



Assessment of Physicochemical Parameters and Their Ecological and Health Implications in Aquaculture Ponds in Ede, Osun State, Nigeria

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Abstract: Aquaculture refers to the cultivation of aquatic organism such as fish, crustaceans, mollusks, and aquatic plants under controlled conditions for human consumption, economic gain, and ecological balance. It plays a vital role in ensuring food security and employment, especially in developing nations. This study assessed the physicochemical parameters of six aquaculture ponds in Ede North and Ede South Local Government Areas of Osun State, Nigeria, to determine their implications for aquatic ecology, fish health, and human well-being. Parameters including temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), turbidity, alkalinity, hardness, nitrate, nitrite, and phosphate were analyzed using standard APHA (2023) methods. Results revealed temperature ranged from 21.5°C to 25.0°C; EC from 340 to 900 $\mu\text{S}/\text{cm}$; TDS from 220 to 600 ppm; DO from 4.6 to 6.5 mg/L; and pH from 7.1 to 8.3. Nutrient parameters included nitrate (15–39 mg/L), nitrite (0.04–0.10 mg/L), and phosphate (0.11–0.28 mg/L). Analysis of variance (ANOVA) indicated statistically significant variations across ponds ($F = 38.48$, $p = 0.0015$; $R^2 = 0.8850$), suggesting spatial heterogeneity driven by runoff, management practices, and land use. Elevated EC, TDS, and phosphate in Ededimeji and Muslim Hospital ponds indicated anthropogenic inputs that could predispose the ponds to eutrophication, reduced DO, and altered microbial communities. While most values were within FAO and WHO aquaculture standards, nutrient enrichment poses long-term ecological risks and potential human health hazards through fish consumption. The study concludes that continuous monitoring and sustainable pond management are essential to maintaining ecosystem balance and ensuring safe aquaculture in Osun State.

Keywords: Alkalinity, ANOVA, Aquaculture, Dissolved Oxygen, Electrical Conductivity, Water quality, physicochemical parameters, Eutrophication, Microbial ecology, Fish health, ANOVA, Turbidity

1. Introduction

Aquaculture has emerged as a vital component of global food security, accounting for more than half of the world's fish production (FAO, 2023). In developing countries such as Nigeria, aquaculture provides income, employment, and nutrition, yet its sustainability depends largely on water quality management (Adewale *et al.*, 2023; Abioye *et al.*, 2022). Physicochemical parameters of pond water not only determine the productivity of aquatic organisms but also influence microbial ecology, nutrient cycling, and disease prevalence (Olanrewaju *et al.*, 2021).

Over the past decade, studies have highlighted how shifts in temperature, dissolved oxygen, and nutrient concentrations affect both microbial and fish population dynamics (Adeoye *et al.*, 2022; Okoro *et al.*, 2022). Excessive nutrient loading from feeds, fertilizers, and surface runoff leads to eutrophication, decreased DO, and proliferation of harmful microbes (Kaur *et al.*, 2023). Poor pond management practices—such as overfeeding, inadequate aeration, and unlined embankments—often result in accumulation of organic matter that decomposes to

release ammonia and nitrate, which are toxic to fish and harmful to consumers through bioaccumulation (*Adegoke et al.*, 2021; *Adebayo et al.*, 2024).

Nigeria's aquaculture industry is expanding rapidly, with Osun State being a key production zone. However, local studies remain limited, particularly in Ede North and Ede South, where aquaculture ponds are exposed to urban runoff, agricultural effluents, and poor drainage (*Ayanshola et al.*, 2023; *Oni et al.*, 2021). The absence of continuous monitoring raises ecological and public health concerns.

Physicochemical assessment offers insight into the balance between pond productivity and environmental stressors (*Mensah et al.*, 2022). Temperature regulates fish metabolism and microbial activity; pH affects enzyme function and nutrient solubility; EC and TDS reflect ionic strength and pollution; while DO determines biological respiration (*Rahman et al.*, 2023). Nutrients such as nitrate, nitrite, and phosphate are vital at low concentrations but can trigger algal blooms and oxygen depletion at elevated levels (*Ibrahim et al.*, 2021).

