Evaluation of Physicochemical Characteristics of Surface Water from Bodo Creek, Gokana Local Government Area, Rivers State, Nigeria

[1]Biebara, Tombari, [1]Anaero-Nweke, G. N. and [1]Green, A. F.
[1]Department of Animal and Environmental Biology,
Rivers State University, Nkpolu-Oroworukwo,
Port Harcourt, Rivers State, Nigeria
Corresponding author: george.anaero-nweke@ust.edu.ng

https://doi.org/10.56201/rjpst.vol.9.no10.2026.pg21.29

Abstract
This study evaluated the physicochemical characteristics of surface water at three stations in Bodo Creek, Gokana Local Government Area, Rivers State, Nigeria, during the dry (January–March) and wet (June–August) seasons of 2025. Seven parameters—salinity, pH, turbidity, dissolved oxygen (DO), temperature, biochemical oxygen demand (BOD_5) and total dissolved solids (TDS)—were measured monthly. Seasonal and spatial effects were examined using two-way analysis of variance (ANOVA) at $p < 0.05$. Salinity ranged from 1.55 to 2.09‰; pH, 7.17–8.95; turbidity, 7.5–15.1 NTU; DO, 4.28–5.64 mg L^{-1}; temperature, 29.5–31.9 °C; BOD_5, 3.74–6.36 mg L^{-1}; and TDS, 51.46–128.54 mg L^{-1}. Temperature and TDS remained within the applicable NESREA limits, while no salinity benchmark was specified. DO was below 5 mg L^{-1} at all stations throughout the dry season and at Stations 1 and 2 in June. Turbidity exceeded 10 NTU at all stations from June to August and at Station 2 in March. pH exceeded 8.5 at Stations 2 and 3 in March and at all stations in June. BOD_5 exceeded 6 mg L^{-1} once, at Station 1 in February. Season significantly affected salinity, turbidity and DO ($p < 0.05$), whereas pH, temperature, BOD_5 and TDS showed no significant seasonal effects. The findings indicate seasonal variation in water quality and support continued monitoring of Bodo Creek.

Keywords: *physicochemical parameters, surface water, seasonal variation, Bodo Creek, Niger Delta*

1. Introduction

Surface water bodies such as rivers, creeks, lagoons and estuaries supply water for domestic use, support fisheries and transport, and sustain the livelihoods of the communities that live beside them. Their ability to perform these functions depends on their physical, chemical and biological quality, which is shaped by natural processes in the catchment and increasingly by human activity (Chapman, 1996; Boyd, 2015; WHO, 2011). Physicochemical parameters such as temperature, salinity, pH, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD5) and total dissolved solids (TDS) are the routine indicators used to judge the condition of a water body. Dissolved oxygen sustains the respiration of aquatic organisms, and persistently low values point

to organic or hydrocarbon pollution, while BOD5 measures the oxygen consumed by micro-organisms in breaking down organic matter. Turbidity reflects the load of suspended particles, which reduces light penetration and carries particle-bound contaminants. Salinity and pH influence the solubility, speciation and bioavailability of metals, so changes in these parameters can alter how contaminants behave in water and sediment (Alloway, 2013; Boyd, 2015).

In tidal creeks of the Niger Delta, these parameters do not stay constant. They respond to tidal exchange with the sea, rainfall, surface run-off and the alternation of dry and wet seasons (Abowei, 2010). A single snapshot therefore says little about the condition of a creek, and sampling across seasons and stations is needed to separate natural variability from the effect of pollution.

