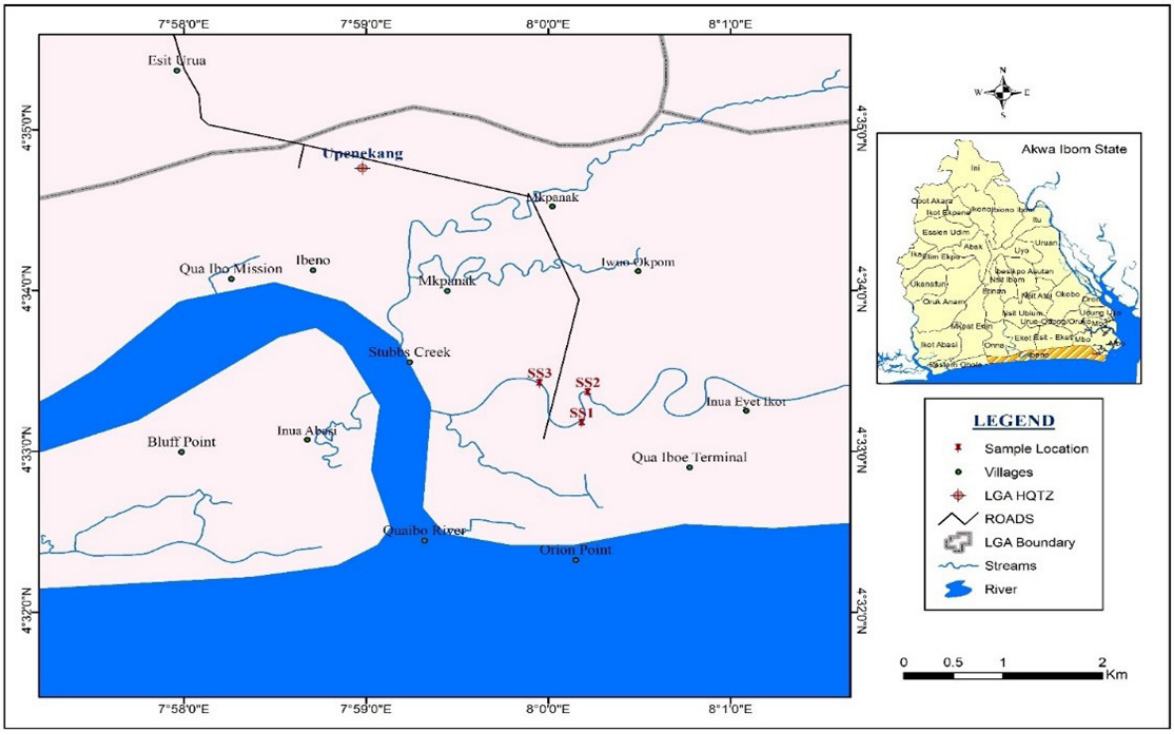

Figure 1. Map of the study area indicating douglas creek and the sample stations

Table 1. GPS Cordinates of the sampling stations

Sampling Station	Latitude	Longitude
Sampling Station 1 (SS1)	Lat 04° 33′ 10.71′′N	Long 008° 0′ 10.50′′E
Sampling Station 1 (SS2)	Lat 04° 33′ 14.7′′N	Long 008° 0′ 11.85′′E.
Sampling Station 1 (SS2)	Lat 04° 33′ 19.1′′N	Long 008° 0′ 10.35′′E

3.2. Water sample collection

Surface water samples were collected directly into appropriate containers from Douglas Creek during both dry (January–March) and wet (July–September) seasons. Sampling sites were spaced approximately 200 meters apart. Collection, preservation, and transportation of samples followed the standard protocols of the American Public Health Association (6). Samples for hydrocarbon analysis were stored in pre-cleaned 1.0 L glass bottles, while 1.5 L polyethylene bottles were used for physicochemical analyses. For metal analyses, samples were acidified to pH 2 with concentrated nitric acid (HNO_3). Each sampling point was sampled in triplicate, homogenized, and collected monthly for six months. Prior to sampling, bottles and caps were cleaned with nitric acid and rinsed three times with site water. Composite samples were stored in an ice box at 4 °C and refrigerated until analysis.

3.3. Determination of physicochemical parameters of water

All analyses were performed following standardized procedures of the American Society for Testing and Materials (6, 7–9). Specific methods and instrumentation are outlined below.

3.4. Determination of pH, Temperature, TDS and Conductivity

pH, temperature, total dissolved solids (TDS), salinity, conductivity, and dissolved oxygen were measured in situ using a Hach multimeter, calibrated with pH 7.0 and 10.0 buffer solutions. Probes were immersed directly in water samples and readings recorded from the digital display. Redox potential in sediment was determined in situ with a Winlab pH/ORP meter (factory calibrated). Electrodes were inserted directly into sediments, readings were taken, and probes rinsed with distilled water after each use.

3.5. Determinations of total suspended solid in water samples

TSS was determined following APHA 2540. Well-mixed samples were filtered through a pre-weighed 0.45 µm Millipore filter using a vacuum pump. Filters were dried at 103–105 °C to constant weight. TSS (mg/L) was calculated as:

$$TSS\ (mg/l) = \frac{(weight\ of\ filter + residue.mg/l) - (weight\ of\ filter.\ mg/l)\ X\ 1{,}000}{Sample\ volume.\ ml}$$

3.6. Determination of alkalinity

Phenolphthalein alkalinity: 50 mL of each sample was titrated with 0.02 M HCl after adding phenolphthalein indicator. The absence of color indicated zero phenolphthalein alkalinity.

Methyl orange alkalinity: The same solution was treated with methyl orange indicator (yellow) and titrated with 0.02 M HCl to a faint pink endpoint.

$$Alkalinity\ (meq/L) = \frac{Volume\ of\ acid\ (mL) \times Normality\ of\ acid}{Volume\ of\ sample\ (L)}$$

3.7. Chemical Oxygen Demand (COD) in water samples

COD was determined using Hach DR Method 8000, based on APHA 5220D. Two mL of water sample was digested with potassium dichromate reagent in COD tubes for 2 hours, cooled, and measured colorimetrically.

3.8. Determination of turbidity

Turbidity was measured using a Hach 2100P turbidimeter (0–800 NTU range), calibrated with distilled water and standards (0.1, 20, 100, 800 NTU). Results were expressed in NTU.

