



## Article Info

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## Assessment of Water Quality Parameters in Selected Fish Farms in Sokoto Metropolis, Nigeria

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This study evaluated water quality parameters from selected fish farms in Sokoto metropolis, Nigeria. Water samples were collected from ten fish farms and analysed using the standard procedures recommended by the American Public Health Association. The parameters such as temperature, turbidity, pH, electrical conductivity (EC), dissolved oxygen (DO), nitrate (NO<sub>3</sub>), and alkalinity were assessed and results were analysed using one way analysis of variance (ANOVA) with the aid of SPSS version 27. The values of the physicochemical parameters of ten fish farms were between the range of 24.03±0.03 to 29.40±0.23°C for temperature, 6.68±0.11 to 7.83±0.05 for pH, 2.07±0.00 to 61.33±0.23 NUT for turbidity, 715.33±195.02 to 1631.67±31.38 µS/cm for EC, 5.23±0.03 to 8.17±0.88 mg/L for DO, 13.70±1.37 to 100.33±0.33 for NO<sub>3</sub>, and 118.67±2.91 to 333.33±33.18 for alkalinity respectively. All parameters examined were within acceptable limits recommended by World Health Organization except NO<sub>3</sub> value which exceed in six farms and may lead to methemoglobinemia, decreased immune response and osmoregulatory function in fish. DO positively correlated with temperature, pH, NTU, EC, NO<sub>3</sub> and alkalinity. Temperature positively correlated with all other parameters except pH. pH positively correlated with NTU, EC and DO but negatively correlated with other parameters. NTU and EC positively correlated with all other parameters except NO<sub>3</sub> and alkalinity. A significant association between the parameters in each farm was observed. Regular monitoring and changing of water can help improve water quality for better fish farming in the area and the country at large.

**Keywords:** Assessment, Water Quality Parameters, Selected Fish Farms and Sokoto Metropolis.

## 1. Introduction

Water is a vital natural resource essential for the well-being of all living organisms, including plants, animals, and humans. It serves as a crucial solvent for various sectors such as agriculture, aquaculture, industries, and tourism (Aydin, 2018). Fish farming, heavily relies on water, necessitating continuous monitoring of water quality. The quality of water directly influences its suitability for use and the ability to sustain the health of aquatic organisms (Orobator *et al.*, 2020).

Water quality parameters encompasses a range of physical, chemical, and biological factors shaping the overall condition of aquatic habitats (Al-khatib *et al.*, 2023). Maintaining an optimal water environment is crucial for the well-being of fish species, as deviations can lead to stress, diseases, reduced growth rates, and even mortality (Iwar *et al.*, 2021). The interdependence between water quality and fish wellbeing highlights the importance of monitoring these parameters in fish farming operations (Yohanna *et al.*, 2020). The influence of water quality on fish growth is a crucial concern in

aquaculture, directly impacting the productivity and profitability of fish farms (Ayeloja *et al.*, 2021).

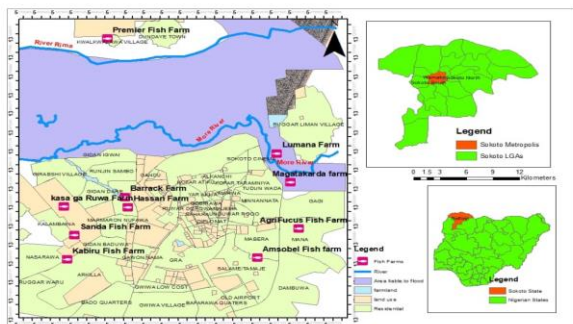
Water quality assessments involve regular monitoring of these parameters to identify potential issues and implement appropriate management actions (Nura *et al.*, 2017). Strategies may include water treatment, aeration, nutrient management, stocking density control, and feed management (Anthony and Richard, 2016). Monitoring and managing water quality are crucial for maintaining optimal conditions for fish growth and health. These parameters can fluctuate due to factors like weather conditions, pollutants, and activities of fish and other organisms in the water (Akpotayire *et al.*, 2020). This research was conducted to assess the water quality parameters of selected fish farms in Sokoto metropolis, Nigeria with a view to improve understanding on the water quality parameters and their importance among fish farmers in Sokoto, Nigeria and world at large.