Bodo Creek, in Gokana Local Government Area of Rivers State, lies within Ogoniland, where oil pollution has been documented to be more extensive than previously assumed and where full ecological recovery has been estimated to take twenty-five to thirty years (United Nations Environment Programme [UNEP], 2011; Fentiman & Zabbey, 2015). The creek supports fishing and is the source of fish and shellfish eaten by surrounding communities. Vincent-Akpu et al. (2015) characterised the physico-chemical properties of Bodo Creek water between September 2011 and January 2012 and found that most parameters were within permissible limits, although mean BOD, chemical oxygen demand, total hardness and sulfate exceeded the levels acceptable for domestic use. Since the earlier assessment, relatively little published information has compared the physicochemical condition of Bodo Creek between the dry and wet seasons at several stations. Such information provides a useful baseline for environmental monitoring and for interpreting metal concentrations measured in the creek's water, sediment and edible biota. This study therefore evaluated the physicochemical characteristics of surface water in Bodo Creek. The specific objectives were to (i) determine the monthly values of seven physicochemical parameters at three stations, (ii) compare the dry and wet seasons, (iii) examine spatial variation among the three stations, (iv) assess compliance with applicable NESREA limits, and (v) examine relationships among the parameters.

2. Materials and Methods

2.1 Study area

The study was conducted in Bodo Creek, a brackish-water environment on the upper reaches of the Andoni–Bonny estuarine system in Gokana Local Government Area, Rivers State, Nigeria. The creek is used for fishing, transportation and mangrove fuel-wood production, and is subject to pressures that include domestic waste disposal and nearby oil-related activities. Three sampling stations were selected: Station 1 (Kpaadoo), a domestic-use area influenced by local human activities; Station 2 (Tekuuru/Patrick water side), an area used for boat transportation, including boats loading for Bonny; and Station 3 (Anmini water side), a reference site with minimal observed anthropogenic influence (Table 1).

Table 1: Sampling stations and coordinates

Station	Longitude	Latitude	Description
1. Kpaadoo	7.263440°E	4.631206°N	Domestic area influenced by local human activities
2. Tekuuru (Patrick water side)	7.257519°E	4.628471°N	Area used for boat transportation, including boats loading for Bonny
3. Anmini water side	7.256218°E	4.635577°N	Control site with minimal anthropogenic impact

2.2 Sample collection

Surface water samples were collected monthly at each station from January to March 2025 (dry season) and from June to August 2025 (wet season), giving six sampling months and 18 station-month observations. Samples were taken approximately 0.3 m below the water surface using containers that had been cleaned with 10% nitric acid and rinsed with distilled water, and the containers were rinsed three times with creek water immediately before sampling. Each sample was labelled with the date and station, kept in an ice box and transported to the laboratory, where it was stored at 4 °C until analysis. Local fishermen assisted with navigation to the stations.

2.3 Physicochemical analysis

In-situ measurements of pH, temperature, dissolved oxygen (DO), salinity and turbidity were taken at approximately 0–30 cm below the water surface using a HORIBA Water Checker (Model U-10). The multiparameter meter was calibrated before field use in accordance with the manufacturer's instructions, and readings were taken at the sampling stations. Total dissolved solids (TDS) were determined in the laboratory using TDS mete. For biochemical oxygen demand (BOD_5), water samples were collected in amber bottles and incubated in the dark at 20 °C for five days. Initial and final dissolved oxygen concentrations were determined using the Winkler method, and BOD_5 was calculated from the oxygen depletion over the incubation period (APHA, 2017). Results were compared with the applicable limits of the National Environmental (Surface and Groundwater Quality Control) Regulations (NESREA, 2011): pH 6.5–8.5, turbidity ≤ 10 NTU, DO ≥ 5 mg L^{-1}, temperature ≤ 40 °C, BOD_5 ≤ 6 mg L^{-1} and TDS ≤ 500 mg L^{-1}. No NESREA limit was specified for salinity.

2.4 Statistical analysis

Data are expressed as mean ± standard deviation. Monthly measurements were treated as temporal replicates (n = 3 per season at each station). Differences between dry- and wet-season values at each station were examined using independent-samples t-tests. The combined effects of season, station and their interaction were tested using two-way ANOVA. Tukey's honestly significant difference test was used for post hoc comparisons following significant main effects. Relationships among parameters were examined using Pearson's correlation coefficient (n = 18). Statistical significance was set at $p < 0.05$.