3.9. Determination of hardness of water

Hardness was determined by EDTA titration, measuring Ca^{2+} and Mg^{2+} concentrations.

$$Hardness\ (ppm\ CaCO_3) = \frac{Volume\ of\ EDTA\ used\ (mL) X\ EDTA\ concentration\ (M)}{Volume\ of\ water\ sample\ (mL)} X\ 1000$$

3.10. Determination of chloride ions

To 100 ml of each water sample, three drops of 5 % K_2CrO_4 indicator was added and titrated with a standard 0.02 M $AgNO_3$ until the colour changed from yellow to brick red.

Chloride concentration in the water sample was calculated using the formula:

$$Chloride\ (mg/L) = \frac{V \times N \times 35.45 \times 1000}{Volume\ of\ the\ Sample}$$

Where,

V = Volume of $AgNO_3$ used in titration (mL); N = Normality of $AgNO_3$ solution (or molarity of $AgNO_3$); 35.45 = Equivalent weight of chloride ion (Cl^-).

3.11. Determination of nitrate (NO^{3-})

Nitrate content in water samples was determined by cadmium reduction method using Hach DR 3900 spectrophotometer in line with Hach method 8039, the method is based on Nitra Ver 5 method. A sample cell was filled with 10ml of water sample to which the content of one Nitra Ver 5 reagent powder pillow was added. A stopper was used to cover the sample cell and the content of the cell shaken vigorously for one minute. The mixture was then allowed to react for 5 minutes. The prepared sample was measured using the Nitrate Hach program number and results displayed in mg/l .

3.12. Determination of phosphate (PO_4^{3-})

Phosphate in water samples was determined using Hach DR 3900 spectrophotometer in line with Hach method 8048 a derivative of EPA standard methods 365.1, 365.3, the method is based on PhosVer 3 (Ascorbic acid) method. A sample cell was filled with 10ml of the water sample to which the content of one PhosVer 3 phosphate powder pillow was added. The mixture was capped and inverted severally to mix allowed a reaction time of 2 minutes. The prepared sample was measured using the Phosphate Hach program number and results displayed in mg/l

3.13. Determination of sulphate (SO_4^{2-})

Sulphate in water samples was determined using Hach DR 3900 spectrophotometer method 8051 adapted from standard methods for the examination of water and wastewater in line with USEPA method 375.4. The method is based on SulfaVer 4 powder pillow method. A sample cell was filled with 10ml of the water sample to which the content of one SulfaVer 4 powder pillow was added. The mixture was capped and swirled to mix and then allowed a reaction time of 5 minutes. The prepared sample was measured using the Sulphate Hach program number and results displayed in mg/l.

3.14. Determination of total petroleum hydrocarbon (TPH)

TPH was analyzed using an Agilent 7890 Gas Chromatograph (GC) following ASTM D7066 and EPA 8015. Samples were extracted with dichloromethane, purified with silica gel and sodium sulfate, and analyzed with GC after calibration with n-alkane standards.

3.15. Determination of Ca^{2+}, Mg^{2+}, K^+ and Na^+ in Water

Cation concentrations were determined using Atomic Absorption Spectrophotometry (AAS; APHA 3111B, 3111D). Standards were prepared to generate calibration curves, and direct aspiration into an air/acetylene flame was used for analysis.

3.16. Statistical analysis

Data were analyzed using independent t-tests in the Statistical Package for the Social Sciences (SPSS) to compare dry and wet season parameters. Correlation analyses were also performed to evaluate relationships among physicochemical parameters.

3.17. Quality assurance and quality control (QA/QC)

To ensure reliability and accuracy of results, strict QA/QC procedures were followed throughout sampling and analysis. All instruments were calibrated prior to use with certified reference standards supplied by the manufacturers. The Hach multiparameter probe, turbidimeter, and spectrophotometer were calibrated daily with appropriate buffer and standard solutions. For Atomic Absorption Spectrophotometry (AAS) and Gas Chromatography (GC) analyses, calibration curves were prepared using multi-element certified standard solutions, and only results within the acceptable correlation coefficient ($R^2 \geq 0.995$) were considered valid. Duplicate samples and procedural blanks were included for every batch of analyses to monitor precision and potential contamination. Recovery experiments were performed by spiking selected samples with known concentrations of analytes, with recovery rates maintained between 85% and 115%. Method detection limits (MDLs) were established for all measured parameters following APHA (1995) guidelines. Reproducibility of results was confirmed by analyzing at least 10% of samples in duplicate, and results were reported as mean values of replicate determinations.

4. RESULTS AND DISCUSSION

Evaluation of water quality parameters revealed clear seasonal fluctuations in Douglas Creek (Table 2). Dry-season samples (January–March 2024) exhibited significantly higher concentrations of several key parameters compared to wet-

season samples (July–September 2023). Electrical conductivity increased from 189–267 µS/cm in the wet season (mean = 278.67 µS/cm) to 25,000–35,000 µS/cm in the dry season (mean = 30,344.67 µS/cm), a statistically significant difference (t = −10.282, p = .009). Chloride concentrations rose sharply from 14.50–25.00 mg/L (mean = 20.02 mg/L) to 11,797–18,976 mg/L (mean = 15,881.00 mg/L; t = −7.455, p = .018). Salinity also increased markedly, averaging 175.33 mg/L in the wet season versus 23,028.67 mg/L in the dry season (t = −15.462, p = .004). Turbidity showed a similar trend, rising from 5.33 NTU to 306.67 NTU (t = −8.325, p = .014). Cation concentrations were notably higher in the dry season, with calcium increasing from 129.33 mg/L to 359.40 mg/L (t = −10.485, p = .009) and potassium from 12.97 mg/L to 198.27 mg/L (t = −7.265, p = .018). In contrast, parameters such as pH, temperature, and dissolved oxygen showed no significant seasonal variation, suggesting relative stability across hydrological cycles (Table 2).