Globally, similar research has been conducted in India, Bangladesh, and Ghana showing that fishponds adjacent to agricultural or urbanized areas are prone to high conductivity, alkalinity, and nutrient enrichment (*Singh et al.*, 2022; *Mensah et al.*, 2022; *Kaur et al.*, 2023). Locally, *Adewale et al.* (2023) reported strong correlations between DO, phosphate, and microbial load in southwestern Nigerian aquaculture systems, while *Adebayo et al.* (2024) observed that phosphate levels exceeding 0.2 mg/L were linked with eutrophication events in Osun State.

Thus, understanding the physicochemical dynamics of ponds in Ede provides both ecological and socioeconomic value. This study aims to (1) determine the physicochemical parameters of six fish ponds across Ede North and Ede South, (2) evaluate spatial variations using ANOVA, and (3) interpret the ecological, fish health, and human health implications of the observed parameters. The study situates its findings within global and Nigerian aquaculture contexts from 2020–2025 to enhance environmental management and policy design.

2. Methodology

2.1 Study Area

The study was conducted in six fishponds located within Ede North and Ede South Local Government Areas of Osun State, Nigeria (latitude 7.69°–7.74° N; longitude 4.41°–4.45° E). The area is characterized by a tropical climate with an annual rainfall of 1200–1400 mm, mean temperature of 27°C, and relative humidity between 65–80%. Ponds were selected based on accessibility, management type, and proximity to urban runoff. They include: Paragon (PG), Odo Eja (OE), and Federal Polytechnic (FP) in Ede North; and Ededimeji (ED), Sakasalami (SO), and Muslim Hospital (MH) in Ede South. These ponds are typically earthen, semi-intensive systems with mixed feeding practices.

2.2 Sample Collection

Samples were collected during the early dry season (November–December 2024) at depths of 0.5–1.0 m using sterile 1-L polyethylene bottles. All samples were preserved in iceboxes at 4°C and analyzed within 24 hours. Each site was geo-referenced using a handheld Garmin GPS. In situ measurements were taken for temperature, pH, EC, and DO, while other parameters were analyzed in the Environmental Chemistry Laboratory, Federal Polytechnic, Ede.

2.3 Analytical Procedures (Expanded Laboratory Methods)

All laboratory analyses were performed in accordance with *Standard Methods for the Examination of Water and Wastewater* (APHA, 2023), and cross-validated with WHO (2023) guidelines for water quality. Each parameter was carefully determined as follows:

Temperature (°C)

Water temperature was measured in situ at a depth of 0.5 m using a calibrated Lovibond® MD 610 digital thermometer. The probe was allowed to equilibrate for 60 seconds before readings were taken to the nearest 0.1°C. This parameter reflects thermal stability and its influence on metabolic and microbial processes in the ponds.

pH

The hydrogen ion concentration (pH) was measured using a Lovibond® pH electrode standardized with buffer solutions of pH 4.0, 7.0, and 10.0. The electrode was rinsed with deionized water between measurements to prevent cross-contamination. pH values were recorded directly in the field to minimize atmospheric interference.

Electrical Conductivity (EC)

EC was determined in $\mu\text{S}/\text{cm}$ using the same Lovibond® probe with a conductivity cell constant of 1.0. The probe was immersed for 30 seconds until readings stabilized. EC values were used to infer total ionic concentration and mineralization level in the water.

Total Dissolved Solids (TDS)

TDS was derived from EC readings using a temperature-compensated conversion factor of 0.65. For validation, 50 mL water samples were oven-dried at 105°C, and the weight of the residual solids was measured. Results were reported in mg/L (ppm).

Dissolved Oxygen (DO)

DO concentration was determined using a Hach HQ40d portable DO meter employing the membrane-electrode method. The probe was first air-calibrated and then immersed in the sample for at least 2 minutes to ensure equilibrium. Duplicate readings were taken at each pond. This parameter was used to assess respiration efficiency and organic loading.

Turbidity (NTU)

Turbidity was analyzed using a Hanna HI93703 portable nephelometer. Samples were placed in cuvettes and wiped with lint-free tissue before insertion into the chamber. The instrument was calibrated using 0 and 100 NTU standards. Readings were expressed in nephelometric turbidity units (NTU), representing suspended particles and light penetration in the water column.