3. Results

3.1 Monthly variation of physicochemical parameters

The monthly values of the physicochemical parameters at the three stations are presented in Table 2. Salinity ranged from 1.55 to 2.09‰, with the lowest value recorded at Station 1 in August and the highest at Station 1 in January. pH ranged from 7.17 (Station 1, February) to 8.95 (Station 2, March), while temperature ranged from 29.5 to 31.9 °C, with the highest values recorded in March and June. Turbidity rose from 7.5–9.0 NTU in January and February to 12.0–15.1 NTU in July and August. DO ranged from 4.28 mg L^{-1} (Station 1, March) to 5.64 mg L^{-1} (Station 3, August), increasing from the dry to the wet season at every station. BOD_5 ranged from 3.74 to 6.36 mg L^{-1} and TDS from 51.46 to 128.54 mg L^{-1}, with no consistent monthly trend.

Table 2: Monthly physicochemical characteristics of surface water at the three stations in Bodo Creek

Month	Stn.	Salinity (‰)	pH	Turbidity (NTU)	DO (mg L^{-1})	Temp. (°C)	BOD_5 (mg L^{-1})	TDS (mg L^{-1})
January	S1	2.09	7.62	8.4	4.72	29.5	5.36	123.13
	S2	2.08	7.59	9.0	4.85	29.5	4.78	97.85
	S3	2.07	8.48	8.0	4.95	29.6	4.51	94.70
February	S1	2.07	7.17	7.8	4.60	29.6	6.36	51.46
	S2	2.03	7.26	8.6	4.74	29.6	5.18	74.19
	S3	2.06	7.36	7.5	4.82	29.6	5.20	63.82
March	S1	1.68	8.00	9.1	4.28	31.5	4.27	68.17
	S2	2.03	8.95	10.2	4.41	31.7	4.89	110.24
	S3	1.87	8.65	8.8	4.53	31.8	3.74	94.13
June	S1	1.70	8.75	11.5	4.86	31.5	5.82	53.81
	S2	2.00	8.94	12.3	4.98	31.6	4.94	67.94
	S3	1.87	8.91	10.2	5.10	31.9	4.51	83.64
July	S1	1.60	8.30	13.8	5.21	30.0	4.36	74.20
	S2	1.96	8.30	15.1	5.35	30.5	4.51	81.67
	S3	1.82	8.40	12.9	5.46	30.9	4.20	128.54
August	S1	1.55	8.10	12.9	5.36	29.8	4.27	68.17
	S2	1.93	8.10	14.2	5.52	30.2	4.89	110.24
	S3	1.82	8.30	12.0	5.64	30.7	3.74	96.13
NESREA limit		NS	6.5–8.5	≤ 10	≥ 5	≤ 40	≤ 6	≤ 500

S1, S2, S3 = Stations 1, 2 and 3; DO = dissolved oxygen; BOD5 = five-day biochemical oxygen demand; TDS = total dissolved solids; NS = no standard. NESREA limits from NESREA (2011).

3.2 Compliance with NESREA limits

Four parameters showed at least one measurement outside the applicable benchmark (Table 2). DO was below the 5 mg L^{-1} benchmark at all stations in every dry-season month (4.28–4.95 mg L^{-1}) and in June at Stations 1 and 2 (4.86 and 4.98 mg L^{-1}). Turbidity exceeded 10 NTU at all stations from June to August and at Station 2 in March (10.2 NTU). pH exceeded 8.5 at Stations 2 and 3 in March (8.95 and 8.65) and at all three stations in June (8.75, 8.94 and 8.91). BOD_5 exceeded 6 mg L^{-1} only once, at Station 1 in February (6.36 mg L^{-1}). Temperature and TDS remained within their respective limits throughout the study; no salinity limit was specified.