Table 2. Seasonal variation in water quality parameters of douglas creek

Parameters	Wet Season		Dry Season				WHO Standards for drinking water quality (2022)
	Mean	Standard Error	Mean	Standard Errort- criteria		p-value	
pH	7.08	0.1965	7.23	0.2667	-0.4	0.728	6.5 – 8.5
Temperature (°C)	25.57	0.3383	26.30	0.3512	-1.065	0.399	
Electrical Conductivity (µS/cm)	278.67	55.44467	30344.67	2907.2545	-10.282	0.009	
Chloride (mg/l)	20.02	3.04309	15881.00	2130.5790	-7.455	0.018	250
Total Dissolved Solids (mg/l)	145.90	39.13877	69166.67	54921.4085	-1.256	0.336	1000
Total suspended Solids (mg/l)	0.68	0.19221	1.97	0.6065	-1.612	0.248	
Chem. Oxygen Demand (mg/l)	10.00	2.3094	10.08	1.4523	-0.026	0.982	
Dissolved oxygen (mg/l)	5.73	0.19877	5.68	0.3032	0.087	0.938	
Salinity (mg/l)	175.33	23.13247	23028.67	1499.3849	-15.462	0.004	
Turbidity (NTU)	5.33	1.85592	306.67	37.5648	-8.325	0.014	<5
Sulphate (mg/l)	18.00	2.64575	15.78	5.3878	0.332	0.772	500
Nitrate mg/l)	0.22	0.01202	0.33	0.0481	-1.877	0.201	50
Phosphate (mg/l)	0.00	0.00	0.05	0.0371	-1.257	0.336	
Mg (mg/l)	173.33	8.08977	306.00	40.4640	-3.571	0.07	
K (mg/l)	12.97	1.07445	198.27	26.2657	-7.265	0.018	
Na (mg/l)	1.10	0.56439	28.10	9.1128	-3.076	0.091	
Ca (mg/l)	129.33	4.66667	359.40	21.6786	-10.485	0.009	
Alkalinity (mg/l)	161.67	23.15407	113.67	13.1698	1.546	0.262	
TPH (mg/l)	0.00	0	0.00	0.0000	-7.312	0.018	
Hardness (mg/l)	101.67	29.62731	4896.67	635.0940	-0.4	0.000	

4.1. pH

The wet season exhibited slightly lower pH values (≈6.70–7.35), likely due to rainfall-driven runoff that introduces organic matter and other inputs capable of acidifying surface waters. In the dry season, pH was marginally higher (≈6.70–7.50), consistent with reduced water volume, diminished dilution, and concentration of alkaline minerals. This pattern aligns with findings from the Lukemi and Luini rivers in the Democratic Republic of Congo, where lower wet-season pH values were similarly reported (Nienie *et al.*, 2017). Notably, more acidic conditions can enhance the mobilization of heavy metals from sediments and surrounding soils, increasing dissolved concentrations of elements such as Pb, As, Cu, Ni, Cd, Cr, and Zn. Consequently, consumption of untreated, low-pH water may elevate the risk of chronic metal exposure and related toxicity, as shown in Figure 2.

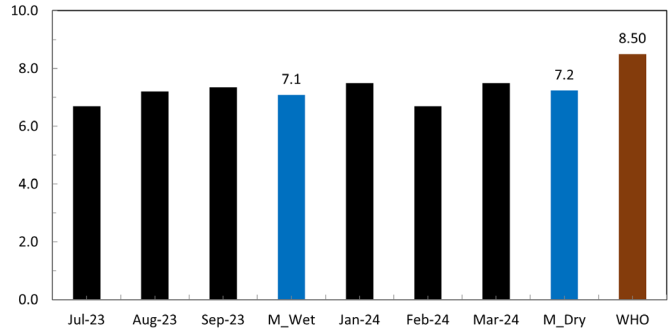

Figure 2. Seasonal Variation of pH of water in Douglas creek

4.2. Temperature

The mean water temperature in the wet season (25.57 °C) falls within the optimal range for most freshwater ecosystems, indicating minimal thermal stress on aquatic organisms. In contrast, the dry-season average (26.63 °C) is slightly above this range and may impose thermal stress on sensitive species. The cooler wet-season values likely reflect increased rainfall, cloud cover, and greater water flow, while higher dry-season temperatures correspond to stronger solar radiation and reduced dilution. Although the World Health Organization (WHO, 2022) does not specify guideline values for temperature, it is recognized as an important factor influencing oxygen solubility and other physicochemical properties that determine ecosystem health. Typical freshwater systems function optimally between 20 °C and 25 °C; thus, the dry-season values in Douglas Creek may marginally reduce water quality and alter ecological balance, as shown in Figure 3.

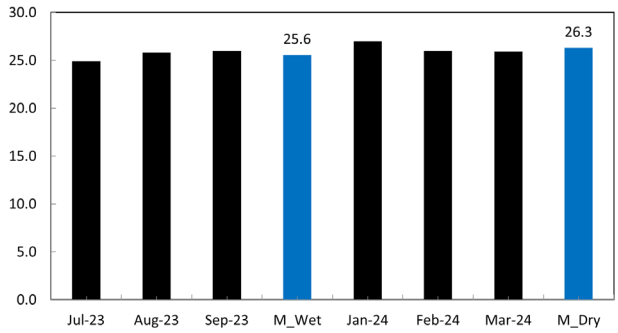

Figure 3. Seasonal variation of temperature of water in douglas creek

4.3. Electrical Conductivity

Electrical conductivity (EC) reflects the concentration of dissolved salts, minerals, and ions in water. Data from Douglas Creek show pronounced seasonal variation, with EC values rising sharply in the dry season compared to the wet season. This increase indicates elevated ionic concentration during low-flow periods, most likely caused by evaporation, reduced freshwater dilution, and enhanced mineral inputs. Conversely, the wet season is characterized by substantially lower EC values, largely due to rainfall and runoff, which dilute dissolved ions (Breen & Maguire, 2020; Evans *et al.*, 2018; Ma *et al.*, 2016; Okpoji *et al.* 2025). These seasonal shifts highlight the strong influence of hydrological cycles on the ionic composition and overall water quality of Douglas Creek, as shown in Figure 4.

