ASSESSMENT OF PHYSICOCHEMICAL AND MICROBIAL WATER QUALITY IN TEACHING AND RESEARCH FARM WATER RESERVOIR, FUTA, NIGERIA

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DOI10.51459/jostir.2026.2.1.0307

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History
Received: 23-06-2025
Accepted: 06-04-2026
Published: April, 2026

https://www.futa.edu.ng

JOSTIR JOURNAL OF SCIENCE, TECHNOLOGY AND INNOVATION RESEARCH
https://jostir.futa.edu.ng

ABSTRACT

Water quality and microbial analyses are critical to safeguarding public health, sustaining aquatic ecosystems and ensuring the reliability of water for domestic, agricultural, and industrial uses. This study investigated the microbial load and physicochemical parameters in two water reservoirs at the Teaching and Research Fish Farm, Federal University of Technology Akure (FUTA) for a period of five months (May to September). Microbial analysis (bacterial, coliforms, faecal bacteria, and fungi counts) and water quality parameters (pH, conductivity, temperature, and dissolved oxygen) were analysed in triplicates following APHA (1998) and Fawole and Oso (2007) methodologies. Results revealed mean total bacterial counts (1.27 ± 1.0 × 10^2 CFU/mL), coliform bacteria (0.2 ± 0.1 CFU/mL), fungal counts (1.6 × 10^2 SFU/mL) while faecal coliforms (0.00 ± 00) were absent throughout the study period. Microbial counts: bacteria, coliform and faecal counts- (2.55 ± 1.10, 0.40 ± 0.30, 0.00 ± 0.00 (CFU/mL) ×102) and fungi (1.60±0.40×102 SFU/mL), peaked in the month of May, however, were within microbial thresholds in water reservoirs. Water quality parameters showed notable variations with mean and range values: temperature (26.64 ± 1.29 and 25.70 – 28.50 °C), conductivity (213 ± 9.98 and 173.60 - 258 μS/cm), pH (7.88 ± 0.37 and 6.58 - 10.10) while 4.99 ± 0.24 and 3.40 - 6.10 mg/L were recorded for dissolved oxygen during the study period. Thus, the findings indicate that the water quality and microbial loads in the reservoirs were within habitable ranges for aquatic organisms by Boyd (1998) and WHO (2017) permissible limits (total bacteria (100 – 500 CFU/100mL) and total fungal and faecal coliform (0 CFU/100mL)).

Keywords: Microbial load, reservoir water, water quality, public health, fish

1. | Introduction

Water quality is a critical factor in maintaining public and environmental with population safety and health in purview. In aquaculture production systems, it directly impacts fish health, growth, and productivity. Similarly, microbial load in water reservoirs plays a pivotal role in determining water quality and the overall health of farmed fish (Boyd and Tucker, 2012; Martinez-Cordova and Lopez-Elias, 2015). A high microbial load can lead to proliferation of pathogenic micro-organisms, which may cause disease outbreaks, reduce fish survival rates, and compromise consumer safety (Austin and Austin, 2012; Roy and Saikia, 2023). Microbial load refers to the concentration of micro-organisms present in a specific environment, including bacteria, fungi, algae, and protozoa. While some microbes play beneficial roles such as nutrient cycling and organic matter decomposition, pathogenic species like *Aeromonas, Pseudomonas, and Vibrios* are associated with disease outbreaks in aquaculture systems (Zorrilla *et al.,* 2003; Moriarty, 2014; Deng *et al.,* 2020 Mu'azu *et al.,* 2024). These pathogens can cause conditions such as septicemia and fin rot, leading to significant economic losses. Water reservoirs are highly susceptible to microbial contamination due to urbanization, rainfall and run-offs, effluent discharge especially from food processing, pharmaceutical industries, domestic and municipal wastes, underground water movement, herd organic wastes, and decaying matter (Natrah *et al.,* 2014; Ogba *et al.,* 2021). The FUTA Teaching and Research water reservoir provide water for animal food production activities. It serves as watershed facility for farm and adjoining local communities. The quality of water used on the farm determines the level of productivity of fish and other agricultural productions as it is used as sources of irrigation during dry season. The relationship between the physico-chemical, elemental and microbial properties of the reservoir is important to understand the quality of the reservoir water (Ikuesan and Ediagonya, 2024). For instance, there is strong correlation between water quality parameters and microbial proliferation, and factors such as temperature, pH, dissolved oxygen levels, and nutrient availability influence microbial growth dynamics with dire consequences bordering on consumer safety, public and environmental health (Daskalov, 2006; Kothari *et al.,* 2021). Periodic assessment of water quality is critical to ensure safety of culture fish, curb disease transmission potential as well as environmental and public health.

