WATER QUALITY OF A FISH POND, CASE STUDY OF FACULTY OF AGRICULTURE FISH FARM.

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CERTIFICATION

This is to certify that this work was carried out by AKHETUAMEN, Blessed, Mat no. ENG2002086, of the Department of Civil Engineering, Faculty of Engineering, University of Benin, Edo State, Nigeria.

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DEDICATION

This project is dedicated to my parents, who have supported me with their prayers, and sacrifices throughout my academic journey.

And above all, I dedicate this work to God Almighty, for His grace, guidance, and mercy

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I give thanks to God Almighty for the wisdom, strength, and grace to carry out this project from start to finish.

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ABSTRACT

This study assessed the water quality of the fish pond located at the Faculty of Agriculture, University of Benin, with the aim of determining its Water Quality Index (WQI) and proposing environmentally sustainable alternative uses in the event of water exchange or discharge. The study was carried out in response to the growing need for scientific evaluation of aquaculture effluents, which, if improperly managed, may cause ecological degradation through nutrient enrichment, heavy metal buildup, and microbial contamination. The research therefore sought to evaluate the physicochemical and microbial characteristics of the pond water, compute its WQI using the Arithmetic Weightage Index Model, and recommend safe reuse or disposal options.

Water samples were collected from two ponds (Sample A and Sample B) representing five-day and thirteen-day retention periods respectively. Laboratory analyses were performed in the Civil Engineering Hydraulics/Water Laboratory following APHA (2017) standard methods to determine parameters such as pH, turbidity, total dissolved solids (TDS), total suspended solids (TSS), etc. The obtained data were analyzed using the Arithmetic Weightage Index Model, where individual parameter values were compared against WHO (2017) and FAO (2011) standards to derive the overall WQI and corresponding water quality grades.

The results showed that Sample A, with a WQI of 20.41, was classified as Excellent, indicating that the pond water met acceptable limits. Sample B, with a WQI of 51.69, fell under the Poor category, signifying moderate pollution resulting from prolonged water retention, organic enrichment, and higher microbial counts. Consequently, while Sample A water could be reused or safely discharged without treatment, Sample B water required simple treatment such as aeration or sedimentation prior to reuse or discharge. The study concluded that proper monitoring of water quality and periodic application of the WQI approach are vital for sustainable aquaculture management. It recommended regular effluent testing, adoption of low-cost pre-treatment systems, and reuse of treated pond water for agricultural irrigation or secondary aquaculture to reduce environmental pollution and promote resource conservation.

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ACRONYMS

DO ------------------- Dissolved Oxygen

TSS ------------------- Total Suspended Solids

TDS ------------------- Total Dissolved Solids

BOD ------------------- Biological Oxygen Demand

COD ------------------- Chemical Oxygen Demand

EPA ------------------- Environmental Protection Agency

NTU ------------------- Nephelometric Turbidity Unit

WHO ------------------- World Health Organization

WQI ------------------- Water Quality Index

FAO ------------------- Food and Agriculture Organization

FEPA ------------------- Federal Environmental Protection Agency

APHA ------------------- American Public Health Association

USGS ------------------- United States Geological Survey

Na ------------------- Sodium

K ------------------- Potassium

Ca ------------------- Calcium

EC ------------------- Electrical Conductivity

HCO_3 ------------------- Bicarbonate

NH_4N ------------------- Ammonium Nitogen

NO2 ------------------- Nitrite

NO3 ------------------- Nitrate

SO4 ------------------- Sulfate

Fe ------------------- Iron

Mn ------------------- Manganese

Cu ------------------- Copper

Cr ------------------- Chromium

Cd ------------------- Cadmium

Ni ------------------- Nickel

Pb ------------------- Lead

V ------------------- Vanadium

THC ------------------- Total Hydrocarbon Content

ppt ------------------- part per thousands

CHAPTER ONE

INTRODUCTION

1.1 Background of The Study

Water is a universal solvent; it is a vital natural resource, and the cornerstone of all life systems. In both ecological and economic contexts, its quality determines its utility and sustainability. In aquaculture and specifically in fish farming systems such as those maintained by universities and agricultural faculties, water quality is directly tied to productivity, environmental safety, and long-term viability. Increasingly, as concerns grow over pollution, and ecosystem degradation, the need to assess not only the condition of water bodies but also their adaptability for alternative uses becomes essential especially when ponds are decommissioned or when their effluent is released or discharged into the environment.