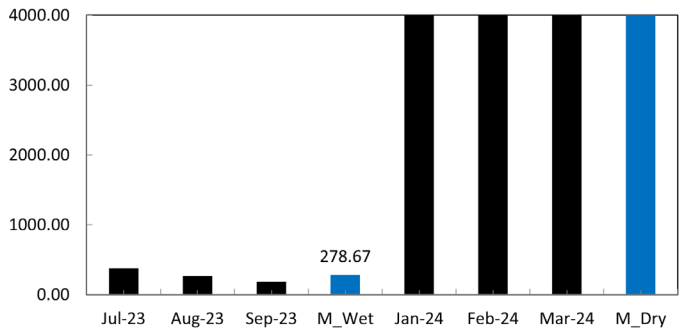

Figure 4. Seasonal Variation of Electrical Conductivity (µS/cm) in water of Douglas creek

4.4. Chloride

Chloride concentrations in Douglas Creek showed marked seasonal differences. During the wet season, values remained relatively low (14.50–25.00 mg/L), reflecting the dilution effect of rainfall and runoff. These levels fall well within the World Health Organization (WHO, 2022) guideline of 250 mg/L for drinking water, indicating that wet-season chloride concentrations are suitable for most domestic and agricultural uses. In contrast, chloride concentrations increased dramatically in the dry season (11,797.00–18,976.00 mg/L), far exceeding the WHO limit and typical freshwater ranges. Such elevated values are likely the result of intense evaporation, reduced freshwater inflow, and possible saline intrusion. Elevated chloride disrupts osmoregulation in freshwater organisms, causing physiological stress or mortality (Evans *et al.*, 2018). Moreover, concentrations of this magnitude pose serious challenges for human and agricultural use, making the water unsuitable for drinking, irrigation, or industrial applications without treatment. The sharp rise in chloride during the dry season also suggests long-term salt accumulation in sediments, which could degrade both soil and water quality (Okpoji *et al.* 2025). These findings align with reports from other estuarine and deltaic environments where seasonal hydrological changes drive salinity imbalances (Breen & Maguire, 2020; WHO, 2022). Collectively, the results highlight chloride as a critical indicator of dry-season water quality deterioration in Douglas Creek, as shown in Figure 5.

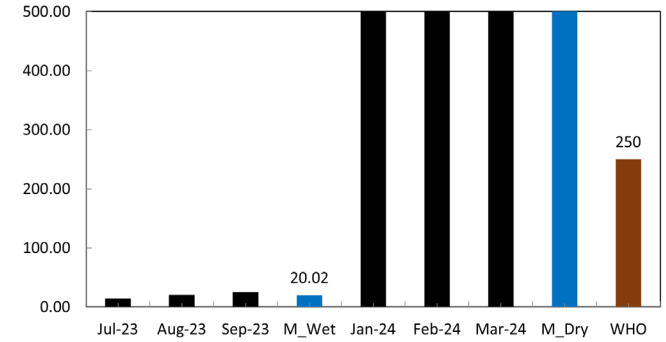

Figure 5. Seasonal variation of chloride (mg/l) in water of douglas creek

4.5. Sulphate

Sulphate concentrations in Douglas Creek exhibited modest seasonal variation, influenced by both environmental conditions and anthropogenic activities. In the wet season, concentrations

ranged from 14.00 to 23.00 mg/L, reflecting the diluting effect of rainfall and increased water flow, which reduce the accumulation of dissolved ions. These values are well below the World Health Organization (WHO, 2022) guideline of 500 mg/L for drinking water, indicating that sulphate does not pose a health concern during this period. In the dry season, sulphate levels fluctuated more widely (6.34–25.00 mg/L). The lower values may be linked to reduced surface runoff and minimal external inputs, whereas the higher values likely result from localized factors such as leaching of sulphate-rich sediments or groundwater contributions (Ma *et al.*, 2016). Evaporation during the dry season may also play a role in concentrating dissolved sulphate. However, sulphate levels in Douglas Creek remain well within permissible limits year-round, and the observed variability highlights the influence of seasonal hydrological processes and potential point sources on water chemistry. Continued monitoring is essential, given sulphate's role in influencing water taste, corrosion, and aquatic ecosystem health, as shown in Figure 6.

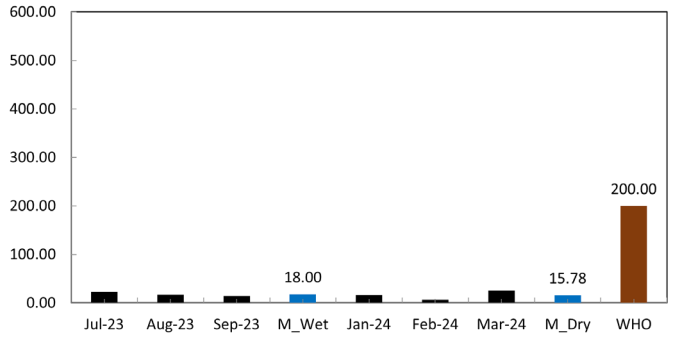

Figure 6. Seasonal variation of sulphate (mg/l) in water of douglas creek

4.6. Nitrate

Nitrate concentrations in Douglas Creek displayed slight seasonal variation but remained consistently low relative to international standards. During the wet season, values ranged from 0.20 to 0.24 mg/L, reflecting the dilution effect of rainfall and increased flow, which reduce nitrate accumulation in surface waters. Nitrate inputs typically originate from agricultural runoff, sewage, or industrial effluents, yet the enhanced dilution during the rainy period likely minimizes their impact (Nienie *et al.*, 2017; Zhu & Ma, 2020). In the dry season, nitrate concentrations rose marginally to 0.24–0.40 mg/L, a pattern attributable to evaporation, reduced water volume, and possible leaching from surrounding soils. Despite this increase, all measured concentrations were well below the World Health Organization (WHO, 2022) guideline of 50 mg/L for drinking water. Nitrate levels in Douglas Creek remain within safe limits for human consumption and do not pose risks such as methemoglobinemia ("blue baby syndrome"). However, continued monitoring is recommended, as elevated nitrate levels can contribute to eutrophication and long-term ecological imbalance if external inputs increase, as shown in Figure 7.