In man-made and natural water shed systems, microbial profiling is essential for maintaining ecological balance and preventing disease outbreaks that can compromise productivity. Overall, integrated water quality and microbiological analyses constitute a scientifically robust framework for evaluating water safety, guiding treatment interventions, and informing sustainable water resource management (Wang *et al.,* 2024). Thus, for effective management of water sources, subjecting the FUTA Teaching and Research Farm water reservoir to microbial load empirical analyses is essential for maintaining clean and safe water to ensure sustainable aquaculture practices and other water dependent activities.

2. | Materials and Methods

2.1 | Study Area

The study was conducted at the Teaching and Research Fish Farm of the Federal University of Technology Akure (FUTA), Ondo State, Nigeria. The farm consists of two major water reservoirs used for aquaculture and other farm operations. The investigated reservoirs were selected because of their primary functions which include being water shed, irrigation and fish farming which predispose them to high microbial contamination from multiple point-sources due to microbial transport and nutrient enrichment from surface run-offs and other biogeochemical interactions. The map of the study is presented in Figure 1.

2.2 | Sample collection

Water samples were collected monthly for five months (May to September) at 0800 hours from two water sources, Reservoir A and B at two stations (3 meters apart) using sterile sample bottles (60 mL) at a depth of approximately 30 cm and immediately transported to Fisheries and Aquaculture Technology Limnology Laboratory for microbial and water quality parameter analyses. The GPS coordinates of the sampling points in Reservoir A and B is presented in Appendix.

2.3 | Microbial Analyses

The microbial load of the two reservoirs were determined by performing a ten-fold serial dilution of the water samples in test tubes containing sterile distilled water. The total viable count was determined using the pour plate technique cultured in nutrient, MacConkey and potato dextrose agar media. The