3.3 Seasonal variation

Seasonal means ± SD at each station are given in Table 3, and the two-way ANOVA results are summarised in Table 4. Season had a significant effect on salinity ($F = 13.33$, $p = 0.003$), turbidity ($F = 68.70$, $p < 0.001$) and DO ($F = 28.20$, $p < 0.001$). Salinity was higher in the dry season, whereas turbidity and DO were higher in the wet season. Across all stations, mean turbidity increased from 8.60 ± 0.81 NTU in the dry season to 12.77 ± 1.48 NTU in the wet season, while mean DO increased from 4.66 ± 0.22 to 5.28 ± 0.26 mg L^{-1}.

Table 3: Seasonal variation (mean ± SD, n = 3 months per season) of physicochemical parameters at the three stations

Parameter	Station	Dry season	Wet season
Salinity (‰)	Station 1	1.95 ± 0.23[a]	1.62 ± 0.08[a]
	Station 2	2.05 ± 0.03[a]	1.96 ± 0.04[b]
	Station 3	2.00 ± 0.11[a]	1.84 ± 0.03[a]
pH	Station 1	7.60 ± 0.42[a]	8.38 ± 0.33[a]
	Station 2	7.93 ± 0.90[a]	8.45 ± 0.44[a]
	Station 3	8.16 ± 0.70[a]	8.54 ± 0.33[a]
Turbidity (NTU)	Station 1	8.43 ± 0.65[a]	12.73 ± 1.16[b]
	Station 2	9.27 ± 0.83[a]	13.87 ± 1.43[b]
	Station 3	8.10 ± 0.66[a]	11.70 ± 1.37[b]
DO (mg L^{-1})	Station 1	4.53 ± 0.23[a]	5.14 ± 0.26[b]
	Station 2	4.67 ± 0.23[a]	5.28 ± 0.28[b]
	Station 3	4.77 ± 0.22[a]	5.40 ± 0.27[b]
Temperature (°C)	Station 1	30.20 ± 1.13[a]	30.43 ± 0.93[a]
	Station 2	30.27 ± 1.24[a]	30.77 ± 0.74[a]
	Station 3	30.33 ± 1.27[a]	31.17 ± 0.64[a]
BOD_5 (mg L^{-1})	Station 1	5.33 ± 1.05[a]	4.82 ± 0.87[a]
	Station 2	4.95 ± 0.21[a]	4.78 ± 0.24[a]
	Station 3	4.48 ± 0.73[a]	4.15 ± 0.39[a]
TDS (mg L^{-1})	Station 1	80.92 ± 37.50[a]	65.39 ± 10.47[a]
	Station 2	94.09 ± 18.32[a]	86.62 ± 21.58[a]
	Station 3	84.22 ± 17.67[a]	102.77 ± 23.17[a]

Within each parameter and station, means sharing the same superscript letter are not significantly different between seasons; different letters indicate a significant seasonal difference based on independent-samples t-tests ($p < 0.05$).

At individual stations, seasonal differences were significant for turbidity and DO at all three stations ($p < 0.05$), and for salinity at Station 2 only. Seasonal differences were not significant for pH, temperature, BOD_5 or TDS at any station. The wet-season mean pH (8.46 ± 0.33) was higher than the dry-season mean (7.90 ± 0.65), but the seasonal effect was not statistically significant ($F = 4.48$, $p = 0.056$). The season × station interaction was not significant for any parameter.