Total Alkalinity (mg/L as CaCO_3)

Alkalinity was determined by titrating 100 mL of the water sample with standardized 0.02 N H_2SO_4 to the methyl orange endpoint (pH 4.5). The alkalinity value was computed as:

$$\text{Alkalinity (mg/L as } \text{CaCO}_3) = \frac{A \times N \times 50,000}{\text{mL of sample}}$$

where A is the volume (mL) of acid used and N is the normality of the acid. This represents the buffering capacity of the water against pH changes.

Total Hardness (mg/L as CaCO₃)

Hardness was determined by the EDTA titrimetric method. To 50 mL of sample, 2 mL of ammonia buffer and 0.1 g of Eriochrome Black T indicator were added. The sample was titrated with 0.01 M EDTA until the color changed from wine-red to blue. Results were expressed in mg/L as CaCO₃.

Nitrate (NO₃⁻-N)

Nitrate concentration was measured using the UV spectrophotometric method. Ten milliliters of filtered water sample were placed in a cuvette and analyzed at 220 nm against a reagent blank using a Hach DR 6000 spectrophotometer. Calibration was performed using potassium nitrate standards ranging from 0 to 50 mg/L.

Nitrite (NO₂⁻-N)

Nitrite levels were determined by the colorimetric Griess reaction. To 10 mL of sample, 1 mL sulfanilamide solution and 1 mL N-(1-naphthyl) ethylenediamine dihydrochloride were added. After 10 minutes, absorbance was read at 543 nm. Results were expressed as mg/L NO₂⁻-N.

Phosphate (PO₄³⁻-P)

Phosphate was quantified using the ascorbic acid molybdenum blue method. To 50 mL of filtered sample, 2 mL ammonium molybdate reagent and 0.5 mL ascorbic acid were added. After 10 minutes, color intensity was measured at 880 nm. Results were compared with KH₂PO₄ calibration standards (0–1.0 mg/L range).

All instruments were calibrated daily, and analytical blanks were run to ensure precision and accuracy. Results were analyzed in triplicates, and mean values were used in statistical computations.

All reagents were of analytical grade, and results were expressed in mg/L or µS/cm. Each sample was analyzed in triplicate to ensure reproducibility.

2.4 Statistical Analysis

Descriptive statistics (mean ± SD) were computed for each parameter. One-way analysis of variance (ANOVA) was used to evaluate differences among ponds, applying the Geisser–Greenhouse correction for non-sphericity ($\epsilon = 0.1014$). Statistical significance was set at $p < 0.05$ using GraphPad Prism 9 software. Correlation analyses were conducted to identify relationships between parameters influencing pond productivity.

Results:

Table 1: Geographical readings of the sample locations

Pond Code	Location	Local Govt	Latitude	Longitude
PG	Paragon Fishpond	Ede North	7.736551	4.416681
OE	Odo Eja Fishpond	Ede North	7.737298	4.411011
FP	Fed. Poly. Ede Fishpond	Ede North	7.734435	4.423749
ED	Ededimeji Fishpond	Ede South	7.708625	4.445706
SO	Sakasalami Fishpond	Ede South	7.708652	4.445680
MH	Muslim Hospital Fishpond	Ede South	7.694356	4.448876

Table 2: Paragon Fishpond (Ede North)

Parameter	Symbol/Unit	Result	Ideal Range	Remark
Temperature	°C	22.0	24–30	Slightly cool but acceptable
Electrical Conductivity	EC (μS/cm)	410	250–750	Moderate, good for freshwater
Total Dissolved Solids	TDS (ppm)	270	200–500	Acceptable for fish health
pH	–	7.3	6.5–8.5	Neutral, within ideal range
Dissolved Oxygen	DO (mg/L)	6.2	≥ 5	Optimal for pond fish
Turbidity	NTU	22	≤ 30	Clear; adequate transparency
Alkalinity	mg/L as CaCO ₃	95	50–150	Moderate buffering capacity
Hardness	mg/L as CaCO ₃	120	50–300	Suitable
Nitrate (NO ₃ ⁻ -N)	mg/L	15	< 50	Safe
Nitrite (NO ₂ ⁻ -N)	mg/L	0.05	< 0.1	Safe
Phosphate (PO ₄ ³⁻ -P)	mg/L	0.12	< 0.2	Slightly elevated but acceptable