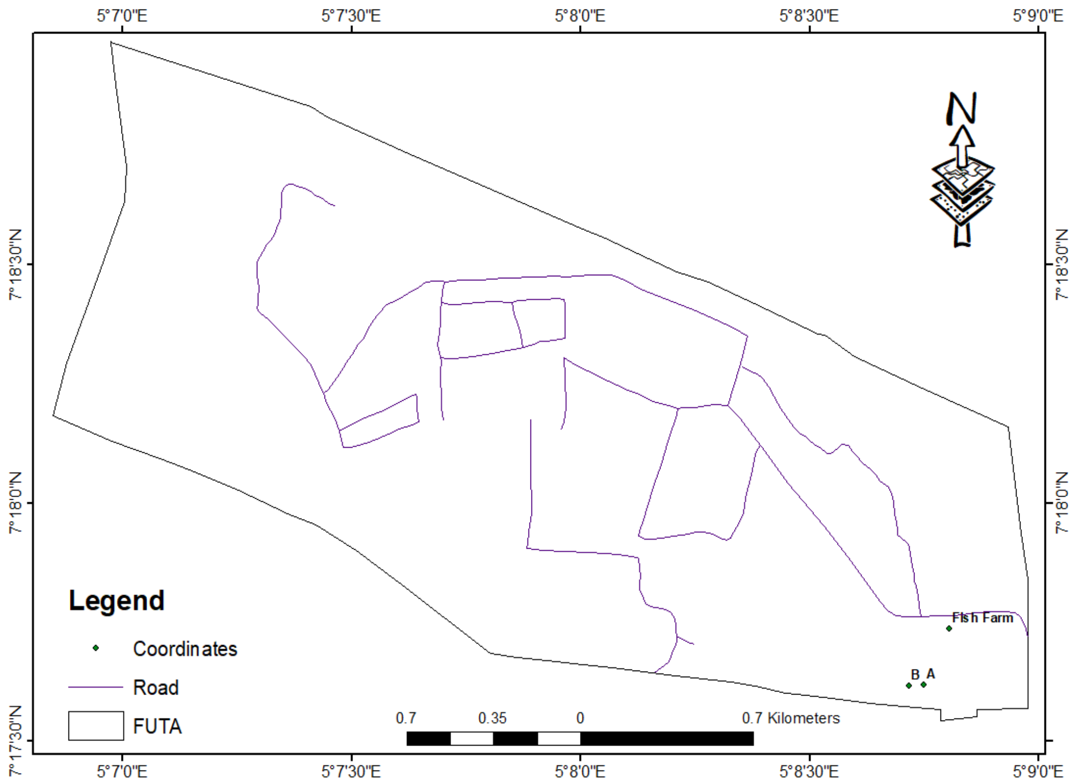

Figure 1 | Map of the Teaching and Research Farm, Oba-Kekere, FUTA

plates were incubated between 35 - 45 °C for 48 h and respective colonies (total bacterial count (TBC), coliform count (TCC), faecal coliform count (FCC) and fungal count (FC)) were counted and expressed in colony forming unit per ml (CFU/mL) and values were estimated by means of triplicate determination (Fawole and Osho, 2007).

2.4 | Water Quality Parameter Determination

Water quality parameters such as temperature, pH, dissolved oxygen and conductivity were measured using Hanna multifunction meter (Model (HI9813-6) by inserting probes into the water samples and readings were taken. Hanna HI9813-6 was calibrated prior before use using buffer solution (APHA, 1998).

2.5 | Statistical Analysis

Data were analyzed using descriptive statistics. Correlation analyses were performed to determine relationships between microbial load and water quality parameters and presented in means ± standard deviations tables using SPSS IBM statistical software version 22.0.

3. | Results

3.1 | Microbial Analysis

Microbial results obtained during the study period (May to September) indicate that bacteria count (3.40 × 10^2 CFU/mL) in Reservoir A were higher than Reservoir B (1.70 × 10^2 CFU/mL) in May. Similar trends were observed in June and August, Reservoir A (1.10 and 0.70 × 10^2 CFU/mL) and Reservoir B (0.30 and 0.20 × 10^2 CFU/mL) respectively. While, in July and September, bacteria counts were higher in Reservoir B (4.40 × 10^2 CFU/mL) than Reservoir A (0.10 × 10^2 CFU/mL) and (6.80 × 10^2 CFU/mL) Reservoir B than (0.60 × 10^2 CFU/mL) in Reservoir A respectively. Fungi count (1.70 × 10^2 CFU/mL) in Reservoir B were higher than Reservoir A (1.50 × 10^2 CFU/mL) in May. Similar trends were observed in June Reservoir B (1.1 CFU/mL) and Reservoir A

(0.30 × 10^2 CFU/mL). In July and September, fungi counts were higher in Reservoir A (0.10 × 10^2 CFU/mL) than Reservoir B (0.00 × 10^2 CFU/mL) and (0.10 × 10^2 CFU/mL) Reservoir A than (0.00 × 10^2 CFU/mL) in Reservoir B respectively while 0.10 × 10^2 CFU/mL were recorded in both Reservoirs A and B. In May, coliform counts were higher in Reservoir A (0.60 × 10^2 CFU/mL) than Reservoir B (0.30 × 10^2 CFU/mL). In June and July, higher coliform counts were recorded in Reservoir B (0.10 × 10^2 and 0.20 × 10^2 CFU/mL) than Reservoir A (0.00 × 10^2 and 0.00 × 10^2 CFU/mL) respectively while 0.00 × 10^2 CFU/mL were recorded both in Reservoir A and B. No faecal counts (0.00 × 10^2 CFU/mL) were recorded in both Reservoirs A and B throughout the study period. Microbial analysis results are presented in Tables 1 and 2

Table 1 | Summary of the Monthly average Microbial Load in the Teaching and Research Farm, FUTA Reservoirs

Month	Pond A Bacteria (CFU/mL) 10^2	Pond B Bacteria (CFU/mL) 10^2	Pond A Fungi (CFU/mL) 10^2	Pond B Fungi (CFU/mL) 10^2	Pond A Coliform (CFU/mL) 10^2	Pond B Coliform (CFU/mL) 10^2	Pond A Faecal (CFU/mL) 10^2	Pond B Faecal (CFU/mL) 10^2
May	3.40± 0.96	1.70±0.31	1.50±0.10	1.70±0.60	0.60±0.36	0.30±0.21	0.00±0.00	0.00±0.00
June	1.10±0.65	0.30±0.15	0.30±0.17	1.10±0.52	0.00±0.00	0.10±0.00	0.00±0.00	0.00±0.00
July	0.10±0.00	4.40±1.68	0.10±0.00	0.00±0.00	0.00±0.00	0.20±0.10	0.00±0.00	0.00±0.00
August	0.70±0.25	0.20±0.10	0.10±0.00	0.10±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
September	0.60±0.17	6.80±0.10	0.10±0.06	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00