## 2. Materials and Methods

### 2.1 Study Area

This research was conducted across ten (10) selected fish farms within the Sokoto metropolis, which comprises the metropolitan local government areas of Sokoto North and Sokoto South. Geographically situated between longitude 13° 3' 5" North and 5° 13' 53" East, Sokoto metropolis spans approximately 20 square kilometers and is home to a population exceeding one million people. It shares boundaries with Kware Local Government Area to the North, Dange Shuni Local Government Area to the South, Silame Local Government Area to the West, and Rabah Local Government Area to the East (Maikano *et al.*, 2020).

The region's vegetation belongs to the Sudan Savannah biome, characterized by abundant grasses with scattered trees, typically reaching heights of 1.5 – 2m for grasses and not exceeding 15m for trees. The primary rainy season spans from May to September, with an average annual rainfall of around 1000mm (Lema *et al.*, 2022). The inhabitants of Sokoto metropolis are predominantly Hausa-Fulani, engaging primarily in farming, animal husbandry, business, and civil service. Significant communities of Yoruba, Igbo, Kabawa, Zamfarawa, and Zabarmawa also reside in the area. Additionally, various other tribes such as Dakkarawa, Igala, Ibra, Nufawa, and Gwarawa are present, drawn to the region due to its diverse economic activities (Lema *et al.*, 2022).



**Figure 1: Map of Sokoto and its Environs showing the Study Area**

**Source: GIS Laboratory, Department of Geography, Sokoto State University, Sokoto**

### 2.2 Study Design

A survey conducted in the study area identified 37 fish farms, though fewer than 15 remain operational due to the country's economic situation. From these, 10 fish farms were randomly selected for this study. At each selected farm, 75cl of water was collected and sent to the National Water Quality Reference Laboratory at the Sokoto Rima River

Basin Development Authority (SRRBDA) for testing. Water quality parameters were analysed using the standard methods recommended by the American Public Health Association (APHA) in 2017 for water and wastewater testing.

### 2.3 Collection of Water Samples

Water samples were collected daily between 7-8 am, before feeding the fish, in clean 75cl plastic bottles from ten selected fish farms in Sokoto metropolis between April and June to assess the physicochemical parameters. The samples were labelled according to the farm names and taken to the National Water Quality Reference Laboratory of the Sokoto Rima River Basin Development Authority for analysis (Ashmawy *et al.*, 2018)

### 2.4 Determination of Water Quality Parameters

Water quality parameter analysis was conducted at National Water Quality Reference Laboratory of Sokoto Rima River Basin Development Authority, (SRRBDA) Sokoto according to standard method of analyzing water and waste water recommended by American Public Health Association (APHA, 2017).

### 2.5 Temperature

Temperatures of the water was measured in the laboratory using multipurpose water quality tester, model: C600 by dipping it into the water and allow the water to settle for about two minutes and reading was recorded as described by APHA, (2017).

### 2.6 Turbidity

Turbidity of water was measured in the laboratory using turbidimeter, model: HACH 2100Q, by diffing it electrode into the water and allow the water to settle for about two minutes and the reading was recorded as described by APHA, (2017).

### 2.7 Potential Hydrogen Ion (pH)

The pH of the water was determined in the laboratory using multipurpose water quality tester, model: C600, by diffing it into the water and allow the water to settle for about two minutes and the reading was recorded as described by APHA, (2017).

### 2.8 Conductivity

Conductivity of the water was measured in the laboratory using conductivity meter, model: Ionix PC50, by diffing it electrode into the water and allow the water to settle for about two minutes and the

reading was recorded as described by APHA, (2017).

### 2.9 Dissolved Oxygen (DO)

Dissolved Oxygen of the water was determined in the laboratory using portable DO analyzer, model: JPB 607A, by diffing it electrode into the water and allow the water to settle for about two minutes and the reading was recorded as described by APHA, (2017).

### 2.10 Nitrate (NO<sub>3</sub>)

The nitrate levels in the water samples were measured in the laboratory using a HACH DR 900 colorimeter. Ten milliliters of each sample were placed into a 25-milliliter colorimeter bottle, which had been rinsed with the sample beforehand. Nitro Ver pillow reagent was then added to the sample and shaken vigorously for one minute. A blank sample was used to zero the colorimeter reading. The prepared sample bottle was then placed into the colorimeter cell tube, covered with the colorimeter cap, and the measurement was initiated by pressing enter and reading was then recorded as described by APHA, (2017)

### 2.11 Alkalinity

Alkalinity of the water samples was measured in the laboratory using Acid-base titration method. One hundred milliliter of the water sample was measured into a 250ml conical flask and 2-3 drops of methyl orange indicator was added, causing the solution to turn yellow. The initial burette reading was recorded and the burette was filled with 0.02 N hydrochloric acid. The titration was then performed until the solution turned a golden colour, at which point the final burette reading was recorded as described by APHA, (2017).

