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Physicochemical Quality Assessment of Borehole Waters in Otuoke, Emelya, and Ogbia Town, Ogbia LGA, Bayelsa State, Nigeria

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ABSTRACT

The research investigates the physicochemical quality of borehole water in Otuoke, Emelya, and Ogbia Town in Ogbia Local Government Area of Bayelsa State, Nigeria. Water samples were collected and analyzed from selected boreholes to assess parameters such as pH, turbidity, total dissolved solids (TDS), conductivity, hardness, dissolved oxygen (DO), biochemical oxygen demand (BOD), and heavy metals like iron, manganese, and zinc. Laboratory and in-situ tests were conducted using standard analytical procedures and equipment. Results showed that most physicochemical parameters complied with World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ) limits, although elevated NSDWQ turbidity (6.27 ± 0.16 NTU) and BOD (2.23 ± 0.21 mg/L) in Ogbia Town and inconsistent calcium readings in Otuoke were observed. The study highlights the need for routine water quality monitoring, improved borehole construction practices, and community sensitization to ensure sustainable access to safe water. The findings provide essential evidence for public health policy and environmental protection in Nigeria's oil-rich Niger Delta.

Keywords: Borehole, Physicochemical, Conductivity, Hardness, Turbidity, pH

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1. INTRODUCTION

The absence of government-provided potable water infrastructure forces over 90% of households in Otuoke, Ogbia Town, and Emelya to depend on boreholes and, to a lesser extent, rainwater harvesting [1, 2]. Boreholes are often privately owned, with depths ranging from 30 to 60 meters, tapping into shallow and deep aquifers.

Boreholes are the primary water source in the three communities, with an average of one borehole serving 10–15 households [3, 4]. Residents prioritize boreholes due to perceived safety compared to contaminated surface water. However, groundwater quality is not guaranteed, as hydrocarbon seepage and saltwater intrusion from coastal aquifers pose risks [5, 6]. Preliminary studies in Ogbia LGA indicate variable borehole water quality. For instance, [7] reported pH levels below World Health Organization (WHO) standards (6.2–6.8) in some Otuoke boreholes, while iron and lead concentrations occasionally exceeded permissible limits. High salinity, attributed to seawater intrusion, has also been documented in coastal boreholes [8].

Borehole ownership is unevenly distributed, with wealthier households investing in private boreholes. Low-income families often purchase water from neighbors, spending up to 10% of their monthly income on water [9, 10]. Consumption of untreated borehole water contaminated with heavy metals (e.g., lead, cadmium) and hydrocarbons has been linked to health issues such as gastrointestinal disorders, skin diseases, and long-term carcinogenic effects [11, 12]. A 2022 community health survey in Emelya reported a 30% prevalence of waterborne illnesses among children under five [13, 14]. Local NGOs and international agencies, including UNICEF, have initiated borehole rehabilitation projects and water quality monitoring programs in Ogbia LGA. However, sustainability remains a challenge due to inadequate maintenance and funding [15, 16].

Several investigations have characterized the physicochemical and microbial quality of borehole waters across Nigeria, highlighting both regional variations and common contamination concerns. In the Niger Delta region, [17], conducted a hydrogeochemical assessment of groundwater in parts of Bayelsa and Rivers States, reporting total dissolved solids (TDS) ranging from 200 to 1,200 mg/L exceeding the 1,000 mg/L WHO guideline at many sites, and hardness values between 100 and 450 mg/L as $CaCO_3$ [18, 19]. Their multivariate analysis identified salinity intrusion and anthropogenic inputs (agricultural runoff and oil-related activities) as principal factors influencing water chemistry in the region [20].

In Ogbia Local Government Area, [21], evaluated 15 borehole samples for major ions, heavy metals. It was discovered that the pH (6.8 – 7.4) and electrical conductivity (150 – 800 µS/cm) were largely within permissible limits, nitrate concentrations averaged 45 mg/L approaching the 50 mg/L WHO threshold and trace metals such as iron and manganese frequently exceeded national standards. Their study also detected coliform bacteria in 40% of samples, underscoring sanitation and well-head protection issues in rural settings. A broader review by [22] synthesized findings from multiple deltaic aquifer studies, noting that shallow Benin formation sands often show elevated chloride (100–350 mg/L) due to occasional saltwater intrusion, particularly in coastal fringes [23]. They recommended routine monitoring and GIS-based vulnerability mapping to preemptively manage salinization risks [24].

In another studies, [25], assessed oil-spill impacts on surface and shallow groundwater in Rivers State, finding total petroleum hydrocarbons (TPH) up to 5 mg/L in borehole samples, far above the 0.01 mg/L WHO guideline, and demonstrated rapid vertical migration of hydrocarbon plumes in sandy aquifers [26].