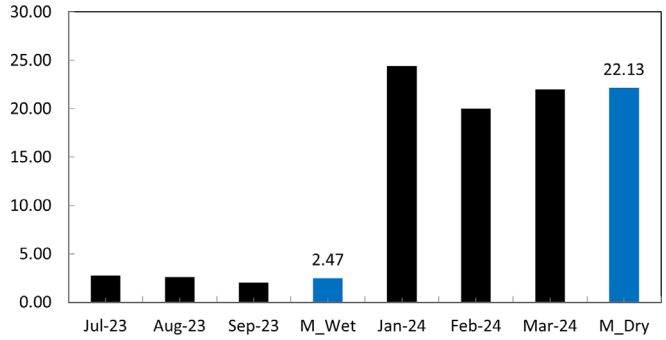

Figure 7. Seasonal variation of nitrates (mg/kg) in sediment of douglas creek

Phosphate is an essential nutrient for aquatic ecosystems, but elevated concentrations can promote eutrophication and degrade water quality. In Douglas Creek, wet-season phosphate concentrations were below detectable limits (0.00 mg/L), likely reflecting rainfall-induced dilution and nutrient flushing. The absence of measurable phosphate also suggests that external inputs were minimal or that available phosphate was rapidly assimilated by aquatic plants or bound to sediments. During the dry season, phosphate concentrations rose slightly, with values of 0.02 mg/L and 0.12 mg/L recorded, while one sample remained undetectable. This modest increase may be linked to reduced water flow, leaching from sediments, or localized anthropogenic influences such as domestic or agricultural runoff (Zhu & Ma, 2020). Although still low, these values highlight the potential for seasonal nutrient enrichment under drier conditions. The World Health Organization (WHO, 2022) does not provide a guideline for phosphate in drinking water, as it is not considered directly hazardous to human health at these concentrations. However, elevated phosphate can indirectly threaten aquatic ecosystems by stimulating algal blooms, which reduce dissolved oxygen and impair biodiversity. Thus, even low-level seasonal increases in phosphate warrant continued monitoring to prevent long-term eutrophication risks, as shown in Figure 8.

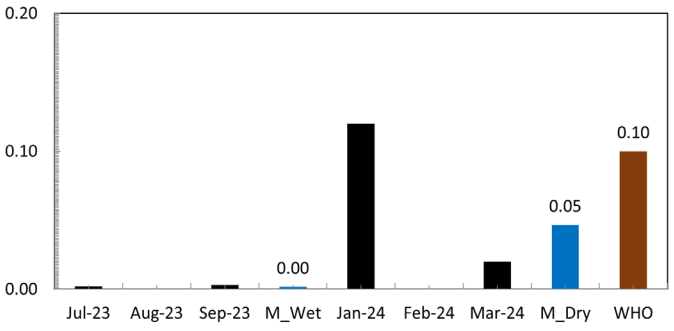

Figure 8. Seasonal variation of phosphates (mg/L) in water of douglas creek

4.7. Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) in Douglas Creek exhibited pronounced seasonal variation, with concentrations rising dramatically during the dry season compared to the wet

season. Peak values reached 179,000 mg/L in March, while wet-season concentrations remained relatively low. This sharp disparity reflects the combined effects of evaporation, reduced freshwater inflow, and the accumulation of dissolved minerals as water levels decline during the dry season. High evaporation rates in arid and semi-arid climates are known to concentrate salts and other dissolved solids, particularly when inflows are limited and minerals are not flushed out by rainfall. Previous studies have shown that TDS tends to increase under conditions of low water flow and intense evaporation, patterns consistent with seasonal hydrological shifts (Breen & Maguire, 2020; Evans *et al.*, 2018; Ma *et al.*, 2016; Williams, 2018). In addition, reduced precipitation and runoff during the dry season may promote the accumulation of salts, while anthropogenic inputs from urban or agricultural sources could further elevate concentrations (World Health Organization [WHO], 2022). Although WHO recommends a limit of 1,000 mg/L for TDS in drinking water (for aesthetic and palatability reasons), dry-season concentrations in Douglas Creek far exceeded this value, making the water unsuitable for direct consumption or many domestic and agricultural uses. Beyond human health concerns, excessive TDS can alter aquatic habitat quality by affecting osmotic balance in aquatic organisms, thereby reducing biodiversity and overall ecosystem resilience (U.S. Environmental Protection Agency [EPA], various years), as shown in Figure 9.

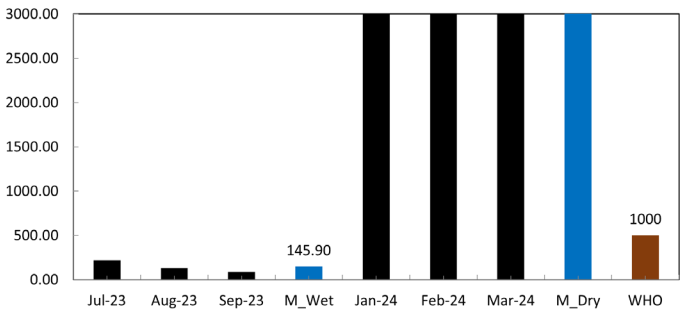

Figure 9. Seasonal variation of total dissolved solids (mg/l) in water of douglas creek

4.8. Chemical Oxygen Demand (COD)

Chemical Oxygen Demand (COD) in Douglas Creek showed seasonal variation, with moderately higher values in the wet season (peaking at 14 mg/L in July) and lower but fluctuating values in the dry season (up to 12 mg/L in March). Elevated wet-season COD reflects runoff carrying organic matter and debris, particularly during early rains when accumulated materials are flushed into the creek (Breen & Maguire, 2020; Evans *et al.*, 2018). As the season progresses, dilution reduces COD, as observed in September (6 mg/L). In contrast, lower dry-season values suggest reduced external inputs, though occasional peaks may result from evaporation concentrating residual organic matter or from human and animal activities near the water (Rodriguez & Tockner, 2020; Bai, 2019), as shown in Figure 10.

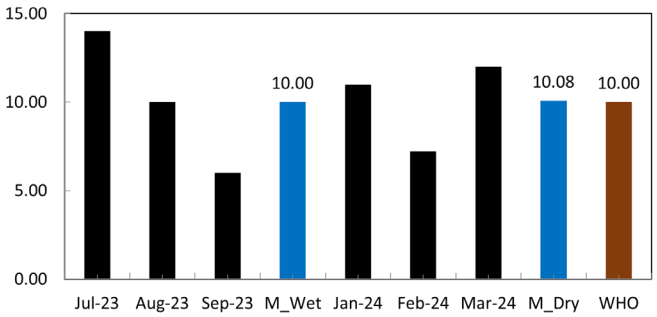

Figure 10. Seasonal variation of chemical oxygen demand (mg/l) in water of douglas creek

4.9. Salinity

Salinity in Douglas Creek varied seasonally, with much higher concentrations in the dry season compared to the wet season. Values peaked at 25,000 mg/L in March, while wet-season levels remained low (130–206 mg/L). This sharp increase is largely attributed to evaporation, reduced freshwater inflow, and possible leaching of salts from surrounding soils and rocks. Similar patterns have been reported in arid and semi-arid systems, where limited rainfall and runoff reduce dilution and promote salt accumulation (Breen & Maguire, 2020; Evans *et al.*, 2018; Ma *et al.*, 2016; Williams, 2018; Hassett, 2021). Such elevated salinity poses ecological risks by stressing freshwater organisms and degrading overall water quality, as shown in Figure 11.