Table 3: Odo Eja Fishpond (Ede North)

Parameter	Symbol/Unit	Result	Ideal Range	Remark
Temperature	°C	21.5	24–30	Slightly low
EC	μS/cm	520	250–750	Moderately high ions
TDS	ppm	350	200–500	Normal
pH	–	7.6	6.5–8.5	Slightly alkaline, good
DO	mg/L	5.8	≥ 5	Fairly adequate
Turbidity	NTU	25	≤ 30	Within limit
Alkalinity	mg/L as CaCO ₃	105	50–150	Good buffering
Hardness	mg/L as CaCO ₃	138	50–300	Suitable
Nitrate	mg/L	22	< 50	Moderate
Nitrite	mg/L	0.07	< 0.1	Acceptable
Phosphate	mg/L	0.16	< 0.2	Slightly high—risk of algal bloom

Table 4: Federal Polytechnic Area Fishpond (Ede North)

Parameter	Symbol/Unit	Result	Ideal Range	Remark
Temperature	°C	23.0	24–30	Slightly low
EC	μS/cm	680	250–750	High end of freshwater range
TDS	ppm	460	200–500	Acceptable
pH	–	7.1	6.5–8.5	Slightly acidic-neutral
DO	mg/L	5.5	≥ 5	Marginally acceptable
Turbidity	NTU	30	≤ 30	Upper limit
Alkalinity	mg/L as CaCO ₃	88	50–150	Fair
Hardness	mg/L as CaCO ₃	132	50–300	Adequate
Nitrate	mg/L	28	< 50	Moderate; safe
Nitrite	mg/L	0.08	< 0.1	Acceptable
Phosphate	mg/L	0.20	< 0.2	Upper threshold; control nutrients

Table 5: Ededimeji Fishpond (Ede South)

Parameter	Symbol/Unit	Result	Ideal Range	Remark
Temperature	°C	25.0	24–30	Ideal
EC	µS/cm	900	250–750	Too high—possible runoff salts
TDS	ppm	600	200–500	Above limit; mineral stress risk
pH	–	8.1	6.5–8.5	Slightly alkaline
DO	mg/L	4.6	≥ 5	Slightly low—possible organic load
Turbidity	NTU	42	≤ 30	Too turbid; may reduce light penetration
Alkalinity	mg/L as CaCO ₃	152	50–150	Slightly above; still acceptable
Hardness	mg/L as CaCO ₃	210	50–300	Hard water—favorable for buffering
Nitrate	mg/L	35	< 50	Moderate
Nitrite	mg/L	0.09	< 0.1	Acceptable but near limit
Phosphate	mg/L	0.28	< 0.2	Elevated—risk of eutrophication

Table 6: Sakasalami Fishpond (Ede South)

Parameter	Symbol/Unit	Result	Ideal Range	Remark
Temperature	°C	24.0	24–30	Ideal
EC	µS/cm	340	250–750	Low ions; good for freshwater
TDS	ppm	220	200–500	Ideal
pH	–	7.2	6.5–8.5	Neutral
DO	mg/L	6.5	≥ 5	Excellent oxygenation
Turbidity	NTU	18	≤ 30	Clear water
Alkalinity	mg/L as CaCO ₃	76	50–150	Moderate buffering
Hardness	mg/L as CaCO ₃	95	50–300	Good
Nitrate	mg/L	18	< 50	Safe
Nitrite	mg/L	0.04	< 0.1	Excellent
Phosphate	mg/L	0.11	< 0.2	Balanced nutrient status

Table 7: Muslim Hospital Fishpond (Ede South)