Their work highlights the necessity of including petroleum-derived contaminants in borehole monitoring protocols where oil activities are prevalent. The aim of the present study is to assess the physicochemical quality of borehole water in Otuoke and Emelya, Ogbia LGA, Bayelsa State, and evaluate its compliance with regulatory standards to inform strategies for improving water safety and public health.

2. MATERIALS AND METHODS

Location

The study was carried out in Otuoke, Emelya, and Ogbia town, all located in Ogbia local government area, Bayelsa state, Nigeria. Bayelsa state lies within the Niger delta region of southern Nigeria, between (latitudes 4º 49N and 5º 23N and longitude 6º 10E and 6º 33E). The climate is tropical with high rainfall 2000 - 4000 mm annually and relative humidity exceeding 70 % [22]. Otuoke, Emelya, and Ogbia town are rural communities situated near the Kolo creek.

Sample collection and Analysis

Water samples were collected from selected boreholes located in Emelya, Otuoke, and Ogbia town in Bayelsa State. The water samples were aseptically collected using 75 Cl sterilized pet cans at early morning, when activities at the source sites were at their peak. Standard sampling and analytical methods were employed to investigate each water sample and assess the physicochemical characteristics of the water samples. In all, six samples were collected in the month of May, two samples each from each site of sampling. Some parameters that were determined *in situ* include: Temperature, pH, Electrical conductivity (EC), total dissolved solid (TDS), Dissolved Oxygen (DO) and turbidity using portable field kits (Hach's CO 150 Conductivity/TDS, pH, Hach's 2100P Turbidimeter and Liuhui UHT003 meters, respectively). All the samples were stored in laboratory, freshly refrigerated at 4 °C in a cooler packed with, ice blocks prior to analysis to avoid microbial actions for *ex-situ* analysis.

Heavy metals and Hardness Determination: Heavy metals such as iron, manganese, and zinc were analysed using Atomic Absorption Spectrophotometer (AAS) (APHA 301A) (model: 5100 PC, Perkin-Elmer, Boston, USA), while hardness was determined using complexometric titration using EDTA.

3. RESULTS AND DISCUSSION

Results

Table 4.1. Descriptive Statistics of Physicochemical Parameters (Mean and Range) Values.

S/N	Parameters	Emelya		Otuoke		Ogbia town		NSDWQ
1	pH	6.70-6.90	6.77± 0.12	7.00-7.20	7.13 ± 0.11	6.70-7.00	6.83± 0.15	6.8 -8.5
2	Turb [NTU]	0.50-0.80	0.63± 0.15	0.30-0.60	0.47±0.15	6.20-6.40	6.27±0.16	5.0
2	chlorine	186.2-186.3		124.80-126.70	125.77±0.95	210.9-211.7	211.27±0.40	100
3	Fe [ppm]	0.10-0.10	0.10± 0.00	0.10-0.30	0.17±0.11	0.10-0.20	0.13 ±0.06	<0.3
4	TDS	28.0-30.0	29.33± 1.15	44.0-46.0	45.00±1.00	68.00-72.00	70.33±2.09	500
5	TH	53.00-60.00	56.33± 3.51	31.00-37.00	33.33±3.21	60.00-65.00	62.67±2.52	<150
6	Conductivity	54.00-60.00	57.33± 3.06	90.00-92.00	90.67±1.15	142.00-145.00	143.67±1.52	1000
7	Temperature	28.50-28.50	28.5± 0.00	27.90-28.40	28.23±0.29	27.7-28.7	28.30±0.53	Ambient
8	Mg	5.42-5.80	5.56± 0.21	1.40-1.80	1.63±0.27	0.80-0.82	0.80±0.01	0.20
9	Ca	0.60-0.80	0.70± 0.10	0.00-1.40	0.46±0.81	0.50-0.70	0.60±0.10	75
10	DO	7.20-8.00	7.70± 0.44	4.10-4.80	4.43±0.35	7.30-7.90	7.57±0.31	5.0
11	BOD	0.60-0.60	0.60± 0.00	0.10-0.50	0.27±0.21	2.00-2.40	2.23±0.21	3-5
12	Mn	0.20-0.20	0.19± 0.00	0.20-0.21	0.20±0.00	0.14-0.14	0.14±0.00	0.1
13	Zn	0.23-0.23	0.23± 0.00	0.26-0.27	0.27±0.00	0.32-0.33	0.32±0.00	5.0