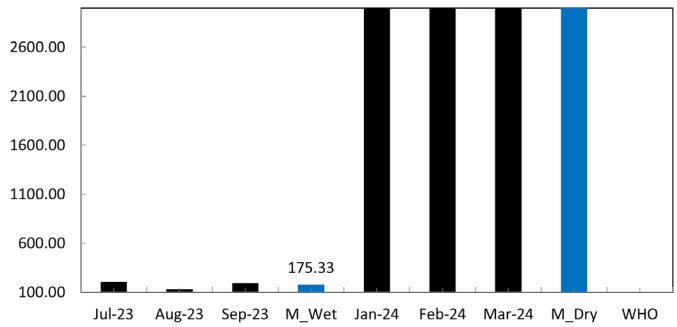

Figure 11. Seasonal variation of salinity (mg/l) in water of douglas creek

4.10. Turbidity

Turbidity reflects the cloudiness of water caused by suspended particles such as sediments, organic matter, algae, and pollutants, and is widely used as an indicator of water clarity. In Douglas Creek, turbidity showed a strong seasonal contrast, with significantly higher values recorded during the dry season (240–370 NTU) compared to the wet season (3–9 NTU). This sharp increase in the dry season likely results from reduced water flow, which prevents suspended particles from being flushed out, as well as enhanced sediment resuspension and particulate accumulation. Similar patterns have been reported in semi-arid streams, where low flows during dry periods allow sediments to persist in the water column (Foster & Brooks, 2018; Chapman, 1996). High turbidity levels reduce light penetration, limiting photosynthesis in aquatic plants, and can increase

water temperature by absorbing more solar radiation. Such conditions degrade habitat quality, impair oxygen dynamics, and may negatively affect aquatic biodiversity. Importantly, dry-season values in Douglas Creek far exceed the World Health Organization (WHO, 2022) aesthetic guideline of <5 NTU for drinking water, making the water unsuitable for direct human consumption without treatment. Water hardness in Douglas Creek also demonstrated marked seasonal variability. During the dry season, hardness levels ranged from 3,800 to 6,000 mg/L, compared to much lower wet-season values. This dramatic increase is primarily attributable to evaporation and reduced freshwater inflow, which concentrate dissolved minerals, particularly calcium and magnesium—the two dominant contributors to hardness (Ma *et al.*, 2016; Williams, 2018). Additional contributions may arise from mineral leaching from surrounding soils during dry conditions. The observed March peak of 6,000 mg/L highlights the intensity of mineral concentration under prolonged dry-season evaporation (Ite *et al.*, 2019). While hardness itself is not directly harmful to health, excessively high values can impair water suitability for drinking, irrigation, and industrial use. Adverse effects include scale formation in pipes and reduced efficiency of boilers and other equipment. Ecologically, extreme hardness can stress aquatic organisms that are sensitive to ionic balance, further diminishing biodiversity and ecosystem resilience (Figure 12).

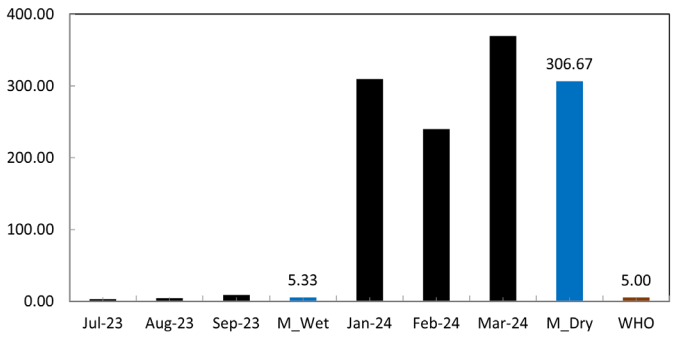

Figure 12. Seasonal variation of turbidity (NTU) in water of douglas creek

4.11. Cations

The results indicate marked seasonal differences in cation concentrations, largely driven by hydrological, geochemical, and biological processes. Magnesium concentrations were higher during the dry season, reflecting the effects of evaporation and reduced water flow, which concentrate dissolved minerals. Contributions from groundwater enriched with magnesium may also have played a role, while the observed decrease in sediment magnesium in the same period suggests desorption into the water column or reduced detrital inputs during low-flow conditions (Chapman, 1996). Calcium followed a similar trend, showing significant increases in the dry season due to evaporation, reduced dilution, and the influence of groundwater rich in dissolved calcium carbonate. Potassium exhibited a sharp rise from an average of 12.97 mg/L in the wet season to 198.27 mg/L in the dry season, a change that may be linked to mineral weathering under reduced dilution and agricultural runoff introducing potassium-based fertilizers. Sodium concentrations also increased substantially, from an average of 1.10 mg/L in the wet season to 28.10 mg/L in the dry season, likely as a result of evapotranspiration and saline groundwater inflow during periods of low rainfall. Collectively, these patterns demonstrate that evaporation and hydrological imbalance during the dry season strongly influence the ionic composition of Douglas Creek, leading to elevated mineral loads that may compromise water quality, reduce suitability for domestic and agricultural uses, and impose stress on freshwater organisms as shown Figure 13.

4.12. Total Petroleum Hydrocarbons (TPH)

In both wet and dry seasons, TPH concentrations were reported as 0.00 mg/L. While this suggests the absence of detectable petroleum hydrocarbon contamination in Douglas Creek during the study period, it is important to interpret this result cautiously. The values likely reflect concentrations below the method detection limit (MDL) rather than an absolute absence of hydrocarbons. The analytical procedure employed (ASTM D7066 and EPA 8015 using GC) has an MDL typically in the range of 0.01–0.05 mg/L, depending on instrument sensitivity and calibration standards. Thus, the recorded value of 0.00 mg/L should be understood as "below detection limit (BDL)."

Given the proximity of Douglas Creek to oil exploration and production facilities, the finding of non-detectable TPH warrants further consideration. It may reflect effective natural attenuation, dilution from tidal exchange with the Atlantic Ocean, or the absence of recent spill events during the sampling period. However, it could also be due to analytical limitations, such as volatilization losses during storage and handling or detection thresholds that were not sufficiently sensitive to capture trace levels of hydrocarbons (Ekanem *et al.*, 2019).