The fish pond at the Faculty of Agriculture, University of Benin, is one such water body that holds dual importance: as a learning and research environment and as a functioning aquaculture system. Like many institutional ponds, it serves academic, economic, and ecological functions. However, as ponds age, the possibility of water discharge arises. In such cases, the quality of the pond water becomes a critical parameter, not just for the health of fish stock, but also for assessing environmental impact and determining safe and sustainable post-discharge applications.

Water quality refers to the physical, chemical, and biological characteristics of water, with regard to its suitability for a particular purpose (Chapman, 1996). These characteristics are evaluated using a wide range of parameters, including temperature, pH, turbidity, dissolved oxygen, electrical conductivity, total dissolved solids (TDS), etc. In fish farming, maintaining these parameters within optimal ranges is essential for ensuring fish health, growth, and survival. Yet, the relevance of these parameters extends beyond aquaculture. They also dictate whether the water can be safely reused for purposes such as irrigation, industrial processes, or even safe discharge into natural ecosystems (Boyd & Tucker, 1998).

To synthesize multiple water quality parameters into an interpretable index, we use tools such as the Water Quality Index (WQI). The WQI provides a composite score based on the relative importance and observed values of selected water quality indicators. Among the most commonly used models is the Arithmetic Weightage Index Model, which assigns weights to individual parameters and aggregates them into a single, categorized score. This enables water bodies to be classified into quality categories such as excellent, good, poor, or very poor—based on their potential usability and environmental impact (Brown et al., 1970). The benefit of this model lies in its simplicity and comprehensiveness, making it especially useful for non-specialist users, decision makers, and researchers evaluating environmental suitability.

In the context of the University of Benin fish pond, such an evaluation can be a necessary step toward future planning. In the case of water exchange or water turnover, a data-driven approach is needed to determine whether the pond water can be safely discharged, reused, or treated. Unchecked discharge of nutrient-rich pond water into surrounding soil or nearby water bodies could lead to eutrophication, algal blooms, groundwater contamination, and other ecological problems (FAO, 2006). Conversely, if the water is found to be of acceptable quality, it may serve as a valuable input for non-potable uses such as irrigation of agricultural plots, or even reused in another aquaculture system. Additionally, there is a growing need in Nigeria and other developing countries to establish water quality benchmarks for small-scale and institutional aquaculture operations. Such data can be useful in sustainability assessments, and long-term water management strategies. However by undertaking a comprehensive water quality analysis and calculating the WQI of the Faculty's fish pond, this research not only supports institutional planning but also contributes to broader environmental stewardship efforts. Critical to this study are also the definitions and understanding of water quality, water quality testing methods, and environmental impact assessments. Several laboratory tests are conducted for evaluating water quality. The results of these tests provide the raw data for WQI computation, which in turn determines potential water usage options and impacts.

In summary, by determining the Water Quality Index of the pond and proposing alternative usage recommendations, the study offers a model for how academic institutions can responsibly transition from active pond use to environmentally sound discharge or repurposing. This aligns with global priorities for water resource conservation, sustainable development, and pollution control.

1.2 Statement of the Problem

The sustainable management of water resources in aquaculture systems is one of the most pressing environmental and operational challenges in modern agriculture. Fish ponds, especially those located within academic institutions, serve multiple purposes: education, food production, research, and demonstration. However, when such ponds face the prospect of water exchange or water turnover, the water they contain becomes a critical focus for environmental assessment. Without proper analysis, discharging pond water directly into the environment may lead to unintended ecological harm. Conversely, failing to identify opportunities for reuse is a missed chance at resource optimization.

The Faculty of Agriculture Fish Farm at the University of Benin is a well-utilized aquaculture facility that has supported both practical learning and small-scale fish production. However, in the case of water exchange or water turnover, there must be a clear understanding of what to do with the water it contains. The central concern of this research is thus rooted in the question: What is the water quality index of the fish pond, and what are the environmentally safe and beneficial alternatives for its discharge or reuse?

This knowledge gap reflects a broader issue in institutional aquaculture management across Nigeria, where water quality is often monitored for fish health but not evaluated in the context of post-use planning or environmental responsibility. The implications of this oversight can include pollution of downstream water bodies, degradation of soil quality, and violations of environmental standards.

However, the use of the Arithmetic Weightage Index Model to calculate the Water Quality Index presents a clear, structured, and scientifically credible approach to addressing these concerns. By compiling laboratory analyses of relevant water quality parameters, the model produces a single score that reflects the pond water's overall status. From this, specific usage recommendations can be drawn—whether for irrigation, reuse, or the need for treatment prior to discharge.

This study will therefore not only provide an objective measure of the pond’s water quality but will also offer actionable insights on how to handle the water responsibly, in a way that aligns with both environmental sustainability and campus resource management goals.