### 2.12 Statistical Analysis

The collected data was analysed using one-way analysis of variance (ANOVA) in SPSS version 27.0 to identify differences between mean values. Correlation among water quality parameters was assessed through Pearson Correlation Coefficient in the same software to evaluate the significance of associations. A p value of  $\leq 0.05$  was considered statistically significant as described by Ashmawy *et al.*, (2018)

## 3. Results and Discussion

### 3.1 Results

#### 3.1.1 Mean Value of Water Quality Parameters of Ten (10) Selected Fish Farm in Sokoto Metropolis.

As presented in table 1, the highest mean water temperature of  $29.40 \pm 0.23$  °C was recorded in Kasa ga ruwa fish farm, while the lowest temperature of  $24.03 \pm 0.03$  °C was observed in Premier fish farm. Maximum mean pH value of  $7.83 \pm 0.05$  was observed in Kabiru farm and minimum value of  $6.68 \pm 0.11$  was recorded in Lumana farm. The highest mean turbidity of  $61.33 \pm 0.23$  NTU was recorded in Kabiru farm, while the lowest of  $2.07 \pm 0.00$  NTU was observed in Premier farm. The highest mean electrical conductivity of  $1631.67 \pm 31.38$   $\mu\text{S/cm}$  was observed in Sanda farm, while the lowest of  $715.33 \pm 195.02$   $\mu\text{S/cm}$  was recorded in Amsobel farm. Dissolve oxygen (DO) was recorded to have the maximum mean value of  $8.20 \pm 0.06$  ppm in Magatakarda farm and the minimum value of  $5.23 \pm 0.03$  ppm in Amsobel farm. The highest mean nitrate of  $100.33 \pm 0.33$  ppm was recorded in Amsobel farm and the lowest value of  $13.70 \pm 1.37$  ppm was observed in Hassan farm. The highest mean alkalinity of  $333.33 \pm 33.18$  was observed in Hassan farm and the lowest value of  $118.67 \pm 2.91$  was recorded in Barrack farm as seen in table 1.

#### 3.1.2 Correlation of the Water Quality Parameters in Selected Fish Farms

The results of this study on the correlation among water quality parameters in selected fish farms are summarized in Table 2. Temperature positively correlated with turbidity, electric conductivity, dissolve oxygen, nitrate and alkalinity but negatively correlated with pH ( $P=0.05$ ). pH shows a positive correlation with turbidity, electric conductivity and dissolved oxygen but show a negative correlation with temperature, nitrate and alkalinity ( $P=0.05$ ). Turbidity positively correlated with temperature, pH, electric conductivity and dissolved oxygen but negatively correlated with nitrate and alkalinity ( $P=0.05$ ). Electric conductivity positively correlated with temperature, pH, turbidity, and dissolved oxygen, but negatively correlated with nitrate and alkalinity ( $P=0.05$ ). Dissolved oxygen shows a positive correlation with temperature, pH, turbidity, electric conductivity, nitrate, and alkalinity ( $P=0.05$ ). Nitrate positively correlated with temperature and dissolved oxygen but negatively correlates with pH, turbidity, electric conductivity and alkalinity ( $P=0.05$ ). Alkalinity positively correlated with temperature and dissolved oxygen, but negatively correlated with pH, turbidity, electric conductivity and nitrate ( $P=0.05$ ).