4. DISCUSSIONS

PH

The pH values recorded for Emelya ranged from 6.7-6.9 with a mean value of 6.77± 0.12 for Otuoke it ranged from 7.00-7.20 with a mean value of 7.13 ± 0.11 and Ogbia town ranged from 6.70-7.00 with a mean value of 6.83± 0.15 all fell within the WHO's and NSDWQ recommended range of 6.5–8.5 for drinking water. This near-neutral pH indicates that the borehole water is neither acidic enough to corrode pipes nor alkaline enough to cause taste issues or scale buildup. A stable, neutral pH supports good plumbing lifespan and minimizes the risk of metal leaching, especially for iron or lead. The slight variations reflect local geology but pose no health threat. Overall, the pH results confirm that the aquifers supplying these communities are chemically balanced and suitable for household use and drinking. These findings were consistent with those of Nwankwoala [24], who reported pH values ranging from 5.32 to 7.70 in groundwater across Bayelsa State. Similarly, [26] observed pH values of 6.8–7.4 in boreholes within Ogbia LGA, indicating stable, near-neutral conditions. Both studies affirm that borehole water in this region generally falls within WHO standards, supporting the reliability of the present results.

Turbidity

The turbidity readings for Emelya ranged from 0.50 to 0.80 with a mean value of 0.63 ± 0.15 and Otuoke 0.3 - 0.6 NTU with a mean value of 0.47 ± 0.15 are well below the NSDWQ's 5.0 NTU limit, confirming that these boreholes produce clear water with minimal suspended solids. However, Ogbia Town's value of 6.2 NTU exceeds this limit, indicating the presence of fine particles, possible organic debris, or microbial contamination. High turbidity reduces the effectiveness of disinfection because suspended particles can shield harmful microorganisms. For consumers, this may lead to unpleasant taste, cloudiness, and increased health risks if the water is consumed untreated. Ogbia Town's persistently high turbidity suggests poor well construction or exposure to surface runoff. The elevated turbidity in Ogbia Town is similar to findings by [23], who reported turbidity levels exceeding WHO limits in boreholes in Okutukutu, Bayelsa State, often linked to poor wellhead protection. [25], also recorded turbidity variations influenced by runoff and sanitation issues, reinforcing the observation that borehole construction and location are key determinants of water clarity in the Niger Delta.

Chloride

The chloride levels recorded were 186.2 ppm for Emelya, 126.7 ppm for Otuoke, and 211.7 ppm for Ogbia Town. While all three remain below the WHO taste threshold of 250 ppm, they significantly exceed Nigeria's lower recommended limit of 100 ppm. Elevated chloride is typical of coastal aquifers in the Niger Delta, where tidal influence and saltwater intrusion can push saline water into shallow boreholes, especially during dry seasons. Although not immediately harmful to health, high chloride can corrode metal pipes and give drinking water an undesirable salty taste. Ogbia Town's level, being the highest, suggests this community is most at risk from saline encroachment.Comparable chloride values were reported by [27], who documented concentrations up to 450 mg/L in coastal Emelya boreholes due to seawater intrusion. Nwankwoala and Walter (2018) similarly noted elevated chloride levels (100–350 mg/L) in deltaic aquifers, aligning with the present study's findings in Emelya and Ogbia Town. These consistencies confirm that salinization is a recurring regional challenge.

Iron

The iron concentration is steady at 0.1 ppm for Emelya, Otuoke, and Ogbia Town, safely within the NSDWQ limit of 0.3 ppm. This low level suggests minimal iron leaching from the aquifer geology or borehole pipes, which is good for both water taste and household plumbing.

Excess iron often causes reddish-brown staining on clothes and fixtures and can encourage iron bacteria growth, which clogs pipes. The uniform low iron values here confirm that the borehole casings are intact and the aquifers have low natural iron content. Routine monitoring should still continue, especially in oil-rich areas where corrosion can increase metal leaching.

The consistently low iron values observed here align with [17], who reported stable iron levels (<0.3 ppm) in boreholes across parts of Bayelsa and Rivers States. Their findings attributed the low concentrations to aquifer geology with minimal iron-bearing minerals, consistent with the results of this study.

Total dissolved solids

(TDS) values are very low for all three communities: 28 ppm in Emelya, 46 ppm in Otuoke, and 71 ppm in Ogbia Town. All these levels are far below the WHO maximum limit of 500 ppm for taste and palatability. Low TDS indicates the water is fresh, free of excessive salts and minerals, and safe for daily consumption. This softness is also beneficial for cooking, washing, and preventing scale buildup in household appliances. The variation among communities shows local geology's influence, with Ogbia Town slightly higher due to possible saltwater mixing. Overall, these TDS results confirm excellent potable water quality.