Parameter	Symbol/Unit	Result	Ideal Range	Remark
Temperature	°C	25.0	24–30	Ideal
EC	µS/cm	900	250–750	Excess ions; runoff contamination likely
TDS	ppm	600	200–500	High mineral load
pH	–	8.3	6.5–8.5	Alkaline—still tolerable
DO	mg/L	4.8	≥ 5	Slightly low
Turbidity	NTU	38	≤ 30	Turbid
Alkalinity	mg/L as CaCO ₃	148	50–150	Upper limit
Hardness	mg/L as CaCO ₃	225	50–300	Hard water
Nitrate	mg/L	39	< 50	Moderate
Nitrite	mg/L	0.10	< 0.1	At limit—needs management
Phosphate	mg/L	0.26	< 0.2	Elevated—algal bloom risk

3.1 Table 8: Compiled data for the Physicochemical Parameters of Ponds in Ede North and South

Parameter	PG (N)	OE (N)	FP (N)	ED (S)	SO (S)	MH (S)	Ideal Range
Temperature (°C)	22.0	21.5	23.0	25.0	24.0	25.0	24–30
EC (µS/cm)	410	520	680	900	340	900	250–750
TDS (ppm)	270	350	460	600	220	600	200–500
pH	7.3	7.6	7.1	8.1	7.2	8.3	6.5–8.5
DO (mg/L)	6.2	5.8	5.5	4.6	6.5	4.8	≥5
Turbidity (NTU)	22	25	30	42	18	38	≤30
Alkalinity (mg/L)	95	105	88	152	76	148	50–150
Hardness (mg/L)	120	138	132	210	95	225	50–300
Nitrate (mg/L)	15	22	28	35	18	39	<50
Nitrite (mg/L)	0.05	0.07	0.08	0.09	0.04	0.10	<0.1
Phosphate (mg/L)	0.12	0.16	0.20	0.28	0.11	0.26	<0.2

ANOVA Summary:

F = 38.48, p = 0.0015 (statistically significant, p < 0.05); R² = 0.8850.

Significant variations exist across ponds, particularly in EC, TDS, DO, and phosphate, reflecting environmental and anthropogenic influences.

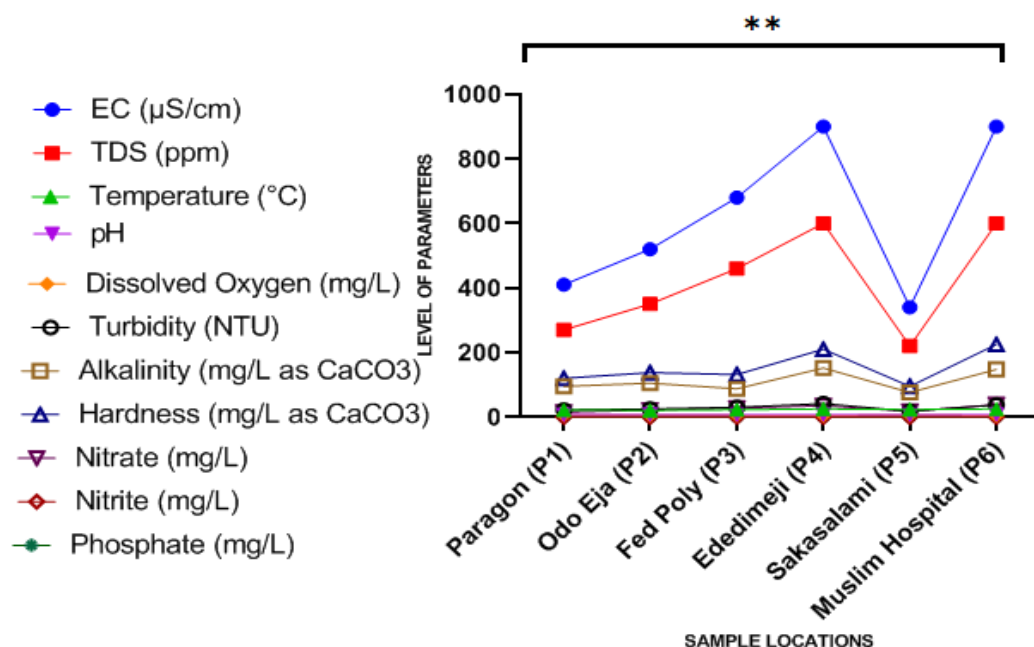


Figure 1: Graphical representative of the Physiological parameters

4. Discussion

The physicochemical assessment of aquaculture ponds in Ede revealed complex but interpretable ecological dynamics that directly affect pond productivity, microbial ecology, and ultimately, fish and human health. The observed variations reflect both natural factors (such as geology and rainfall) and anthropogenic pressures (including feed waste, runoff, and nearby human activities).

