International Journal of Fisheries and Aquatic Research
www.fishjournals.com
ISSN: 2456-7248
Received: 27-01-2026, Accepted: 26-02-2026, Published: 13-03-2026
Volume 11, Issue 1, 2026, Page No. 76-79

Evaluation of the physicochemical and microbiological quality of fish pond effluents at Mega Fish Farm Damaturu

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Abstract
This study investigated the physicochemical and microbiological characteristics of fish pond effluents in selected aquaculture facilities at Mega fish farm Damaturu, Yobe State, Nigeria. The aim was to assess the quality of pond discharge water and its compliance with environmental and public health standards. An observational cross-sectional design was adopted, and samples were collected from three points influent, in-pond, and effluent across multiple sampling rounds. Laboratory analyses were performed following APHA (2022) [2] and WHO (2022) standard methods, with effluent compliance evaluated using NESREA (2019) guidelines. The physicochemical parameters analyzed included temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), total suspended solids (TSS), dissolved oxygen (DO), biochemical oxygen demand (BOD), and turbidity. Results showed that temperature (27.1–28.2°C), pH (6.8–7.0), TDS (119–124 ppm), and EC (190–238 µS/cm) were within acceptable limits. However, turbidity (115.8–132 NTU) and TSS (101–141 mg/L) exceeded WHO standards, while DO levels (3.7–4.8 mg/L) in some samples were below the minimum threshold of 5 mg/L, indicating organic pollution and oxygen depletion. Microbiological analyses revealed high aerobic mesophilic bacterial counts (>10^8 CFU/mL), total coliforms (up to 24,000 MPN/100 mL), and the presence of Staphylococcus aureus, Escherichia coli, and Enterobacter spp., confirming significant microbial contamination. E. coli isolation further indicated fecal pollution, likely from decomposing feed, fish waste, and poor pond hygiene. The study concludes that fish pond effluents in Damaturu are highly polluted with organic matter and microbial load, posing potential risks to aquatic ecosystems and downstream water users. It recommends the adoption of effluent treatment systems, periodic water quality monitoring, and enforcement of environmental regulations to ensure sustainable aquaculture practices in the region.

Keywords: Fish pond effluent, physicochemical parameters, microbial load, water quality, damaturu

Introduction

Aquaculture, the farming of aquatic organisms including fish, crustaceans, mollusks, and aquatic plants, has witnessed exponential growth over the last few decades. With global fisheries experiencing stagnation and overexploitation, aquaculture has become the fastest-growing sector of animal food production globally. According to the Food and Agriculture Organization (FAO, 2022) [3]. Therefore, aquaculture now contributes over 50% of the world's fish supply, making it critical for global food security, nutrition, and economic development. In sub-Saharan Africa, and particularly in Nigeria, the sector offers a potential solution to malnutrition, unemployment, and rural poverty. However, its expansion has also brought into focus the environmental and public health implications of effluent discharge from fish farms (Amusan *et al* 2023) [1].

Effluents from aquaculture systems are a complex mix of organic and inorganic substances, including uneaten feed, fish feces, nitrogenous wastes, residual antibiotics, fertilizers, suspended solids, and heavy metals. These waste products, when released untreated into nearby ecosystems, contribute significantly to aquatic pollution. They alter the natural balance of aquatic environments by modifying physicochemical properties, introducing toxic contaminants, and increasing microbial loads that can pose health risks to humans and aquatic life alike (Ogedengbe *et al.,* 2021) [6].

Physicochemical parameters are essential indicators of water quality. These include pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), turbidity, temperature, electrical conductivity (EC), and nutrient concentrations such as nitrates and phosphates. Alterations in these parameters can have cascading effects on aquatic ecosystems. For instance, elevated BOD and COD deplete dissolved oxygen, leading to hypoxic conditions that threaten aquatic biodiversity (Madu *et al.,* 2023) [5].

In Nigeria, where many fish farms operate without effluent treatment systems, these pollutants are commonly discharged into streams, rivers, and farmlands. The cumulative impact has led to increased cases of water contamination, loss of aquatic biodiversity, and degradation of natural resources. Unfortunately, most fish farmers remain unaware of these consequences, and enforcement of environmental standards remains weak due to resource limitations and lack of political will (Olawale *et al.,* 2021; Ibe and Adebayo, 2022) [4, 8].