In conclusion, the problem this study addresses is the lack of structured data and reuse planning for fish pond water in the case of pond removal or discharge, or in the event of water exchange or water turnover. By filling this gap, the study supports smarter water resource use, reduces potential environmental impacts, and sets a precedent for similar assessments across other institutions and private aquaculture ventures.

1.3 Aim and Objectives

The main aim of this research is to assess the water quality of the fish pond located within the Faculty of Agriculture, University of Benin, and to determine the most environmentally responsible and practical alternative uses for the pond water, particularly in the event of water exchange or turnover, pond removal or discharge.

To achieve this aim, the research is guided by the following specific objectives:

i. To identify and evaluate the key physical, chemical, and biological parameters of the fish pond water using standardized laboratory procedures. This includes testing for parameters such as pH, temperature, turbidity, dissolved oxygen, total dissolved solids (TDS), and other relevant indicators of water quality.

ii. To calculate the Water Quality Index (WQI) of the fish pond water using the Arithmetic Weightage Index Model. This model will help integrate multiple water quality parameters into a single, interpretable value that reflects the overall status of the water body.

iii. To classify the water based on its WQI score, grading it into standard categories such as excellent, good, fair, or poor, thereby providing a benchmark for understanding the usability of the pond water.

iv. To explore and recommend alternative uses for the pond water, particularly in scenarios of water exchange and water turnover or in cases where the pond is decommissioned or its water is discharged. Possible recommendations will include use for irrigation, reuse in agriculture or aquaculture, or the need for treatment before discharge into the environment.

v. To assess the potential environmental impacts of discharging or reusing the pond water based on the water quality results and WQI grading, ensuring that any recommended actions are ecologically sound and comply with environmental standards.

1.4 Scope of Study

This research is designed to comprehensively evaluate the water quality of the fish pond at the Faculty of Agriculture, University of Benin, with the ultimate goal of determining its Water Quality Index (WQI) and suggesting environmentally sustainable usage recommendations in the event of water exchange or water turnover and discharge. The scope encompasses all aspects of the research process, from fieldwork and sampling to laboratory testing, data analysis, and interpretation. The scope also includes the application of standardized models to assess the water's status and grade its suitability for potential post-use applications.

The study will begin with a detailed assessment of the study area — the Faculty of Agriculture fish farm — which is located within the University of Benin campus. This includes site visits to understand the pond's physical characteristics, history of usage, source of water supply, aquaculture practices, and any observable environmental or operational challenges.

Following this, water sampling will be conducted under controlled conditions. Samples will be taken from different ponds to ensure and account for spatial variability. These samples will be properly stored in clean, labeled containers and immediately transported to the Hydraulics/Water Laboratory in the Civil Engineering Department for analysis.

In the laboratory, the study will focus on measuring a defined set of key water quality parameters. These parameters have been selected based on their relevance to aquaculture health, environmental safety, and their inclusion in the arithmetic weightage index model. They include: Turbidity, Temperature, Odour, Colour, Total Suspended Solids (TSS), Total Dissolved Solids (TDS), pH, Dissolved Oxygen, and other important parameters. Each of these parameters will be evaluated using the appropriate laboratory methods.

The data obtained from the laboratory analysis will serve as the input for the next phase of the study, which involves the application of the Arithmetic Weightage Index Model. This model assigns weight values to each parameter based on its relative importance to overall water quality. The measured values are then compared to standard values (such as WHO or EPA guidelines) and aggregated to calculate a single Water Quality Index. The resulting WQI will be used to grade the water into a category — ranging from “Excellent” to “Unfit for Use.”

Once the WQI is calculated, the research will proceed to interpret the implications of the results. This includes evaluating whether the water meets the standards required for various uses such as irrigation, recreational discharge, secondary aquaculture, or if it requires treatment before disposal. Recommendations will be made with a focus on environmental protection, waste reduction, and sustainable resource use. The final stage of the research will involve documentation, presentation of findings, and formulation of recommendations for environmental regulators and future researchers.

1.5 Justification of Study

The relevance and necessity of this study are grounded in both practical and environmental concerns. In recent years, the demand for sustainable water management in aquaculture has grown in tandem with global efforts to reduce environmental degradation and promote responsible resource use. The fish pond at the University of Benin's Faculty of Agriculture represents more than just an academic or economic asset; it is also a potential source of environmental liability if improperly managed. Therefore, understanding the water quality status and determining the most responsible way to managing or reuse the pond water is both timely and essential.