The low TDS values in this study (28–71 ppm) mirror those observed by [7], who reported generally low TDS levels in Otuoke boreholes. In contrast, Amadi et al. (2019) documented higher TDS (200–1,200 mg/L) in other parts of the Niger Delta, highlighting that spatial variability exists depending on proximity to saltwater intrusion and pollution sources.

Conductivity

Electrical conductivity for Emelya (58 µS/cm) with a mean value of 57.33±3.06, Otuoke (92 µS/cm) and a mean value of 90.67±1.15, and Ogbia Town (144 µS/cm) with a mean value of 143.67±1.52 indicates low ionic content, matching the low TDS results. All values are far below the NSDWQ limit of 1,000 µS/cm for drinking water, showing the groundwater is fresh and not saline. Conductivity reflects dissolved ions like chloride, sulfate, and nitrates. Ogbia Town's higher reading aligns with its higher chloride, hinting at slight saltwater intrusion. Low conductivity also means the water is unlikely to cause scaling or mineral deposits in household pipes and appliances. Overall, these safe values confirm minimal dissolved salt impact and suitability for domestic consumption. Conductivity readings in this study are consistent with those reported by [7], who found values between 150 and 800 µS/cm in Ogbia LGA, indicating fresh groundwater. Similarly, Nwankwoala and Walter (2018) noted that shallow Benin Formation aquifers typically show low to moderate conductivity, except in coastal fringes affected by salinity intrusion.

Temperature

Measured temperatures Emelya (28.5 °C), Otuoke (27.9 °C), and Ogbia Town (27.7 °C) are typical for shallow aquifers in tropical climates like the Niger Delta. These values match expected ambient ground temperatures and do not pose any direct health concern. Slight temperature variations reflect local depth and surrounding soil heat retention. Warm groundwater can slightly influence dissolved oxygen levels: higher temperatures may reduce oxygen solubility, but all sites still show healthy DO. This consistent range suggests the boreholes are stable and not thermally polluted by oil operations or gas flaring. Overall, the water's temperature supports good taste and safe use.

These results align with Nwankwoala & Walter (2018), who described groundwater in the Niger Delta as typically reflecting ambient conditions (27 – 29 °C). Comparable findings were also reported by [17], confirming that aquifer temperatures in this region are stable and unaffected by significant geothermal or anthropogenic disturbances.

Total Hardness

Total hardness values 53 ppm (Emelya), 32 ppm (Otuoke), and 63 ppm (Ogbia Town) show the borehole water is soft to moderately hard. All are well below the NSDWQ limit of 150 ppm. Hardness measures calcium and magnesium ions, which are essential minerals but excessive levels cause scaling. These low values mean less soap is needed for washing, no pipe scaling, and no taste problems. Ogbia Town's slightly higher hardness aligns with its higher chloride and conductivity, supporting mild mineral presence. Soft water is safe but contributes little dietary calcium or magnesium, so other dietary sources are still important for health.

The soft to moderately hard classification observed here is consistent with Amadi et al. (2019), who reported hardness values between 100 and 450 mg/L in Niger Delta groundwater. Likewise, [7] found similar low to moderate hardness levels in Ogbia LGA boreholes, affirming that groundwater in this region typically has low mineralization.

Calcium and Magnesium

Calcium levels are very low Emelya (0.6 ppm), Ogbia Town (0.5 ppm) while Otuoke's negative value (–1.8 ppm) clearly indicates a measurement or titration error that should be rechecked for accuracy. Naturally low calcium matches the soft water classification. Magnesium is higher in Emelya (5.47 ppm), moderate in Otuoke (1.7 ppm), and lowest in Ogbia Town (0.8 ppm). These levels pose no health risk and do not exceed any standards, but suggest local geologic variations. Both minerals are vital for health, yet too low here to significantly contribute dietary intake, confirming the need for monitoring accuracy and good lab practices.

The low calcium levels and variable magnesium concentrations observed align with [26], who noted calcium deficiencies and fluctuating magnesium in Otuoke boreholes. Similarly, [5] found seasonal fluctuations in calcium and magnesium levels in Southern Ijaw groundwater, confirming that these parameters are locally controlled by geology and recharge conditions.

Dissolved Oxygen

Dissolved oxygen (DO) levels Emelya (7.9 mg/L), Otuoke (4.4 mg/L), Ogbia Town (7.5 mg/L) reflect the water's ability to support aerobic conditions and resist pollution. Emelya and Ogbia Town have healthy oxygen levels near saturation, indicating fresh recharge and minimal organic decay. Otuoke's lower DO (4.4 mg/L) is still acceptable but suggests more organic matter or slightly slower recharge. Good DO levels help control harmful anaerobic bacteria, reduce odors, and indicate that the borehole water is relatively clean. Combined with low BOD, high DO supports the conclusion that the aquifers remain mostly unpolluted and safe for household use.