**Table 1: Mean Value of Water Quality Parameters of Ten (10) Selected Fish Farm in Sokoto Metropolis**

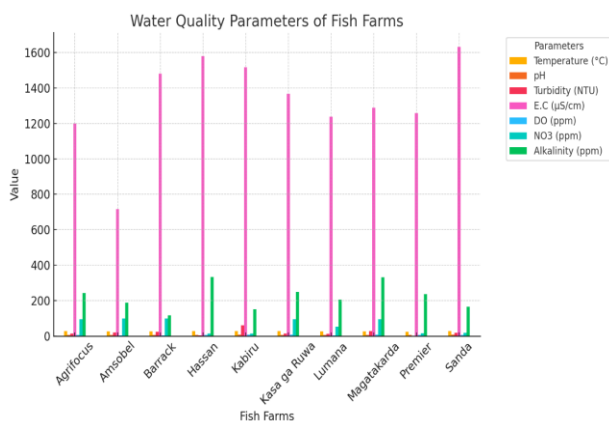
Parameters	Temperature (°C)	pH	Turbidity (NTU)	E.C (µS/cm)	DO (ppm)	NO <sub>3</sub> (ppm)	Alkalinity (ppm)
Agrifocus Farm	29.27±0.18 <sup>a</sup>	7.22±0.04 <sup>abc</sup>	13.67±0.19 <sup>f</sup>	1198.67±19.10 <sup>bc</sup>	7.53±0.20 <sup>b</sup>	95.23±1.18 <sup>b</sup>	244.00±2.33 <sup>b</sup>
Amsobel Farm	26.97±1.09 <sup>b</sup>	7.16±0.22 <sup>bc</sup>	20.33±0.37 <sup>d</sup>	715.33±195.02 <sup>d</sup>	5.23±0.03 <sup>f</sup>	100.33±0.33 <sup>a</sup>	187.67±4.04 <sup>cd</sup>
Barrack Farm	27.40±0.23 <sup>bc</sup>	7.23±0.18 <sup>abc</sup>	25.73±0.32 <sup>c</sup>	1480.33±73.34 <sup>ab</sup>	5.27±0.67 <sup>f</sup>	100.00±0.00 <sup>a</sup>	118.67±2.91 <sup>f</sup>
Hassan Farm	27.97±0.03 <sup>bc</sup>	7.41±0.27 <sup>ab</sup>	4.05±0.01 <sup>b</sup>	1578.33±39.22 <sup>a</sup>	6.63±0.22 <sup>c</sup>	13.70±1.37 <sup>e</sup>	333.33±33.18 <sup>a</sup>
Kabiru Farm	28.43±0.12 <sup>ab</sup>	7.83±0.05 <sup>a</sup>	61.33±0.23 <sup>a</sup>	1516.67±4.26 <sup>ab</sup>	8.17±0.33 <sup>a</sup>	14.93±0.46 <sup>e</sup>	152.33±1.45 <sup>e</sup>
Kasa ga Ruwa Farm	29.40±0.23 <sup>a</sup>	6.68±0.19 <sup>c</sup>	13.73±0.12 <sup>f</sup>	1367.00±0.58 <sup>bc</sup>	8.17±0.88 <sup>a</sup>	94.70±0.40 <sup>b</sup>	249.00±0.58 <sup>b</sup>
Lumana Farm	27.23±0.15 <sup>bc</sup>	6.68±0.11 <sup>c</sup>	11.77±0.09 <sup>g</sup>	1236.67±81.19 <sup>bc</sup>	5.47±0.33 <sup>ef</sup>	53.07±0.07 <sup>c</sup>	206.33±0.33 <sup>c</sup>
Magatakarda Farm	27.53±0.09 <sup>bc</sup>	7.21±0.12 <sup>abc</sup>	28.77±0.07 <sup>b</sup>	1288.67±20.74 <sup>bc</sup>	8.20±0.06 <sup>a</sup>	95.23±0.15 <sup>b</sup>	332.67±0.33 <sup>a</sup>
Premier Farm	24.03±0.03 <sup>c</sup>	7.43±0.23 <sup>ab</sup>	2.07±0.00 <sup>i</sup>	1258.33±62.83 <sup>bc</sup>	5.67±0.19 <sup>e</sup>	15.73±0.18 <sup>e</sup>	238.00±2.52 <sup>b</sup>
Sanda Farm	28.00±0.00 <sup>bc</sup>	7.68±0.28 <sup>ab</sup>	18.83±0.03 <sup>e</sup>	1631.67±31.38 <sup>a</sup>	6.13±0.03 <sup>d</sup>	18.03±0.94 <sup>d</sup>	166.67±0.33 <sup>de</sup>

Values are expressed as Mean±SEM of three replicates. Values in row having different superscript differs significantly at P<0.05 level (One Way ANOVA)