One of the central justifications for this study lies in the need to generate scientific data regarding the water quality of institutional fish ponds, which are often overlooked in larger environmental monitoring efforts. Unlike industrial fish farms that may be subject to regular inspection, small-scale or academic ponds are rarely assessed for their long-term environmental impact, especially in scenarios of water exchange or water turnover. By undertaking this research, the project addresses a clear data gap and creates a reference point for similar institutions across Nigeria and West Africa.

Moreover, this study is instrumental in supporting the University's commitment to sustainability and responsible land-use management. If the Faculty of Agriculture ever decides to repurpose the land currently occupied by the pond, decisions on how to safely dispose of or reuse the water must be based on solid environmental evidence. An unregulated discharge could introduce excessive nutrients or pollutants into the surrounding ecosystem, leading to soil contamination, groundwater pollution, or eutrophication of nearby water bodies (FAO, 2006; Boyd & Tucker, 1998). This research aims to preemptively address such risks by providing a roadmap based on water quality analysis and WQI classification.

Another major rationale is the potential for alternative usage recommendations. Rather than treating pond water as waste, this study seeks to explore its value as a resource. If the WQI shows the water to be of acceptable quality, it can be reused for purposes such as irrigation, landscape watering, or even reused in other aquaculture settings. This not only conserves water but also aligns with circular economy principles, which advocate for the reuse and recycling of resources wherever possible (UNEP, 2019).

From a broader societal and industrial perspective, this study provides guidance for small and medium-scale fish farmers who may not have the resources to routinely monitor or manage pond water at the end of production cycles. By demonstrating how to conduct water quality assessments and interpret WQI using the arithmetic weightage index model, the research offers a replicable method that can help fish farmers make informed decisions and avoid environmental penalties.

In summary, this study is justified by its potential to:

i. Provide vital data on the water quality of the Faculty of Agriculture fish pond.

ii. Propose scientifically backed alternative usage recommendations for the pond water.

iii. Prevent environmental degradation in the event of pond discharge or removal.

iv. Contribute practical solutions to aquaculture sustainability in academic and small-scale settings.

Ultimately, the study is not just relevant — it is necessary, impactful, and aligned with local, national, and global priorities in environmental conservation and sustainable water use.

CHAPTER TWO

LITERATURE REVIEW

2.1. Water Quality

Water quality is defined as the chemical, physical, and biological characteristics of water in relation to its suitability for a particular purpose such as drinking, recreation, agriculture, and aquaculture. According to the World Health Organization (WHO, 2017), water quality is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose. It involves a broad range of physical, chemical, and biological characteristics that can vary depending on the intended use of the water. For example, water suitable for irrigation may not be fit for drinking, and water safe for human consumption may not necessarily support aquatic life if it lacks adequate dissolved oxygen levels.

Water quality is determined by measuring a variety of parameters, which include, but are not limited to temperature, pH, turbidity, biological oxygen demand (BOD), chemical oxygen demand (COD), dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS). These parameters serve as indicators of the health and usability of a water body (Chapman, 1996). The determination of water quality is crucial for environmental management, public health, and sustainable water use, especially in sectors such as aquaculture, where fish and other aquatic organisms are directly impacted by the surrounding water (Boyd & Tucker, 1998).

According to the U.S. Geological Survey (USGS), good water quality depends largely on the context in which the water will be used (USGS, 2020). Hence, the assessment is relative and use-specific, reinforcing the importance of research like this one, which aims to evaluate water specifically for aquaculture and subsequent alternative uses.

2.2. Components of Water Quality

The following are the key components of water quality (Boyd & Tucker, 1998):

i. Physical Characteristics: These characteristics include color, turbidity, temperature, and taste. They affect the aesthetic and sensory properties of water and influence chemical and biological processes (Sawyer et al., 2003).

ii. Chemical Characteristics: The chemical characteristics of water quality includes pH, dissolved oxygen (DO), total dissolved solids (TDS), total suspended solids (TSS), conductivity, nutrients (e.g., nitrogen and phosphorus compounds), and contaminants like heavy metals.

iii. Biological Characteristics: They include Presence of microorganisms such as bacteria, viruses, and protozoa (Bitton, 2011).