Material and Method

Study Area

The study site is a large -scale aquaculture facility located at Mega fish farm Damaturu, Yobe State, Nigeria. The latitude and latitude 11.75°N and Longitude 11.97°E. The facility comprises earthen/concrete ponds with periodic water exchange to a compound drain that connects to the municipal drainage network.

Sample Collection and Preservation

Water samples was collected following standard field protocols to minimize contamination and ensure representativeness of the fish pond effluents. All sampling bottles was pre-cleaned with acid, rinsed with deionized water, and further rinsed on site with sample water prior to collection according to (APHA, 2022) [2]. Personnel wire sterile gloves, and chain of custody records were maintained to track all samples from field to laboratory. In-situ measurements of temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), and turbidity were taken immediately using portable calibrated meters, as these parameters are unstable and may change rapidly after collection (Ojewole *et al*., 2024) [7]. Samples for nutrient and ion analysis were collected in 500 mL polyethylene bottles, stored on ice at 4 ± 2 °C, and analyzed within recommended holding times. Biochemical oxygen demand (BOD_5) samples were collected in 300 mL BOD bottles without air bubbles and incubated at 20 °C for five days, while chemical oxygen demand (COD) samples was preserved with concentrated sulfuric acid to pH < 2 in 250 mL bottles. Microbiological samples were collected in sterile 100 mL polypropylene bottles containing sodium thiosulfate to neutralize residual chlorine when present, transported on ice, and analyzed within six hours of collection to ensure microbial viability. These procedures guaranteed that the integrity of physicochemical and microbial analyses was preserved until laboratory examination (Ojewole *et al*., 2024) [7].

Physicochemical Analyses

Target variables are selected based on aquaculture literature and regulatory relevance: Temperature, pH, EC/TDS, DO, turbidity, color, alkalinity, hardness, chloride, sulfate, nitrate, nitrite, ammonium, orthophosphate, BOD, COD, total suspended solids (TSS). Analytical methods and QA follow APHA (24th ed.); results were compared to WHO guideline values (where applicable) and national water/effluent standards to contextualize risk (Onajobi *et al*., 2023) [9].

Microbiological Analyses

Microbial quality of the fish pond effluents was assessed using the membrane filtration technique in accordance with standard methods for the examination of water and wastewater (APHA, 2022) [2]. A 100 mL water sample (or appropriate dilution) were passed through a sterile 0.45 µm pore size membrane filter, which was then placed on selective culture media. Total coliforms were enumerated on m-Endo agar at 35 °C for 24 h (SM 9222B), while thermotolerant coliforms and *Escherichia coli* were determined on m-FC agar at 44.5 °C for 24h (SM 9222D), with confirmation of *E. coli* colonies on selective differential media when required. Heterotrophic plate counts (HPC) were obtained by pour plating or spread plating on Plate Count Agar at 35 °C for 48h to estimate the general bacterial load. Colony counts were expressed as colony-forming units (CFU/100 mL for coliforms or CFU/mL for HPC), applying appropriate dilution factors, and results were benchmarked against WHO (2022) microbial guideline values for contextual interpretation Counts were expressed as CFU/100 mL (coliforms) or CFU/mL (HPC), applying dilution factors: Methods align with Standard Methods and US EPA MF procedures; results were benchmarked against WHO verification values for *E. coli* in water used for domestic purposes in the receiving according to WHO (2022).

Results and Discussion

Table 1 show the analytical results of three different fish pond effluents. The samples comfortably comply with WHO standards for Temperature, pH, TDS, and EC. The TDS values (119-124 PPM) and pH levels (6.8-7.0) are well within the acceptable ranges of <2000 PPM and 6-9, respectively. The Turbidity levels (115.8, 126.8, and 132 NTU) exceed the WHO limit of 5 NTU, indicating highly polluted water. This is corroborated by elevated TSS readings (101-141 Mg/L against a standard of 30 Mg/L). Furthermore, the Dissolved Oxygen (DO) is critically low in Sample A (3.7 Mg/L) and Sample B (4.8 Mg/L), falling below the recommended >5 Mg/L, which could stress to some aquatic life. The DO for Sample C (132 Mg/L) exceeded the standard limit While BOD levels (1.4-2.7 Mg/L) remain low, the high turbidity and low DO signify a polluted water body, likely impacted by siltation or organic pollution.