Table 2 | Total Average Microbial Load in the Teaching and Research Farm, FUTA, Reservoir

Month	Bacteria (CFU/mL) ×10^2	Fungi (CFU/mL) ×10^2	Coliform (CFU/mL) ×10^2	Faecal (CFU/mL) ×10^2
May	2.55±1.10	1.60±0.40	0.40±0.30	0.00±0.00
June	0.70±0.50	0.70±0.50	0.10±0.10	0.00±0.00
July	2.25±2.60	0.05±0.10	0.10±0.10	0.00±0.00
August	0.45±0.30	0.10±0.00	0.00±0.00	0.00±0.00
September	0.40±0.30	0.02±0.00	0.00±0.00	0.00±0.00

3.2 | Water Quality Parameters

Water quality parameter obtained revealed that highest mean temperature values (28.50 ± 1.70 °C) in Reservoirs A and B were recorded in May. However, similar trends were recorded 26.90±1.59 and 26.80 ± 1.58 °C, 25.80 ± 1.30 and 25.70 ± 1.14 °C, 26.00 ± 1.02 and 26.10 ± 1.03 °C and 26.10 ± 0.92 and 26.00 ± 0.92 °C in June, July, August and September in Reservoirs A and B respectively. Conductivity values recorded in Reservoir A (198.40 ± 11.67 µS/cm) were higher than Reservoir B (188.70 ± 11.12 µS/cm) in May. Also, 193.90 ± 11.42µS/cm recorded in Reservoir A were than 173.60 ± 10.23 µS/cm in Reservoir B in June. Similar conductivity values (198.90 ± 10.05 and 198.20 ± 8.76 µS/cm) were recorded in Reservoirs A and B in July. 258.00 ± 10.14 µS/cm recorded in Reservoir A were higher than 241.00 ± 9.47 µS/cm in Reservoir B in August while 244.00 ± 8.63 µS/cm recorded in Reservoir B were higher than 236.00 ± 8.34 µS/cm in Reservoir A in September. Dissolved oxygen in reservoir showed slight variations during the study period. In May, 5.70 ± 0.35 mg/L recorded in Reservoir A were lower than 6.10 ± 0.36 mg/L in Reservoir B while 5.30 ± 0.31, 3.60 ± 0.18, 5.50 ± 0.22 and 5.20 ± 0.20 mg/L were marginally higher than 4.80 ± 0.28, 3.40 ± 0.15, 5.20±0.22 and 5.10±0.18 in June, July, August and September respectively. Water quality parameter results is presented in Table 3.

Table 3 | Summary of Monthly Average Water Quality Parameters from Teaching and Research Farm, FUTA

Month	Sample	Temperature (°C)	Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)
May	A	28.50±1.70	198.40±11.67	6.58±0.37	5.70±0.35
	B	28.50±1.68	188.70±11.12	6.60±0.39	6.10±0.36
June	A	26.90±1.59	193.90±11.42	7.06±0.42	5.30±0.31
	B	26.80±1.58	173.60±10.23	6.99±0.41	4.80±0.28
July	A	25.80±1.30	198.90±10.05	7.00±0.35	3.60±0.18
	B	25.70±1.14	198.20±8.76	7.04±0.31	3.40±0.15
August	A	26.00±1.02	258.0±10.14	8.99±0.35	5.50±0.22
	B	26.10±1.03	241.00±9.47	9.20±0.36	5.20±0.20
September	A	26.10±0.92	236.00±8.34	10.10±0.36	5.20±0.18
	B	26.00±0.92	244.00±8.63	9.25±0.33	5.10±0.18
Average		26.64±1.29	213.07±9.98	7.88±0.37	4.99±0.24
Boyd (1998)		25 – 32 °C	20 – 1500	7.5 – 8.5	≥ 5

3.3 | Correlation Relationship

Correlational relationship between the investigated microbial (bacteria, fungi and coliform counts) and water quality (temperature, dissolved oxygen, conductivity and pH) parameters revealed that there was strong correlation (0.9828, 0.9686 and 0.9263) between bacteria, fungi, coliform and temperature ($p>0.05$) respectively. Weak correlation (0.3437, 0.4419 and 0.3656) exists between conductivity, bacteria, fungi and coliform. Weak correlation (0.4693) was between pH and bacteria while mild correlation (0.5624 and 0.5015) was between fungi, coliform and pH. Dissolved oxygen has strong correlation (0.6203) with bacteria, and weak correlation (0.4614 and 0.4267) with fungi and coliform respectively. Correlation relationship results is presented in Table 4.