2.3. Importance of Water Quality

Maintaining high water quality is essential for the following sectors and applications (FAO, 2011):

i. Human and Public Health: Contaminated water can lead to the transmission of waterborne diseases such as cholera, typhoid, and dysentery. Poor water quality has been linked to significant public health burdens, particularly in low- and middle-income countries (WHO, 2017).

ii. Aquatic Ecosystem Health: Aquatic life is sensitive to fluctuations in parameters like temperature, dissolved oxygen, and pH. An imbalance in these parameters can cause fish mortality, reduce growth rates, and increase susceptibility to disease (Boyd & Tucker, 1998).

iii. Agriculture and Irrigation: Water quality impacts crop yields, soil health, and the long-term sustainability of agricultural systems. For instance, water with high salinity or heavy metals can render soil infertile (Ayers & Westcot, 1985).

iv. Industrial Use: Many industries require high-quality water for processing, cooling, and cleaning. Poor water quality can damage equipment, reduce production efficiency, and lead to non-compliance with environmental regulations (Spellman, 2014).

v. Environmental Sustainability: Maintaining high water quality helps preserve biodiversity, ensures the proper functioning of ecosystems, and sustains the natural purification processes that water bodies perform (UNEP, 2010).

In the context of this study, water quality is vital not just for fish farming success but also for exploring sustainable reuses of pond water in ways that minimize harm to the environment. Poor water quality can also lead to disease outbreaks, reduced agricultural productivity, and loss of biodiversity (Akinrotimi et al., 2010).

2.4. Water Quality Parameters

Water quality parameters can be classified as, but not limited to the following:

i. Turbidity. Turbidity is a measure of the cloudiness or haziness of water due to the presence of suspended particles. It affects the aesthetic value of water and can also greatly impact aquatic life.

Turbidity is typically measured in Nephelometric Turbidity Units (NTU) using a turbidimeter.

The acceptable level of turbidity varies depending on the intended use of the water. For example, drinking water should have a turbidity of between 1 - 5 NTU. (APHA, 2017).

ii. Temperature.

Temperature affects the physical, chemical, and biological properties of water. It can impact the growth and survival of aquatic organisms.

Temperature is typically measured in degrees Celsius (°C) using a thermometer.

The acceptable temperature range varies depending on the intended use of the water. For example, aquatic life requires temperatures between 10°C and 30°C. (Boyd & Tucker, 1998; APHA, 2017).

iii. Odour.

Odour is a measure of the unpleasant smell of water. It can be caused by the presence of organic matter, bacteria, or other substances. (APHA, 2017).

iv. Colour.

Colour is a measure of the hue or tint of water. It can be caused by the presence of organic matter, minerals, or other substances.

Colour is typically measured using a spectrophotometer or a colorimeter.

The acceptable level of colour varies depending on the intended use of the water. For example, drinking water should be colourless. (Sawyer et al., 2003; APHA, 2017).

v. Total Suspended Solids (TSS).

TSS is a measure of the amount of suspended particles in water. It can affect the clarity and the quality of water.

TSS is typically measured using a gravimetric method.

The acceptable level of TSS varies depending on the intended use of the water. (APHA, 2017).

vi. Total Dissolved Solids (TDS)

TDS is a measure of the amount of dissolved substances in water. It can affect the taste, odour, and quality of water.

TDS is typically measured using a gravimetric method.

The acceptable level of TDS varies depending on the intended use of the water. For example, drinking water should have a TDS of less than 500 mg/L. (WHO, 2017; APHA, 2017).

vii. pH

pH is a measure of the acidity or alkalinity of water.

pH is typically measured using a pH meter or pH paper.

The acceptable pH range varies depending on the intended use of the water. For example, drinking water requires a pH between 6.5 and 8.5. (APHA, 2017).

viii. Dissolved Oxygen (DO)

DO is a measure of the amount of oxygen dissolved in water. It can affect the growth and survival of aquatic organisms.

DO is typically measured using a DO meter or a Winkler titration method.

The acceptable level of DO varies depending on the intended use of the water. For example, aquatic life requires a DO level of at least 5 mg/L. (Boyd & Tucker, 1998; APHA, 2017).

ix. Biological Oxygen Demand (BOD)

BOD is a measure of the amount of oxygen required by microorganisms to break down organic matter in water. It can affect the quality of water and the growth and survival of aquatic organisms.

BOD is typically measured using a 5-day BOD test.

The acceptable level of BOD varies depending on the intended use of the water. (Bitton, 2011 ; APHA, 2017).

Each parameter must be analyzed within context to assess overall water health and suitability for different purposes, including aquaculture and post-aquaculture uses.

2.5. Who Standards for Water Quality Parameters

The World Health Organization (WHO) provides internationally recognized guidelines for acceptable water quality parameters, especially for potable water. While this project focuses on fish pond water, these standards serve as a benchmark to assess safety for secondary usage, especially in scenarios like irrigation, discharge into public waterways, or even limited domestic purposes.