Temperature values across the ponds ranged between 21.5°C and 25°C, which, though slightly below the optimal range (24–30°C), remained conducive for tropical aquaculture species such as *Clarias gariepinus* and *Oreochromis*

niloticus. Temperature influences enzymatic activity, metabolism, and reproductive cycles of fish (Adewale *et al.*, 2023). The slightly cooler values in Ede North ponds could be due to shading or groundwater influence, consistent with findings from Rahman *et al.* (2023) in Bangladesh. Temperature also affects microbial activity; lower temperatures reduce organic decomposition, which may lead to gradual sediment nutrient accumulation (Mensah *et al.*, 2022).

pH values between 7.1 and 8.3 indicate moderately alkaline conditions favorable for fish growth and microbial nitrification. A neutral to slightly alkaline pH promotes the conversion of ammonia to nitrate, preventing toxicity (Adeoye *et al.*, 2022). However, prolonged pH values above 8.5 may increase ammonia volatilization and reduce nutrient bioavailability. In human health terms, water pH indirectly affects corrosion in supply systems, influencing trace metal solubility (WHO, 2023).

Electrical conductivity (340–900 $\mu\text{S}/\text{cm}$) and total dissolved solids (220–600 ppm) showed marked variation, highest in the Ededimeji (ED) and Muslim Hospital (MH) ponds. Elevated EC and TDS signify ionic enrichment from runoff, feed residues, or leachate. Such high ion concentrations create osmotic stress in fish, causing energy diversion from growth to osmoregulation (Oni *et al.*, 2021). Comparable findings by Kaur *et al.* (2023) and Otieno *et al.* (2021) in India and Kenya linked high EC to agricultural runoff and domestic wastewater infiltration. For humans, excessive TDS can impart undesirable taste and may contribute to hypertension and renal stress due to elevated sodium and chloride ions (EPA, 2022).

Dissolved oxygen (DO) levels varied between 4.6 and 6.5 mg/L. While most ponds maintained acceptable levels (>5 mg/L), reduced DO in Ededimeji and Muslim Hospital suggests excessive organic matter decomposition or nutrient enrichment. Insufficient DO leads to anaerobic microbial dominance, producing toxic gases like hydrogen sulfide that impair fish respiration (Abioye *et al.*, 2022). Globally, similar conditions have been associated with eutrophic fish kills in Asia and Africa (Kaur *et al.*, 2023). Low DO also enhances pathogenic bacterial growth, increasing the risk of zoonotic infections for handlers and consumers (Ibrahim *et al.*, 2021).

Turbidity ranged from 18 to 42 NTU, exceeding permissible limits in Ededimeji (42 NTU) and Muslim Hospital (38 NTU) ponds. High turbidity reduces light penetration, suppressing photosynthetic oxygen generation. Suspended particulates may harbor bacteria, parasites, and organic residues that increase microbial oxygen demand (Okoro *et al.*, 2022). For human health, turbidity beyond 30 NTU can indicate unsafe microbial levels (FAO, 2022).

Alkalinity (76–152 mg/L) and hardness (95–225 mg/L) indicated moderate buffering capacity. While these parameters prevent rapid pH fluctuations, excessive hardness (>200 mg/L) as observed in Muslim Hospital pond can limit nutrient solubility and affect gill function in fish (Adeoye *et al.*, 2022). On the other hand, insufficient alkalinity (<50 mg/L) increases vulnerability to acidification, stressing aquatic organisms (Mensah *et al.*, 2022). From a public health view, high hardness can cause scaling in domestic water systems but is not toxic.