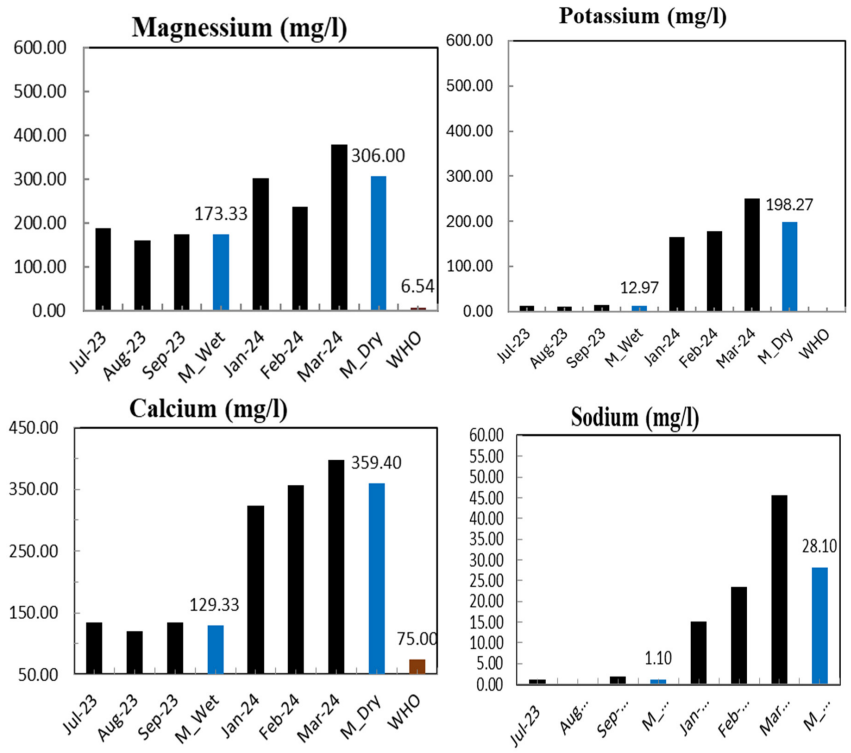

Figure 13. Seasonal variation of cations (mg/l) in water of douglas creek

5. CONCLUSION

The assessment of seasonal variations in Douglas Creek revealed profound differences in water and sediment quality between the wet and dry seasons. While rainfall during the wet season enhanced dilution and reduced pollutant concentrations, the dry season was characterized by extreme increases in conductivity, chloride, salinity, turbidity, hardness, and cation loads. These shifts are not merely alterations in water chemistry but represent ecologically catastrophic conditions that threaten aquatic biodiversity and destabilize ecosystem resilience. The exceedance of multiple World Health Organization (WHO) limits in the dry season underscores a public health crisis for communities that rely on the creek for drinking water, fishing, and other domestic uses.

The finding that Douglas Creek becomes highly saline and mineral-laden during the dry season means the water is unsuitable for consumption, irrigation, or most domestic applications without significant treatment. This situation endangers food security, livelihoods, and long-term ecological sustainability in the Niger Delta. Continuous monitoring, strict regulation of industrial discharges, and urgent intervention measures are required to mitigate these risks. In addition, awareness campaigns must be intensified to educate local communities on the dangers of direct creek use during the dry season. Without decisive management actions, Douglas Creek could transition into a permanently degraded aquatic system with severe socio-economic and health consequences.

REFERENCES

Anarado, C. J. O., Okpoji, A. U., & Anarado, C. E. (2023). Bioaccumulation and health risk assessment of lead, cadmium, arsenic, and mercury in blue crabs found in creeks in Bayelsa State of Niger Delta region of Nigeria. *Asian Journal of Environmental & Ecology, 21*(4), 46–59.

American Public Health Association. (1995). *Standard methods for the examination of water and wastewater* (19th ed.). APHA.

ASTM International. (2016). *ASTM D7066 and related standards for petroleum hydrocarbons in water.*

Bai, J. (2019). Seasonal variations in chemical oxygen demand and organic load in arid and semi-arid streams. *Water Research, 155*, 127–135. https://doi.org/10.1016/j.watres.2019.02.020

Benson, R., Conerly, O. D., Sander, W., Batt, A. L., Boone, J. S., Furlong, E. T., Glassmeyer, S. T., Kolpin, D. W., Mash, H. E., Schenck, K. M., & Simmons, J. E. (2017). Human health screening and public health significance of contaminants of emerging concern detected in public water supplies. *Science of the Total Environment, 579*, 1643–1648. https://doi.org/10.1016/j.scitotenv.2016.03.146

Breen, J., & Maguire, L. (2020). Chloride concentration variations in arid and semi-arid urban creeks: Seasonal impacts of evaporation and reduced inflow. *Environmental Monitoring and Assessment, 192*, 553. https://doi.org/10.1007/s10661-020-08565-1

Chapman, D. (1996). *Water quality assessments: A guide to the use of biota, sediments, and water in environmental monitoring* (2nd ed.). UNESCO/WHO/UNEP.

Ekanem, A., Ikpe, E., & Ekwere, I. (2019). Assessment of polycyclic aromatic hydrocarbons levels in soil around automobile repair workshops within Eket metropolis, Akwa Ibom State, Nigeria. *International Journal of Research and Scientific Innovation, 6*(1), 102–107.

Evans, M., Frick, C., & Poirier, D. (2018). The effect of chloride on freshwater ecosystems: A comprehensive review. *Environmental Reviews, 26*(2), 152–162. https://doi.org/10.1139/er-2017-0040

Foster, R. C., & Brooks, M. L. (2018). Sediment dynamics and turbidity in low-flow arid streams. *Hydrological Processes, 32*(7), 1120–1132. https://doi.org/10.1002/hyp.11481

Hach Company. (various years). *Hach methods 8000, 8039, 8048, 8051; DR 3900 procedures*. Loveland, CO.

Hassett, B. (2021). Seasonal organic matter dynamics and oxygen demand in semi-arid watersheds. *Environmental Monitoring and Assessment, 193*, 470. https://doi.org/10.1007/s10661-021-09192-2

Ite, A. E., Harry, T. A., Obadimu, C. O., & Ekwere, I. O. (2019). Comparison of indoor air quality in schools: Urban vs. industrial 'oil & gas' zones in Akwa Ibom State, Nigeria. *Journal of Environment Pollution and Human Health, 7*(1), 15–26.