Table 2.1: WHO standards for water quality parameters.

Parameter	**WHO Standard (Aquaculture)**
pH	6.5 – 8.5
TDS	< 1000 mg/L
TSS	< 200 mg/L
DO	> 5 mg/L
Temperature	Species-dependent
Turbidity	< 30 NTU
Colour	Clear to slight tint
Odour	No foul odour

Source: WHO (2017), FAO Aquaculture Guidelines

2.6. Water Quality Index (WQI)

The WQI is a single number that expresses overall water quality at a certain location and time based on several water quality parameters. It simplifies the reporting of water quality data. Water quality index aggregates various water quality parameters into a single numerical score. (Tyagi et al., 2013).

The WQI works by:

i. Assigning weight to each parameter based on its relative importance.

ii. Calculating the quality rating for each parameter.

iii. Combining all weighted scores to obtain an overall index (Brown et al., 1970).

WQI is especially useful in civil and environmental engineering because it:

i. Allows easy communication of water quality status to the public and policymakers.

ii. Supports decision-making regarding treatment needs or regulatory compliance. (CCME, 2001).

iii. Facilitates historical or regional comparisons.

For this study, the WQI provides an effective way to evaluate the fish pond’s water quality holistically and determine its suitability for alternative uses or environmental discharge.

2.6.1. Interpretation of WQI

i. 0–25: Excellent

ii. 26–50: Good

iii. 51–75: Poor

iv. 76–100: Very Poor

v. >100: Unsuitable for use (Tyagi et al., 2013; Ramakrishnaiah et al., 2009).

2.7. Arithmetic Weightage Index Model

The Arithmetic Weightage Index Model is a statistical method used to calculate a weighted average of various parameters or indicators. The Arithmetic Weightage Index Model uses weighted average calculations to compute the WQI. It assigns weight to each parameter and computes the quality rating to evaluate the overall water quality (Ramakrishnaiah et al., 2009). It is commonly used in decision making and evaluation processes such as assessing water quality, environmental impacts. (Chatterjee & Raziuddin, 2002).

2.8. Water quality status, grading, usage according to arithmetic weightage index model.

Once the WQI is calculated, the quality of the water is categorized based on standard grading scales. This helps in identifying the level of intervention required before the water can be used for any specific purpose.

Table 2.2: water quality status, grading, and possible usage

WQI Range	Status	Grading	Usage Recommendation
0 – 25	Excellent	A	Continued Aquaculture use, irrigation of sensitive crops, and direct discharge into the environment without treatment.
26 – 50	Good	B	Irrigation of non-edible crops, groundwater recharge after sedimentation or filtration.
51 – 75	Poor	C	Should undergo aeration or sedimentation before reuse. After treatment, suitable for limited irrigation use.
76 – 100	Very Poor	D	Not suitable for aquaculture or irrigation. After biological and physico-chemical treatments, can be reused for wetlands recharge.
>100	Unsuitable	E	Heavily contaminated and should undergo proper treatment before discharged.

Source: Boyd, C.E. & Tucker, C.S. (1998). Pond Aquaculture Water Quality Management. Springer Science & Business Media, New York. Tyagi, S., Sharma, B., Singh, P. & Dobhal, R. (2013). Water Quality Assessment in Terms of Water Quality Index. American Journal of Water Resources, 1(3), 34–38.

2.9 General Overview of Fish Pond Water

Fish pond water refers to the aquatic environment used for rearing fish in artificial or semi-natural ponds (FAO, 2021). These ponds may be earthen, concrete, or plastic-lined, and they simulate natural aquatic systems under controlled or semi-controlled conditions (Boyd & Tucker, 1998). The primary purpose of fish pond water is to provide suitable living conditions for fish species such as Clarias gariepinus (African catfish), Oreochromis niloticus (Nile tilapia), and Heterobranchus spp., among others.

Key characteristics of fish pond water include:

i. High Nutrient Load: Fish feed contains nitrogen and phosphorus. Excess feed and fish waste contribute to nutrient enrichment (eutrophication), which can promote algal blooms and oxygen depletion (Akinrotimi et al., 2010).

ii. Fluctuating pH and DO: Due to respiration, photosynthesis, and organic decomposition, pond water often exhibits diurnal variations in dissolved oxygen and pH levels.

iii. Presence of Organic Matter: Fish excreta, decomposed feed, and microbial activity increase the Biological Oxygen Demand (BOD) and Total Organic Carbon (TOC) (Bitton, 2011).

iv. Elevated TSS and Turbidity: Frequent movement of fish and uneaten feed lead to increased suspended solids, reducing clarity (Ofojekwu et al., 2016).

v. Temperature Sensitivity: Shallow ponds are more vulnerable to temperature fluctuations, which can affect metabolic and growth rates of aquatic organisms.