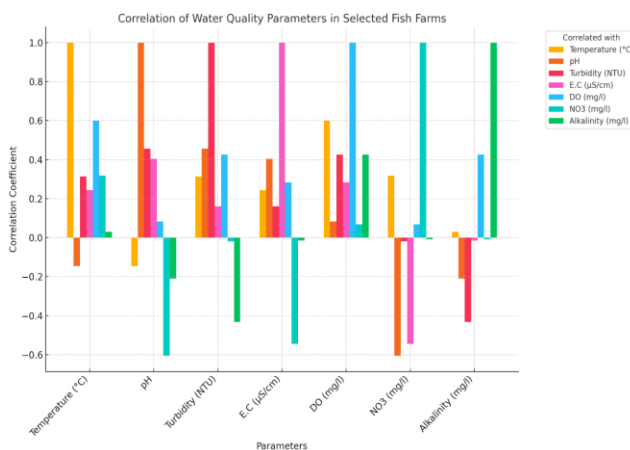
**Table 2: Correlation of the Water Quality Parameters in Selected Fish Farms in Sokoto Metropolis**

Parameters	Temperature (°C)	pH	Turbidity (NTU)	E.C (µS/cm)	DO (mg/l)	NO <sub>3</sub> (mg/l)	Alkalinity (mg/l)
Temperature (°C)	1.000	-0.146	0.313	0.243	0.600 <sup>*</sup>	0.318	0.031
pH	-0.146	1.000	0.457	0.404	0.083	-0.606 <sup>*</sup>	-0.209
Turbidity (NTU)	0.313	0.457	1.000	0.160	0.425	-0.018	-0.433
E.C (µS/cm)	0.243	0.404	0.160	1.000	0.283	-0.544	-0.015
DO (mg/l)	0.600 <sup>*</sup>	0.083	0.425	0.283	1.000	0.069	0.426
NO <sub>3</sub> (mg/l)	0.318	-0.606 <sup>*</sup>	-0.018	-0.544	0.069	1.000	-0.008
Alkalinity (mg/l)	0.031	-0.209	-0.433	-0.015	0.426	-0.008	1.000

\*Correlation is significant at p=0.05



**Fig 2: Mean Value of Water Quality Parameters of Ten (10) Selected Fish Farm in Sokoto Metropolis**



**Fig 3: Correlation of the Water Quality Parameters in Selected Fish Farms in Sokoto Metropolis**

### 3.2 Discussion

The results of this study on water quality parameters show some variations across the selected fish farms. The maximum mean temperature of 29.40±0.23 that was recorded in Kasa ga Ruwa fish farm and minimum mean temperature of 24.03±0.03 that observed in Premier fish farm may be due to weather and geographical locations of the farms. The result was higher than the findings of Danba *et al.* (2015) who reported a maximum mean temperature of 27.8±1.03 in their study on Physicochemical analysis of pond water conservation in Kano State Nigeria and Ezeanya *et al.* (2015) who reported a mean temperature of 26.9±0.00 in their study on Standard Water Quality Requirement and Management Strategies for Fish Farming (A Case of Otamire River). The result was slightly higher than the findings of Bubu-Davies and Kpikpi (2021) who reported higher mean temperature of 28.68±1.92 in their study on Evaluation of Water Quality Index in Some Artificial Aquatic Environment in Port Harcourt, River State, Nigeria, Collins and Sawere (2019) who reported high temperature of 27.00 in their study on Determination of Some Physicochemical Parameters and Selected Heavy Metals from Water Collected from Concrete Fish Pond in Ozoro Town, Saanu *et al.* (2017) who reported maximum mean temperature of 26.53±0.56 in their study on Assessment of Effect of Fish Feeding Practices on Water Quality of Some Fish Pond, Ado Ekiti, Nigeria, Ukwe and Abu (2016) who reported high temperature of 26.99, and Akpotayire *et al.* (2020)

who reported high temperature of 25.4 respectively. However, the result was lower than that of Khan *et al.* (2018) who reported high temperature of 30.5 in their study on Water Quality Requirement and Management Strategy for Fish Farming, Mustapha (2017) who reported maximum mean temperature of  $35.9 \pm 0.1$  in his study on Comparative Assessment of the Water quality of Four Type of Aquaculture Pond Under Different Culture System and Onajobi *et al.* (2023) who reported a maximum temperature of 34.2 in their study on Microbiological and Physicochemical Assessment of Selected Fish Pond Water Samples in South-West, Nigeria. Both the maximum and minimum temperature recorded in this study are within the acceptable permissible limit reported by Iwar *et al.* (2021) and Orobator *et al.* (2020) respectively. However, the temperature significantly correlates positively with dissolve oxygen and positively correlates with turbidity, electric conductivity, nitrate, alkalinity and prevalence of the fish parasites but negatively correlates with pH.