Table 4: Two-way ANOVA of the effects of season and station on physicochemical parameters (F value, with p value in parentheses; df = 1, 2 and 2 for season, station and interaction; error df = 12)

Parameter	Season F (p)	Station F (p)	Season × Station F (p)
Salinity	13.33 (0.003)	6.10 (0.015)	1.90 (0.191)
pH	4.48 (0.056)	0.62 (0.552)	0.21 (0.812)
Turbidity	68.70 (< 0.001)	3.70 (0.056)	0.35 (0.713)
DO	28.20 (< 0.001)	1.47 (0.268)	0.00 (0.996)
Temperature	1.18 (0.299)	0.27 (0.767)	0.13 (0.879)
BOD_5	1.18 (0.299)	2.09 (0.166)	0.10 (0.905)
TDS	0.02 (0.893)	1.36 (0.293)	0.90 (0.432)

3.4 Spatial variation

Station had a significant overall effect on salinity ($F = 6.10$, $p = 0.015$) (Table 4). However, Tukey's post hoc comparisons did not identify statistically significant pairwise differences among Stations 1, 2 and 3 ($p > 0.05$). Station did not have a significant effect on pH, turbidity, DO, temperature, BOD_5 or TDS ($p > 0.05$).

3.5 Relationships among parameters

The correlation matrix is presented in Table 5. pH was strongly and positively correlated with temperature ($r = 0.80$, $p < 0.001$), and turbidity was positively correlated with DO ($r = 0.74$, $p < 0.001$). Turbidity was negatively correlated with salinity ($r = -0.52$, $p < 0.05$). No other pairwise correlations were statistically significant ($p > 0.05$).

Table 5: Pearson correlation matrix of physicochemical parameters of surface water (n = 18)

	Salinity	pH	Turbidity	DO	Temp.	BOD_5	TDS
Salinity	1.00						
pH	-0.32	1.00					
Turbidity	-0.52*	0.43	1.00				
DO	-0.29	0.16	0.74***	1.00			
Temperature	-0.30	0.80***	0.21	-0.16	1.00		
BOD_5	0.43	-0.43	-0.33	-0.36	-0.31	1.00	
TDS	0.26	0.17	0.12	0.23	0.00	-0.38	1.00

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

4. Discussion

Salinity ranged from 1.55 to 2.09‰, indicating low-salinity, brackish conditions throughout the study. The significant seasonal decline in salinity from the dry to the wet season is consistent with freshwater input from rainfall and land run-off. Although the overall station effect on salinity was significant, post hoc comparisons did not establish statistically significant differences between individual station pairs. TDS remained below the NESREA limit of 500 mg L^{-1} and did not differ significantly between seasons or stations.

pH was mostly within the NESREA range of 6.5–8.5, but exceeded 8.5 at Stations 2 and 3 in March and at all stations in June. Wet-season values tended to be higher, although the seasonal effect was only marginal, and the strong correlation between pH and temperature ($r = 0.80$) suggests that warmer conditions coincided with higher pH. One plausible explanation is increased photosynthetic removal of dissolved carbon dioxide by algae in warm, sunlit water, but this was not tested here. It is relevant mainly because pH affects the solubility and bioavailability of metals, so a creek whose pH shifts between seasons may also show seasonal changes in metal behaviour (Alloway, 2013). Temperature (29.5–31.9 °C) was well below the 40 °C limit and did not differ significantly between seasons, which is expected in a tropical location with a narrow annual temperature range. Turbidity was strongly affected by season. It was significantly higher in the wet season at every station and exceeded the 10 NTU benchmark at all stations from June to August. This pattern may be associated with increased surface run-off and resuspension of fine sediment during the rainy season, although these processes were not measured directly. Because metals can be transported on fine particles, increased wet-season turbidity may influence the movement of particle-associated contaminants. The negative correlation between turbidity and salinity is consistent with the coincidence of higher turbidity and lower salinity during the wet season; it does not, by itself, establish the source of suspended particles.