2.10 Key Components of Fish Pond Water

The major elements that define the quality and functionality of fish pond water include (Boyd & Tucker, 1998; FAO, 2021):

i. Physical characteristics: They include temperature, turbidity, and transparency

ii. Chemical properties: They include dissolved oxygen (DO), pH, ammonia, nitrite, nitrate, and alkalinity.

2.11 Fish Pond Water Management Practices

2.11.1 Water Sourcing and Quality

Sources of water for fish ponds in Nigeria include (Ayeni et al., 2019):

i. Surface water (rivers, streams)

ii. Groundwater (boreholes, wells)

iii. Rainwater collection

2.11.2 Water Exchange and Waste Discharge

In many fish farms, periodic water exchange is employed to dilute waste concentrations and maintain water quality. However, in Nigeria, this often involves direct discharge into surrounding environments without treatment, leading to environmental degradation (Ofojekwu et al., 2016).

2.12 Water Quality in Fish Ponds in Nigeria: Common Issues

Nigeria’s rapidly growing aquaculture sector, particularly catfish farming, has brought with it several water quality challenges due to poor regulation, limited awareness, and environmental stressors (Akinrotimi et al., 2010).

Common issues in Nigerian fish ponds:

i. Polluted Water Sources: Many ponds are filled using surface water from nearby streams or shallow wells, often contaminated by agricultural runoff, domestic waste, or industrial discharge (Oyelude & Ahenkorah, 2012).

ii. Overstocking and Overfeeding: Driven by economic pressures, farmers often stock fish at densities beyond recommended levels, leading to increased waste and oxygen depletion (Oyelude & Ahenkorah, 2012).

iii. Lack of Water Circulation: Most earthen and concrete ponds lack aeration or water flow systems, resulting in stagnant conditions that promote anaerobic decomposition and pathogen proliferation.

iv. Limited Monitoring: Few farms in Nigeria regularly test for parameters like ammonia, nitrite, or dissolved oxygen, increasing the risk of mass fish deaths.

v. Seasonal Effects: During the dry season, evaporation concentrates pollutants, while the rainy season causes runoff that may introduce pathogens or pesticides into ponds.

Examples from literature:

i. Oyelude & Ahenkorah (2012) reported excessive ammonia and low DO in smallholder ponds in southern Nigeria.

ii. Akinrotimi et al. (2010) noted that catfish mortality in the Niger Delta region was often linked to poor pond water management and runoff from nearby oil fields.

Such issues make it critical to assess pond water periodically, not just for immediate fish health but for broader environmental safety and potential reuse (Ayoola, 2002).

2.13 Environmental Impact of Fish Pond Water

Discharging untreated or poorly managed pond water into the environment poses significant ecological and public health threats, especially in densely populated or agricultural areas (FAO, 2011). Fish pond effluents often contain nutrients, suspended solids, organic matter, pathogens, and sometimes residual chemicals like antibiotics or pesticides.

i. Eutrophication and Algal Blooms: Discharge of nitrogen and phosphorus compounds from fish ponds promotes excessive algal growth, leading to eutrophication. This phenomenon results in oxygen depletion, fish kills, and alteration of aquatic ecosystems (UNEP, 2010).

ii. Soil and Groundwater Pollution: Fish pond water, especially from unlined earthen ponds, may infiltrate surrounding soils and enter groundwater aquifers. The infiltration of nutrients and organic waste leads to changes in soil pH, salinity, and microbial activity, which negatively affect agricultural productivity (Ayers & Westcot, 1985).

iii. Water pollution: Untreated fish pond wastewater can contaminate nearby water bodies, affecting their quality and harming aquatic life (Chatterjee & Raziuddin, 2002).

iv. Public Health Concerns: Poor management of fish pond waste can facilitate the spread of waterborne diseases. Stagnant and nutrient-rich pond effluents serve as breeding grounds for mosquitoes, increasing the risk of malaria and other vectorborne diseases (WHO, 2017).

v. Aesthetic Pollution: Discharge of dark-colored or foul-smelling pond water into urban drains and streams reduces the aesthetic and recreational value of local water bodies (Boyd & Tucker, 1998).

2.14. Empirical Framework

Below is an enhanced Empirical Framework (past projects) featuring carefully summarized case studies from Nigeria and other developing nations related to this study.