Table 2 the results showed extremely high counts across all samples, where sample A show $2.01x10^8$, while the sample B show the number of colonies where $1.92x10^8$, while the last sample C show the result where $2.21x10^8$ with values exceeding 10^8 Colony Forming Units per milliliter (CFU/mL). This indicates a heavily contaminated effluent with a substantial load of decomposing organic matter, as these bacteria are primarily responsible for breaking down waste.

Table 3 and figure 1 the table showed a details of a fungal load in the effluent samples, recorded as Colony Forming Units per milliliter (CFU/mL). The counts vary between samples, with Sample B 1.8×10^6 showing the highest concentration. The presence of fungi confirms the diversity of the microbial community involved in decomposing complex organic compounds like cellulose and chitin found in fish feed and waste. While lower than bacterial counts, the significant fungal population contributes to the nutrient cycling and organic matter breakdown within the pond system.

Table 4 and figure 2 This show the concentration of total coliform bacteria using the Most Probable Number (MPN) method, a statistical estimate of viable microorganisms. Samples A and B show identical MPN values of 1,100 per 100ml, while Sample C has a mark higher value of >24,000 per 100ml. Total coliforms are used as indicator organisms for general water sanitary quality. The high MPN in Sample C, in particular, signals a severe compromise in water quality and a high probability of fecal contamination, potentially from animal waste or other environmental sources. This poses a direct public health risk, indicating the potential presence of pathogenic bacteria and underscoring the necessity for disinfection or advanced treatment before the effluent is discharged or reused.

Table 5 and 6 below shows the prevalence of the three identified bacterial isolates in each of the three effluent samples. *S. aureus* and *Enterobacter spp.* were found in all three samples (100% occurrence), indicating they are common and persistent contaminants in the fish pond system. *E. coli*, was isolated only from Sample A. The total count of seven isolations across the samples provides a snapshot of the bacterial ecology, revealing a system consistently contaminated with opportunistic and potentially pathogenic bacteria, which is a significant concern for both fish health and human safety. While the table 6 summarize the proportional contamination of each sample. Sample A have the highest contamination level, accounting for 42.88% of all bacterial isolations, as it contained all three bacterial species. Samples B and C each accounted for 28.56% of isolations, containing two species each.

Table 1: Physicochemical Analysis of Fish Pond Effluent

Parameters	Sample A	Sample B	Sample C	WHO Standard
Temp (^{O}C)	28.2	27.1	27.8	<40
Ph	7.0	6.8	7.0	6-9
TDS (PPM)	119	124	124	2000
EC (µs/cm)	190	231	238	3000
TSS (Mg/L)	101	128	141	30
DO (Mg/L)	3.7	4.8	132	>5
BOD (Mg/L)	1.4	1.8	2.7	30
Turbidity (NTU)	115.8	126.8	132	5

Table 2: Enumeration of Aerobic Mesophilic Bacteria from Fish Pond Effluent

Sample	Number of Colonies (Cfu/mL)
Sample A	2.01×10^8
Sample B	1.92×10^8
Sample C	2.21×10^8