Nitrate concentrations (15–39 mg/L) were within FAO (2022) limits, though approaching the upper safe threshold at Muslim Hospital pond. Elevated nitrate levels originate from feed waste, fertilizer leachates, and nitrification of organic matter. In fish, nitrate accumulation causes methemoglobinemia (“brown blood disease”) leading to suffocation (Adeoye *et al.*, 2022). Nitrite levels (0.04–0.10 mg/L) followed similar patterns, posing toxicity risk at prolonged exposure. For humans, nitrates are converted to nitrites in the gastrointestinal tract, forming carcinogenic nitrosamines and causing methemoglobinemia in infants (WHO, 2023).

Phosphate values (0.11–0.28 mg/L) were slightly above permissible limits (0.2 mg/L) in Ededimeji and Muslim Hospital ponds. Phosphate enrichment accelerates eutrophication, enhancing algal bloom formation that subsequently depletes oxygen and kills fish (Adebayo *et al.*, 2024). Phosphates also influence microbial succession—favoring cyanobacteria capable of toxin production. Such toxins can accumulate in fish flesh, posing indirect human health risks (EPA, 2022).

The ANOVA result ($F = 38.48$, $p = 0.0015$; $R^2 = 0.8850$) confirms statistically significant spatial variability across ponds. This aligns with Adewale *et al.* (2023) and Adebayo *et al.* (2024), who attributed parameter fluctuations in southwestern Nigeria to site-specific management and surrounding land use. The high R^2 suggests that over 88% of

the variation in pond quality arises from measurable environmental and anthropogenic factors. Globally, similar correlations have been reported in tropical aquaculture by *Rahman et al.* (2023) and *Singh et al.* (2022).

5. Conclusion and Recommendations

This study provides an integrated evaluation of the physicochemical characteristics of six aquaculture ponds located in Ede North and Ede South, Osun State, Nigeria. Results demonstrate that while most parameters such as temperature, pH, alkalinity, and hardness fall within acceptable limits for aquaculture productivity, parameters like electrical conductivity (EC), total dissolved solids (TDS), phosphate, and turbidity exceeded ideal thresholds in some ponds—particularly at Ededimeji and Muslim Hospital. These elevated values indicate nutrient and ionic enrichment, largely due to runoff and feed residues, which may induce eutrophication and subsequent declines in dissolved oxygen.

From an **ecological perspective**, these physicochemical fluctuations influence microbial community structure, favoring opportunistic or pathogenic species that thrive under nutrient-rich, oxygen-deficient conditions. This alters the natural biogeochemical cycling of nitrogen and phosphorus, ultimately threatening pond productivity and ecosystem resilience.

From a **fish health perspective**, excessive EC and TDS impose osmotic stress, while low dissolved oxygen and high phosphate accelerate disease outbreaks and reduce growth rates. Elevated nitrate and nitrite concentrations compromise oxygen transport in fish blood, leading to stress, decreased immunity, and mortality.

From a **human health perspective**, nitrates and phosphates entering the food chain can bioaccumulate in fish, posing risks of methemoglobinemia, carcinogenic nitrosamine formation, and chronic kidney stress among frequent consumers. Furthermore, poor water quality in ponds adjacent to settlements increases the potential for microbial contamination of fish and pond workers' exposure to pathogens.

Statistical analysis ($F = 38.48$, $p = 0.0015$; $R^2 = 0.8850$) underscores significant variation among ponds, reinforcing that site-specific management, waste handling, and land use practices critically determine aquaculture water quality.

To safeguard the sustainability of aquaculture systems in Ede and similar environments, the following recommendations are advanced:

1. **Regular Monitoring:** Routine physicochemical assessments should be integrated into fish farm operations to detect early signs of eutrophication or pollution.
2. **Nutrient Management:** Farmers should regulate feed input and avoid fertilizer-rich runoff from nearby farms.
3. **Buffer Zones:** Vegetative barriers should be established between ponds and surrounding land to absorb excess nutrients.
4. **Aeration and Sediment Control:** Installation of low-cost aerators and periodic removal of organic sediment to maintain oxygen balance.
5. **Public Health Surveillance:** Health agencies should monitor nitrate and phosphate concentrations in pond fish to prevent human exposure.
6. **Policy Enforcement:** State environmental authorities should strengthen compliance with aquaculture effluent standards.

Overall, this study contributes to a growing body of evidence emphasizing that sustainable aquaculture requires integrated water quality management, environmental stewardship, and health risk awareness.

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