Ma, Y. H., Su, C. L., Liu, W. J., Zhu, Y. P., & Li, J. X. (2016). Identification of sulfate sources in the groundwater system of Zaozhuang: Isotopic and hydrochemical evidence. *Environmental Science, 37*, 4690–4699.

Nienie, A. B., Sivalingam, P., Laffite, A., Ngelinkoto, P., Otamonga, J. P., Matand, A., Mulaji, C. K., Mubedi, J. I., Mpiana, P. T., & Poté, J. (2017). Seasonal variability of water quality by physicochemical indexes and traceable metals in suburban area in Kikwit, DRC. *International Soil and Water Conservation Research, 5*(2), 158–165. https://doi.org/10.1016/j.iswcr.2017.02.002

Nriagu, J. O., Udofia, E. A., Ekong, I., & Ebuk, G. (2016). Health risks associated with oil pollution in the Niger Delta, Nigeria. *International Journal of Environmental Research and Public Health, 13*(3), 346. https://doi.org/10.3390/ijerph13030346

Nwilo, P. C., & Badejo, O. T. (2005). Oil spill problems and management in the Niger Delta. *Proceedings of the International Oil Spill Conference, 2005*(1), 567–573. https://doi.org/10.7901/2169-3358-2005-1-567

Okpoji, A. U., Anarado, C. O., Mmuta, E. C., Ekwere, I. O., Alaekwe, I. O., Odibo, U. E., Igwegbe, K. C., Eboj-Ajoku, I. O., & Obunezi, O. C. (2025). Toxicological evaluation of Pb, Cd, As, and Hg in blue crab from oil-polluted creeks in the Niger Delta. *Journal of Life Science and Public Health, 1*(1), 24–31. https://doi.org/10.69739/jlsph.v1i1.879

Okpoji, A. U., Chinyere, U. E., Nwokoye, J. N., Ezekwuemen, O. I., Alaekwe, I. O., Odidika, C. C., Owughara, C. N., Enyi, C. M., & Kolawole, O. O. (2025). Environmental assessment of heavy metals and hydrocarbon pollution in surface waters of oil-bearing communities in Andoni, Rivers State, Nigeria. *International Journal of Modern Science and Research Technology, 3*(8), 22–30. http://www.ijmsrt.com

Okpoji, A. U., Eboh-Ajoku, I. O., Mmuta, E. C., Ndubuisi, J. O., Alaekwe, I. O., Odibo, U. E., Nwoka, N. G., Okafor, C. A., & Obunezi, O. C. (2025). Integrated environmental risk assessment of BTEX and PAHs in water and sediment samples from the Bonny River, Nigeria. *ISA Journal of Multidisciplinary, 2*(4), 14–21.

Okpoji, A. U., Emem, J. A., Ekwere, I. O., Odibo, U. E., Alaekwe, I. O., Warder, A. B., & Eboj-Ajoku, O. I. (2025). Bioaccumulation of nickel, lead, and cadmium in tissues of Callinectes sapidus from the Iko River, Nigeria: Implications for human health risk and environmental safety. *Journal of Environment, Climate, and Ecology, 2*(2), 29–37. https://doi.org/10.69739/jece.v2i2.844

Okpoji, A. U., Ndubuisi, J. O., Eboh-Ajoku, I. O., Emem, J. A., Ekwere, I. O., Alaekwe, I. O., Odibo, U. E., Igwegbe, K. C., Onoja, C. R., Warder, A. B., & InyangAbia, A. J. (2025). Trematode infections and histopathological effects in Chrysichthys nigrodigitatus from the polluted Andoni River, Niger Delta, Nigeria. *Journal of Agriculture, Aquaculture, and Animal Science, 2*(2), 66–72. https://doi.org/10.69739/jaaas.v2i2.882

Okpoji, A. U., Nwoka, N. G., Odibo, U. E., Alaekwe, I. O., Okafor, C. A., Ogwu, N. G., & Akatakpo, C. U. (2025). Seasonal variation in hydrochemical characteristics and heavy metal risk assessment of groundwater in Andoni-Isiokwan District, Niger Delta, Nigeria. *International Journal of Modern Science and Research Technology, 3*(8), 44–51. http://www.ijmsrt.com

Rodriguez, C., & Tockner, K. (2020). Impacts of seasonal hydrology on COD in arid region rivers. *Journal of Environmental Quality, 49*(3), 824–832. https://doi.org/10.1002/jeq2.20094

Schlesinger, W. H. (2019). Water quality in arid regions: The role of sediment and turbidity in aquatic ecosystems. *Journal of Arid Environments, 169*, 101860. https://doi.org/10.1016/j.jaridenv.2019.06.005

Ubong, U. U., Ekwere, I. O., & Ikpe, E. E. (2020). Risk and toxicity assessments of heavy metals in Tympanotonus fuscatus and sediments from Iko River, Akwa Ibom State, Nigeria. *International Journal of Environment and Climate Change, 10*(3), 38–47.

Udo, G. J., Awaka-Ama, J. J., Uwanta, E. J., Ekwere, I. O., & Chibueze, I. R. (2020). Comparative analyses of physicochemical properties of artisanal refined gasoline and regular automotive gasoline. *Frontiers in Chemistry, 8*, 753. https://doi.org/10.3389/fchem.2020.00753

Ugochukwu, C. N. C., & Ertel, J. (2008). Negative impacts of oil exploration on biodiversity management in the Niger Delta area of Nigeria. *Impact Assessment and Project Appraisal, 26*(2), 139–147. https://doi.org/10.3152/146155108X316397

U.S. Environmental Protection Agency. (various years). Method 8015; 365.1/365.3; 375.4 and related guidance.

Williams, W. D. (2018). Salinity tolerance in freshwater biota of arid and semi-arid regions. *Hydrobiologia, 221*(1), 105–119. https://doi.org/10.1007/BF00010362

World Health Organization. (2022). *World health statistics 2022: Monitoring health for the SDGs*. WHO.

Zhu, X., & Ma, J. (2020). Recent advances in the determination of phosphate in environmental water samples: Insights from practical perspectives. *TrAC Trends in Analytical Chemistry, 127*, 115908. https://doi.org/10.1016/j.trac.2020.115908