DO was the most important water quality concern. It remained below the 5 mg L^{-1} benchmark for healthy aquatic life at all stations in every dry-season month (4.28–4.95 mg L^{-1}) and rose significantly in the wet season (5.14–5.40 mg L^{-1} at the station means), although it was still below 5 mg L^{-1} at Stations 1 and 2 in June. Persistently low oxygen of this kind is typical of waters in which the decomposition of organic matter consumes oxygen faster than it is replaced, and it is a form of chronic stress for fish and shellfish. The wet-season improvement is probably due to rainfall, run-off and increased turbulence and mixing, although the positive correlation between DO and turbidity shows that high-DO and high-turbidity periods coincided rather than demonstrating cause. BOD_5 stayed within the 6 mg L^{-1} limit except at Station 1 in February (6.36 mg L^{-1}), at the height of the dry season when DO was already at its lowest. That single exceedance at one station shows that one-off sampling could miss the periods when the creek is under the most strain. Overall, the results indicate that Bodo Creek experienced seasonal changes in salinity, turbidity and dissolved oxygen during the study period. Vincent-Akpu et al. (2015) also reported that most physicochemical parameters of Bodo Creek water were within permissible limits, although the two studies differed in sampling period and design and cannot be compared quantitatively. This study was limited to three stations and six sampling months in one year. The relatively small number of monthly observations per season limits the power of station-level comparisons, and the observed seasonal patterns should be confirmed through longer-term monitoring.

5. Conclusion and Recommendations

Surface water in Bodo Creek showed low salinity and TDS. Temperature and TDS remained within the applicable NESREA limits throughout the study, while no salinity benchmark was specified. Season significantly affected salinity (higher in the dry season), turbidity and DO (higher in the wet season). The main departures from the applicable benchmarks were low DO during the dry season and at Stations 1 and 2 in June, elevated turbidity during the wet season, pH above 8.5 in March and June, and one BOD_5 exceedance at Station 1 in February. Although the overall station effect on salinity was significant, post hoc tests did not identify significant differences between individual station pairs. It is recommended that (i) DO, turbidity and BOD_5 be monitored at least monthly, and preferably continuously at selected points, to identify periods of oxygen stress and elevated suspended particles; (ii) the sampling record be extended over several years and include additional stations to confirm the seasonal patterns reported here; (iii) physicochemical monitoring be conducted alongside metal analysis in water, sediment and biota, because pH, salinity and turbidity can influence metal mobility and bioavailability; and (iv) possible sources of organic loading and suspended particles be investigated, particularly around areas of domestic use and boat transportation.

Conflict of interest: The authors declare that no competing interest exists.
Funding: The authors did not receive any sponsorship for this research work.

References

Abowei, J. F. N. (2010). Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. *Advance Journal of Food Science and Technology, 2*(1), 36–40.

Alloway, B. J. (2013). *Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability* (3rd ed.). Springer.

American Public Health Association, American Water Works Association, & Water Environment Federation. (2017). *Standard methods for the examination of water and wastewater* (23rd ed.). APHA Press.

Boyd, C. E. (2015). *Water quality: An introduction* (2nd ed.). Springer.

Chapman, D. (Ed.). (1996). *Water quality assessments: A guide to the use of biota, sediments and water in environmental monitoring* (2nd ed.). E & FN Spon.

Fentiman, A., & Zabbey, N. (2015). Environmental degradation and cultural erosion in Ogoniland: A case study of the oil spills in Bodo. *The Extractive Industries and Society*, *2*(4), 615–624.

National Environmental Standards and Regulations Enforcement Agency. (2011). *National Environmental (Surface and Groundwater Quality Control) Regulations* (S.I. No. 22). Federal Republic of Nigeria Official Gazette.

United Nations Environment Programme. (2011). *Environmental assessment of Ogoniland*. UNEP.

Vincent-Akpu, I. F., Tyler, A. N., Wilson, C., & Mackinnon, G. (2015). Assessment of physico-chemical properties and metal contents of water and sediments of Bodo Creek, Niger Delta, Nigeria. *Toxicological and Environmental Chemistry, 97*(2), 135–144.

World Health Organization. (2011). *Guidelines for drinking-water quality* (4th ed.). WHO Press.