Table 4 | Correlation Analysis of Water Samples from FUTA Teaching and Research

	Temperature (°C)	Conductivity (µS/cm)	pH	Dissolved Oxygen (mg/L)	Bacteria	Fungi	coliform
Temperature (°C)	1						
Conductivity (µS/cm)	-0.489	1					
pH	-0.563	0.8452*	1				
Dissolved Oxygen (mg/L)	0.5698	0.3105	0.2066	1			
Bacteria	0.9828*	-0.3437	-0.4693	0.6203*	1		
Fungi	0.9686*	-0.4419	-0.5625	0.4615	0.9816*	1	
coliform	0.9263*	-0.3656	-0.5015	0.4267	0.9612	0.9899*	1

Correlation level of significance at p>0.05*

4. | Discussion

Comparatively, microbial analyses investigated in two FUTA reservoir water samples revealed that total bacteria count values (2.55±1.10 x 10^2 CFU/mL) were significantly lower than (5.90 x 10^5 CFU/mL) and (12.10 x 10^5 CFU/mL) in some fish pond water in Wukari and Ilorin metropolis reported by Agwaranze *et al.,* (2024) and Aborisade *et al.,* (2023) findings respectively. In the same vein, range of total bacteria counts (1.50 x 10^4 – 1.13 x 10^6 CFU/mL) reported by Torimiro *et al.,* (2014) were significantly higher than the values reported in this study. The presence of bacteria isolates in water reservoir indicated environmental contamination due to run-off, biogeochemical cycle Also, nutrient enrichment from leftover fish feed fed to culture fish stocks due to poor management practices (Orji *et al.,* 2022) contribute to bacteria proliferation.

Total coliform count (0.40±0.30 x 10^2 CFU/mL) reported in the study were significantly lower than 4.00 x 10^3 CFU/mL in ponds within Uyo (Amande and Nwaka, 2013), 4.20±0.91 x 10^3 CFU/mL (Aborisade *et al.,* 2023) and 4.20±0.20 x 10^1 - 6.00±0.0 x 10^3 CFU/mL (Anyim, 2017). Coliform detection particularly in drinking and water related food productions is precursory to the presence of pathogenic microbes in water sources (Some *et al.,* 2021).

Njoku *et al.,* (2015) fungi count in earthen (2.40 x 10^5 CFU/mL) and concrete (2.25 x 10^5 CFU/mL) fish pond waters within the Niger-Delta region were within range (2.40±0.15 x 10^3 CFU/mL) obtained by Aborisade *et al.,* (2023) but higher than (1.60±0.40 x 10^2 CFU/mL) reported in the study. Also, range of fungi counts reported in pond water biofilm (4.00±0.20 x 10^2 - 5.20±0.00 x 10^2 CFU/mL) and pond water (4.00±0.20 x 10^2 - 5.80±0.20 x 10^3 CFU/mL) by Anyim (2017) in fish ponds within Okigwe, Imo State were higher than values reported in this study. Comparatively, fungi count was higher in biofilm than pond water.

Faecal counts were absent in FUTA Teaching and Research Farm water reservoir subjected to investigation during the study period, significant range values (1.50 - 2.80 lg_{10} CFU/mL) were recorded in earthen ponds (Olalemi *et al.,* 2023), (9.00 x 10^8 - 2.10 x 10^8 SFU/mL) catfish culture water in Rivers State (Obire and Ovienovie, 2017) and (3.00±0.10 x 10^5 - 5.50±0.20 x 10^3 CFU/mL) in ponds within Okigwe (Anyim, 2017).

Microbial presence in reservoir water may be as a result of location, biogeochemistry processes, high organic contents, employed management practices and strategies among others (Chukwuma *et al.,* 2020).

Optimum water quality parameters are germane to the survival and health of fish under culture. Mean pH value (7.88 ± 0.37) reported in this study was significantly higher than 6.97 ± 0.02, 6.94±0.01 and 6.39±0.01 reported by Mgbemena *et al.,* (2021) in artificial ponds in Anambra, Imo and Lagos metropolitan cities respectively. Hydrogen ion values (7.10 ± 0.006 - 8.39 ± 0.01) in ponds in Fisheries and Aquaculture Department and Oda fish farm commune, Akure reported by Olukunle and Oyewumi (2017) were within the range reported in this study. Similar pH trends (6.80±0.03 - 7.10±0.62) were observed by Danba *et al.,* (2015) in ponds within Kaduna Local Government Areas.