The highest mean pH that was observed in Kabiru fish Farm  $7.83 \pm 0.05$  and lowest that was recorded in Lumana fish farm  $6.68 \pm 0.11$  could also be related to location of the farms and soil nature of the area. This result was relatively higher than the findings of Danba *et al.* (2015) who reported a maximum mean pH of  $7.1 \pm 0.62$  in their study on Physicochemical analysis of pond water conservation in Kano State Nigeria, Soliman *et al.* (2022) who also reported a maximum pH of 7.8 in their study on Fish Growth Performance, Body Composition and Water Quality in Integrated System. Additionally, the result was higher than the results of Orobator *et al.* (2020) who reported higher pH of 6.39 in their study on Water Quality Evaluation from Selected Aquaculture pond in Benin city, Nigeria. Similarly, this result was lower compare to the findings of Aydin (2018) who reported a maximum mean pH of  $8.590 \pm 0.146$  in his study on Statistical Analysis of Water Quality Parameters for Pollution Source Identification in Bektas Pond, Turkey, Mustapha (2017) who reported maximum mean pH of  $8.03 \pm 0.2$  in his study on Comparative Assessment of the Water quality of Four Type of Aquaculture Pond Under Different Culture System. However, both the minimum and maximum mean pH recorded in this study are within the acceptable permissible limit reported by Orobator *et al.* (2020), Iwar *et al.* (2021), Soliman *et al.* (2022) and Yohanna *et al.* (2020) respectively. The pH value positively correlates with turbidity, electric conductivity, dissolve oxygen and prevalence of the fish parasites but negatively correlates with temperature, alkalinity and significant correlate negatively with nitrate.

The highest mean turbidity of  $61.33 \pm 0.23$  that was recorded in Kabiru fish farm and lowest of  $2.07 \pm 0.00$  that was observed in Premier fish farm could be due to location where the farms are

located. This results was slightly lower than the result of Danba *et al.* (2015) who reported high turbidity of 65.0 in their study on Physicochemical analysis of pond water conservation in Kano State Nigeria. Similarly, the result was lower compare to the findings of Iwar *et al.* (2021) who reported high mean turbidity of  $275.5 \pm 50.848$  in their study on Assessment of Heavy Metals and Physicochemical Pollution Loadings of River Benue Water at Makurdi using Water Quality Index and Multivariate Statistics, Akongyuure and Alhassan (2021) who reported maximum mean turbidity of  $142.56 \pm 75.16$  in their study on Variation of Water Quality Parameters and Correlation Among them and Fish Catch per Unit Effort of Tono Reservoir of Northern Ghana, Khan *et al.* (2018) who reported high turbidity of 316 in their study on Water Quality Requirement and Management Strategy for Fish Farming, Saanu *et al.* (2017) who reported maximum mean turbidity of  $185.92 \pm 66.58$  in their study on Assessment of Effect of Fish Feeding Practices on Water Quality of Some Fish Pond, Ado Ekiti, Nigeria and Onajobi *et al.* (2023) who reported high turbidity of 79.8 in their study on Microbial and Physicochemical Assessment of Selected Fish Pond Water Sample in South-West, Nigeria. However, the mean turbidity obtained in this study was higher compare to the result of Bubu-Davies and Kpikpi (2021) who reported higher mean turbidity of  $33.16 \pm 25.81$  in their study on Evaluation of Water Quality Index in Some Artificial Aquatic Environment in Port Harcourt, River State, Nigeria. Aduwo and Adeniyi (2019) who reported maximum mean turbidity of  $47.7 \pm 6.9$  in his study on the Physicochemical Water Quality of Obafemi Awolawo University Teaching and Research Farm Lake, Ile Ife, Southwest Nigeria, Akpotayire *et al.* (2020) who reported the maximum turbidity of 33.3 in their study on Assessment of Physicochemical Characteristics of Artificial Fish pond Water in Ogoni, A case Study of Ka-Gwara Community, Lawal *et al.* (2015) who reported higher mean turbidity of  $9.99 \pm 2.13$ , Unique *et al.* (2016) who reported maximum mean of  $1.49 \pm 0.00$  and Bello *et al.* (2018) who also reported higher turbidity of  $5.45 \pm 0.87$ . The turbidity positively correlates with temperature, pH, electric Conductivity, dissolve oxygen and prevalence of the fish parasites but negatively correlates with nitrates and alkalinity.