Keys: Cfu/mL: Colony Forming Unit Per Mile

Table 3: Enumeration of Fungi from Fish Pond Effluent

Sample	Number of Colonies (Cfu/mL)
A	1×10^5
B	1.8×10^6
C	3×10^5

Keys: Cfu/mL: Colony Forming Unit Per mile

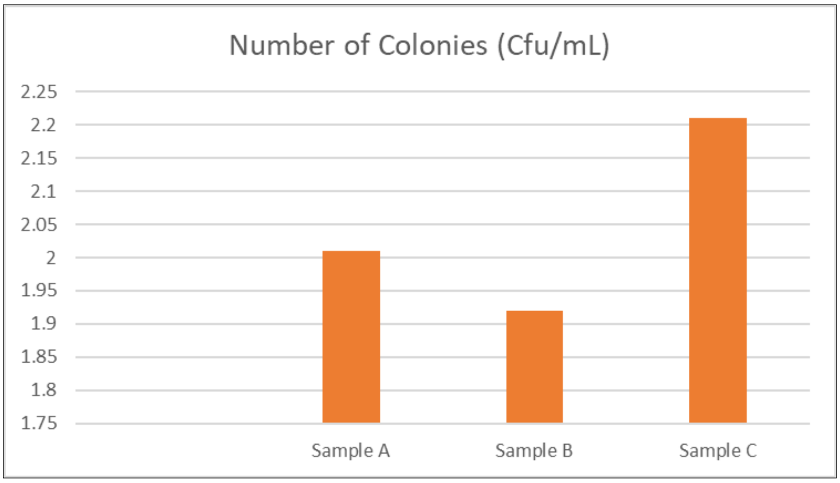

Fig 1:

Table 4: Enumeration of Total Coliform (TC) Bacteria from Fish Pond Effluent

Sample	Number of Positive Tubes			MPN Per 100ml	95% Confidence Limit	
	5 of 10ml	5 of 1ml	5 of 0.1ml		Lower	Upper
A	5	3	5	1100	400	2800
B	5	3	5	1100	400	2800
C	5	5	4	24000	1200	-

Keys: MPN: Most Probable Number

Table 5: Distribution of Isolated Bacteria Across the Three Samples

Bacterial Isolate	Sample ID			Total
	A	B	C	
S.aureus	+	+	+	3
E.coli	+	-	-	2
Enterobacter spp	+	+	+	3
TOTAL	3	2	2	7

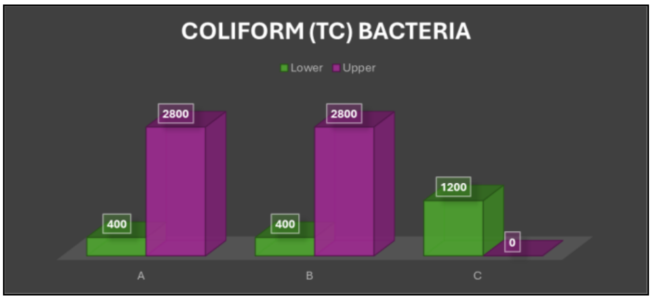

Fig 2:

Table 6: Percentage Occurrence of Bacterial Isolates Across the Samples

Sample ID	Total Bacterial Isolates (%)
A	3 (42.88)
B	2 (28.56)
C	2 (28.56)
TOTAL (%)	7 (100%)

Conclusion:

This study assessed the physicochemical and microbiological characteristics of effluents from selected fish ponds located at Mega fish farm Damaturu, Yobe State, Nigeria. The investigation aimed to evaluate water quality conditions in terms of compliance with WHO (2022) and NESREA (2009) standards for effluent discharge and environmental safety.

The physicochemical parameters such as temperature, pH, total dissolved solids (TDS), electrical conductivity (EC), dissolved oxygen (DO), biochemical oxygen demand (BOD_5), total suspended solids (TSS), and turbidity were analyzed. The results revealed that while temperature, pH, TDS, and EC were within acceptable limits, turbidity and TSS values were significantly higher than permissible standards, indicating heavy siltation and organic loading in the pond systems. Dissolved oxygen levels were critically low in some ponds, particularly in Sample A, suggesting oxygen depletion due to microbial decomposition of organic waste.

Microbiological analysis showed extremely high bacterial counts, with aerobic mesophilic bacteria exceeding 10^8 CFU/mL, implying a high organic and microbial load. Total coliform (TC) and *Escherichia coli* counts were also elevated, particularly in Sample C, which exceeded 24,000 MPN/100 mL far beyond acceptable limits for effluent discharge. This confirms significant fecal contamination and poor sanitary quality of the pond discharge.

The fungal population, though lower than bacterial counts, was also prominent, reflecting the presence of saprophytic fungi associated with organic matter degradation. Identified bacterial isolates included *Staphylococcus aureus, E. coli*, and *Enterobacter spp.* all of which were confirmed through biochemical characterization. *S. aureus* and *Enterobacter spp.* were consistently found across all samples, while *E. coli* was limited to Sample A, suggesting localized fecal contamination. Overall, Sample A exhibited the highest contamination (42.88%), followed by Samples B and C (each 28.56%). The dominance of these bacterial species and the high turbidity, TSS, and coliform levels highlight the deteriorating quality of fish pond effluents and the associated environmental health risks.

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