Comparable dissolved oxygen values were reported by [26], who found DO ranging from 4–8 mg/L in Otuoke boreholes, consistent with aerobic conditions. Likewise, [26] documented similar DO levels across Niger Delta aquifers, reinforcing the present study's findings of fresh, oxygenated groundwater.

Biochemical Oxygen Demand

BOD levels show how much oxygen is needed to break down organic matter in the water. Emelya (0.6 mg/L) and Otuoke (0.2 mg/L) have very low BOD, indicating minimal organic pollution. Ogbia Town's BOD (2.0 mg/L) is still below the NSDWQ maximum (3–5 mg/L) but clearly higher, confirming some organic contamination. Elevated BOD in Ogbia Town, together with its high turbidity, suggests runoff or poor borehole casing might be introducing organic waste. High BOD can promote bacterial growth and reduce dissolved oxygen over time. This emphasizes the need for improved wellhead hygiene and periodic disinfection.

The relatively low BOD values reported here (0.2–2.0 mg/L) are consistent with Eze and Nwagbara (2021), who recorded BOD levels below 3.0 mg/L in Ogbia LGA boreholes. In contrast, [26], observed elevated BOD in boreholes near oil spill sites in Rivers State, demonstrating that the moderate levels observed in Ogbia Town here may be linked to localized organic infiltration rather than petroleum contamination.

Manganese and Zinc

Manganese levels Emelya (0.198 ppm), Otuoke (0.205 ppm), Ogbia Town (0.140 ppm) are slightly above the typical NSDWQ threshold (0.1 ppm) but still safe for short-term use. Long-term exposure could cause staining and taste issues. Zinc values Emelya (0.231 ppm), Otuoke (0.267 ppm), Ogbia Town (0.321 ppm) are far below the 5.0 ppm limit, posing no health risk. These metals likely come from natural mineral leaching or old pipes. Their presence is not immediately hazardous but should be monitored routinely, especially near oil activities, to detect possible corrosion or contamination buildup. No urgent treatment is needed, but monitoring is wise. The results of this study are consistent with similar investigations carried out in the Niger Delta region. Otuoke recorded the lowest BOD and moderate TDS and turbidity, suggesting relatively higher quality, while Ogbia Town showed higher chloride, turbidity, and BOD, hinting at possible organic and saltwater influences. Also, Emelya recorded high DO and the highest magnesium content, indicating good oxygenation and moderate mineralization. The results of this study are consistent with similar investigations carried out in the Niger Delta region. For instance, [27] reported pH values ranging between 6.8 and 7.4 and conductivity levels of 150–800 µS/cm in borehole waters from Ogbia LGA, which align closely with the values recorded in Emelya, Otuoke, and Ogbia Town.

Their study also highlighted that chloride and turbidity levels were elevated in coastal and low-lying communities, a finding that resonates with the high chloride and turbidity observed in Ogbia Town in this present research. Similarly, [5] documented total dissolved solids (200–1,200 mg/L) and hardness values within the range reported here, attributing the variations to both geogenic influences and anthropogenic inputs such as oil-related activities. These consistencies across multiple studies reinforce the reliability of the present findings and emphasize the broader hydrogeochemical challenges faced by groundwater resources in Bayelsa State and the wider Niger Delta.

5. CONCLUSIONS

The physicochemical analysis of borehole waters from Emelya, Otuoke, and Ogbia Town in Ogbia LGA, Bayelsa State, revealed that the water quality in all three locations generally complies with the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) guidelines. Key parameters such as pH, total dissolved solids (TDS), conductivity, total hardness, iron, and major ions were within acceptable limits, indicating that the groundwater in these areas is suitable for domestic and drinking purposes. However, certain site-specific concerns were noted. Ogbia Town recorded elevated turbidity and biochemical oxygen demand (BOD), suggesting slight organic pollution. The negative calcium value observed in Otuoke likely reflects a measurement anomaly and highlights the importance of procedural accuracy during laboratory analyses.

Despite these concerns, the boreholes exhibited adequate levels of dissolved oxygen (DO), and no heavy metal concentrations exceeded critical health thresholds.

Overall, the findings confirm that borehole water in the study areas is largely safe for consumption. Nonetheless, continuous monitoring, routine microbial testing, and community sensitization on borehole protection and sanitary practices are essential to maintaining and improving water quality, especially in communities with growing human activity and proximity to oil operations.

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