The highest mean electric conductivity that was recorded in Sanda fish farm  $1631 \pm 31.38$  and lowest that was observed in Amsobel fish farm  $715.33 \pm 195.02$  may as a results of water changing time. This result was higher than the results of Danba *et al.* (2015) who reported maximum of  $613.7 \pm 3.03$  in their study on Physicochemical analysis of pond water conservation in Kano State Nigeria, Orobator *et al.* (2020) who reported high conductivity of 330.00 in their study on Water Quality Evaluation from Selected Aquaculture pond in Benin city, Nigeria, Aydin (2018) who reported a



maximum mean conductivity of  $310.9 \pm 31.06$  in his study on Statistical Analysis of Water Quality Parameters for Pollution Source Identification in Bektas Pond, Turkey, Akpotayire *et al.* (2020) who reported high conductivity of 822, Mustapha (2017) who reported maximum conductivity of  $472 \pm 0.1$ , Collins and Sawere (2019) who reported high conductivity of 191.2, Bubu-Davies and Kpikpi (2021) who reported high conductivity of  $238.08 \pm 81.34$ , Saanu *et al.* (2017) who reported maximum mean conductivity of  $529.27 \pm 142.54$  and Onajobi *et al.* (2023) who reported high conductivity of 196 in their various studies on water quality parameters respectively. Similarly, both maximum and minimum mean electric conductivity obtained in this study are within the permissible limits reported by Orobator *et al.* (2020), Iwar *et al.* (2021), Soliman *et al.* (2022) and Yohanna *et al.* (2020) respectively. However, electric conductivity positively correlates with temperature, pH, turbidity and dissolve oxygen but negatively correlates with nitrate, alkalinity and prevalence of fish parasites.

The highest mean Dissolve oxygen that was observed in Magatakarda fish farm  $8.20 \pm 0.06$  and the lowest that was recorded in Amsobel fish farm  $5.27 \pm 0.67$  may be related to the water sources and location of the farms. The result is slightly higher than that of Mustapha (2017) who reported maximum mean dissolve oxygen of  $6.1 \pm 0.1$  in his study on Comparative Assessment of Water Quality of Four Type of Aquaculture Pond Under Different Culture Systems, Bubu-Davies and Kpikpi (2021) who also reported higher dissolve oxygen of  $7.09 \pm 3.16$  in their study on Evaluation of Water Quality Index in Some Artificial Aquatic Environment in Port Harcourt, River State, Nigeria, Akpotayire *et al.* (2020) who reported the maximum dissolve oxygen of 6.45 in their study on Assessment of Physicochemical Characteristics of Artificial Fish pond Water in Ogoni, A case Study of Ka-Gwara Community, Ukwé and Abu (2016) who reported the higher dissolve oxygen of  $6.36 \pm 1.85$  in their study on Physicochemical Parameters of Water Holdin Tanks of *Clarias gariepinus* induced with Ovaprim and Ovulin Hormones and Orobator *et al.* (2020) who reported high dissolve oxygen of 7.34 in their study on Water Quality Evaluation from Selected Aquaculture Pond in Benin City, Nigeria. Additionally, the results was much higher than the result of Danba *et al.* (2015) who reported high dissolve oxygen of  $3.08 \pm 0.13$  in their study on Physicochemical analysis of pond water conservation in Kano State, Nigeria, Khan *et al.* (2018) who reported maximum dissolve oxygen of 5.6, Mramba and Kahindi (2023) who reported high dissolve oxygen of  $5.7 \pm 1.6$  and Onajobi *et al.* (2023) who also reported maximum dissolve oxygen of 4.95 in their different studies on water quality parameters. However, the result is also slightly lower than that of Collins and Sawere. (2019) who reported maximum dissolve oxygen of

9.3, Aydin (2018) who reported high dissolve oxygen of  $13.583 \pm 0.304$  and Saanu *et al.* (2017) who reported maximum dissolve oxygen of  $9.23 \pm 1.41$  respectively. The maximum and minimum mean dissolve oxygen obtained in this study are also within the acceptable permissible limit reported by Orobator *et al.* (2020), Iwar *et al.* (2021), Soliman *et al.* (2022) and Yohanna *et al.* (2020) respectively. Dissolve oxygen significantly correlates positively with temperature and positively correlates pH, turbidity, electric conductivity, nitrate and alkalinity but negatively correlates with the prevalence of fish parasites.