Conductivity values (173.60±10.23 - 258.00±10.14 µS/cm) reported in this study were significantly lower compared to (296.30±1.73 - 613.70±3.03 µS/cm) observed by Danba *et al.,* (2015) but higher than (0.012 - 0.017 mS/cm) observed by Ehiagbonare and Ogunrinde (2020) in Okada and its environ pond waters, Edo State.

Significant variations were observed in temperature range values (20.20 - 29.50 °C) and (19.10 - 34.50 °C) recorded by Roy and Saikia (2023) and Mehta and Kumari (2022) respectively in comparison to (25.70 – 28.50 °C) obtained herein. However, (25.70±1.07

- 27.80±1.03 °C) values obtained by Danba *et al.,* (2015) were within range reported in this study.

Seasonal dissolved oxygen values (5.50 - 10.10 mg/L) obtained by Mehta and Kumari (2022) in Darbhanga ponds, India vary significantly to (3.40 - 6.10 mg/L) reported during this study period. Ditto for (9.30 - 16.20 mg/L) reported by Ehiagbonare and Ogunrinde (2020) in pond waters but higher than (2.01±0.03 - 3.05±1.03 mg/L) reported by Danba *et al.,* 2015. Apart from low levels of dissolved oxygen, water quality parameters reported herein are within favorable range for aquaculture. Variations in the levels of dissolved oxygen and other water quality parameters could be attributed to seasonal change, sources of culture water, species of fish raised, fish culture management strategy, time of the day, sun intensity, etc.

Water quality correlational analysis is critical to identify and predict mutual relationships among various investigated parameters to understand potential pollution, risk assessment and spatial variation in different water sources (Wang *et al.,* 2024). Temperature and dissolved oxygen correlation coefficient (-0.31) reported by Karmakar and Singh (2022) study showed negative relationship in water samples collected from industrial sites in West District, Tripura, India compared to positive coefficient (0.57) reported in the study. Also, similar coefficient (0.39) was observed between conductivity and temperature in comparison with (0.49) in this study.

pH and conductivity correlation coefficient (0.25) reported by Suleiman *et al*, (2022) in water samples from Jaen District, Kano, (0.19) Agarwal *et al.,* (2014) and (0.20) by Kothari *et al.,* (2021) studies on underground water sources from various districts in India were positive and significant compared to negative and weak values (-0.14) reported by Shroff *et al.,* (2015) and (0.49) from underground water sources Valsad District, India and in this study respectively.

According to Gu *et al.,* (2021), strong and moderation positive relationship (0.77 and 0.58) between temperature, fungal and bacterial community profile in Pearl River Estuary were significantly lower than (0.97 and 0.10) obtained herein ($P>0.05$). Similarly, strong positive relationship (0.93) between pH and total coliform obtained in this study was significantly higher than weak negative value (0.20) reported by Kothari *et al.,* (2021). Variations in correlation analysis of water quality parameters could be linked to several factors such as type of water, seasonal variations, presence of pollutants such as metalloids, organic, inorganic, heavy metals, etc, geographical location, biogeochemical and other natural processes such as nutrient cycling, erosion, runoffs among others (Zoua *et al.,* 2024).

5. | Conclusion

This study revealed that microbial loads in the FUTA Teaching and Research Farm reservoirs were within permissible limits (total bacteria (100 – 500 CFU/100mL) and total fungal and faecal coliform (0 CFU/100mL)) for aquaculture. The absence of faecal confirmed the suitability of the water for fish farming. Water quality parameters varied across months but remained within safe range. The findings demonstrate that both reservoirs are suitable for aquaculture operations under current management practices and would not constitute health hazard to the public and environment.

Acknowledgement

The authors appreciate the technical contributions of Mr. Michael Ojuola and Victor Adams during the water quality parameters benchwork, and the Department of Fisheries and Aquaculture Technology, The Federal University of Technology, Akure for providing laboratory facilities.

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Appendix

AppendixTable I: Water Sample Collection GPS Coordinates

S/N	Locations	Coordinates (x)	Coordinates (y)	Shape*
1	Point A	5.145833	7.293661	Point
2	Point B	5.145278	7.293611	Point
3	Fish Farm	5.146765	7.295609	Point