The highest mean nitrate that was recorded in Amsobel fish farm  $100.33 \pm 0.33$  and lowest that was observed in Hassan fish farm  $13.70 \pm 1.37$  could be as a result of management practice and water changing time. The result was higher than that of Bubu-Davies and Kpikpi (2021) who reported maximum mean nitrate of  $0.50 \pm 0.71$  in their study on Evaluation of Water Quality Index in Some Artificial Aquatic Environment in Port Harcourt, River State, Nigeria, Aydin (2018) who reported a maximum mean nitrate of  $3.898 \pm 0.428$  in his study on Statistical Analysis of Water Quality Parameters for Pollution Source Identification in Bektas Pond, Turkey, Saanu *et al.* (2017) who reported maximum mean nitrate of  $7.63 \pm 1.65$  in their study on Assessment of Effect of Fish Feeding Practices on Water Quality of Some Fish Pond, Ado Ekiti, Nigeria and Orobator *et al.* (2020) who reported high nitrate of 59.40 in their study on Water Quality Evaluation from Selected Aquaculture pond in Benin city, Nigeria. However, this result was lower compare to the findings of Onajobi *et al.* (2023) who reported high nitrate of 600.0 in their study on Microbial and Physicochemical Assessment of Selected Fish Pond Water Sample in South-West, Nigeria. The minimum mean nitrate obtained in this study is within the acceptable permissible limit but the maximum exceed the permissible limit reported by Orobator *et al.* (2020), Iwar *et al.* (2021), Soliman *et al.* (2022) and Yohanna *et al.* (2020) respectively. Nitrate positively correlates with temperature, dissolve oxygen and prevalence of fish parasites but significantly correlates negatively with pH and also negatively correlates with turbidity, electric conductivity and alkalinity.

The highest mean alkalinity that was observed in Hassan fish farm  $333.33 \pm 33.18$  and lowest that was recorded in Barrack fish farm  $118.67 \pm 2.91$  may related to the water source and farm location. This result is higher than the findings of Mustapha (2017) who reported higher mean alkalinity of  $245 \pm 0.2$  in his study on Comparative Assessment of Water Quality of Four Type of Aquaculture Pond Under Different Culture Systems, Akpotayire *et al.* (2020) who reported the maximum alkalinity of 310.00 in their study on Assessment of Physicochemical Characteristics of Artificial Fish pond Water in

Ogoni, A case Study of Ka-Gwara Community, Saanu *et al.* (2017) who reported maximum mean alkalinity of 173.63±55.49 in their study on Assessment of Effect of Fish Feeding Practices on Water Quality of Some Fish Pond, Ado Ekiti, Nigeria and Collins and Sawere (2019) who reported high alkalinity of 36.10 in their study on Determination of Some Physicochemical Parameters and Selected Heavy Metals from Water Collected from Concrete Fish Pond in Ozoro Town, Orobator *et al.* (2020) who also reported the maximum alkalinity of 12.78 in their study on Water Quality Evaluation from Selected Aquaculture Pond in Benin city, Nigeria and Onajobi *et al.* (2023) who reported maximum of 23.30 respectively. Similarly, the result was within the acceptable limit for aquaculture operation. However, both maximum and minimum mean alkalinity obtained in this study are within the acceptable permissible limit for aquaculture operation reported by Orobator *et al.* (2020), Iwar *et al.* (2021), Soliman *et al.* (2022) and Yohanna *et al.* (2020) respectively. Alkalinity positively correlates with temperature and dissolve oxygen but negatively correlates with pH, turbidity, electric conductivity, nitrate and prevalence of fish parasites.

#### 4. Conclusion

The results of this study show that the water quality parameters are generally within permissible limits, making it suitable for fish farming and aquaculture. However, nitrate levels in the Agrifocus, Amsobel, Barrack, Hassan, Lumana, and Magatakarda fish farms exceed acceptable limits, which could lead to eutrophication, disease outbreaks, or fish mortality due to increased oxygen demand.

1. Continues monitoring of the water quality parameters should be carried out by the farmers on a regular basis to improve the quality of the water.
2. Aeration and filtration systems should be introduced to also improved the quality of the water parameters.
3. Further research should be carried out by other researchers in the area on the same topic to evaluate other water quality parameters that have not be captured in this research.

#### Conflict of interest

The authors declare no conflict of interest.

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