Ehiagbonare & Ogunrinde (2010) investigated the Physico-Chemical Analysis of Fish Pond Water in Okada, Edo State. The aim was to evaluate the water quality of concrete and earthen fish ponds around Okada to determine their suitability for aquaculture. Twenty-one parameters were measured using standard lab methods (pH, DO, turbidity, TDS, COD, BOD, heavy metals). The lab results for the various Parameters were largely within WHO/FEPA limits; pH (6.75–7.10), TDS (22–906 mg/L), DO (9.3–16.2 mg/L); occasional spikes in turbidity and COD. The conclusion reached was that the Pond waters was generally suitable for fish culture, but consistent monitoring is recommended to prevent long-term accumulation of harmful substances.

Kpikpi & Bubu-Davies (2021) conducted WQI Assessment of Artificial Aquatic Environments, Port Harcourt. They evaluated water quality status in concrete, earthen, and plastic pond tanks. A total of nine parameters were measured monthly (temperature, pH, EC, TDS, turbidity, DO, BOD, NO_3, PO_4) and applied Weighted Arithmetic WQI. WQI classifications ranged from "good" to "moderate" across pond types; plastic tanks scored lowest in water quality. They concluded that the WQI effectively differentiated the pond types; earthen ponds provided superior water quality compared to plastic ones.

Perera et al., 2023. This paper is about the WQI Analysis in Kelani River, Sri Lanka. It aimed to Monitor WQI trends in a major river basin over several years. The method employed was the weighted arithmetic index applied to annual data (2005–2012); multiple stations across basin. After analysis, the WQI ranged from 35.9–58.7 ("fair" to "poor"), indicating the river was unsuitable for drinking without treatment. The paper then stated that regular monitoring and effluent regulation are necessary to improve water quality in river systems impacted by industrial and agricultural activities.

Adewumi et al., (2020). This paper reported on the Effluent Impact on Odo-Owa Stream, Ogun State, Nigeria. It investigate fish-farm effluent impacts on downstream water quality. The paper monitored seven stations (upstream, discharge point, downstream), measured pH, DO, turbidity, NO_3, PO_4 and calculated the WQI based on this parameters. The results gotten were as follows; Downstream WQI declined significantly, DO reduced, nutrients and turbidity increased post-discharge. It then concluded that the Effluents degrade stream quality and that mitigation measures like effluent treatment are essential before discharge.

Kar et al., (2017). This paper investigated the Loktak Lake WQI in North-East India. It Developed and applied a WQI model to assess the lake water quality. The Weighted arithmetic WQI method was used alongside physicochemical measurements of some water quality index parameters (pH, DO, TDS, nutrients). The WQI scores ranged from 64–77, classifying the lake as “poor” to “very poor” and unsuitable for drinking. It then concluded that Regular WQI-based monitoring is essential to track changes and address sources of pollution.

Odesiri-Eruteyan & Urhibo, (2022) investigated the Bacteriological & Physicochemical Analysis of Fish Pond Effluents in Warri. They evaluated microbial loads and physico-chemical characteristics of effluents from earthen and concrete ponds in Warri. A total of Six pond effluent samples were collected and analyzed for bacterial counts (total bacteria, coliforms, E. coli) and water quality parameters (pH, DO, EC, turbidity). The Earthen pond effluent showed extremely high bacterial loads, including pathogens; turbidity and hardness exceeded WHO/FEPA limits and other parameters were within acceptable ranges. They then concluded that Discharged pond effluents pose health risks and contain antibiotic-resistant pathogens, signaling a need for treatment before environmental release.

Njoku et al., (2015). This paper reported the Physico-Chemical and Bacteriological Analysis of Niger Delta Ponds. It evaluated the water quality and bacterial contamination in smallholder fish ponds. It carefully Analyzed 15 parameters (e.g., pH, DO, TDS) plus bacterial load (coliforms, Aero Monas), and Employed WQI framework based on weighted arithmetic index. The results gotten included the following; DO (3.2–5.8 mg/L), TDS (150–370 mg/L), coliform counts exceeded WHO limits, Aero Monas detected in 60% of ponds. The paper therefore concluded the Water quality is poor to moderate and microbial contamination is a health risk and propose Regular WQI monitoring could guide safe reuse or discharge.

Akinsulire et al. (2019). This paper evaluated the water quality of Eriwe fish farm, Ogun state for aquaculture viability. It carefully analysed water quality parameters such as DO, pH, temperature and ammonia levels. The water was within tolerable limits but required periodic monitoring. It was then concluded that it was suitable for aquaculture with proper management.

Ayeni et al. (2019). This study evaluated the physicochemical properties of fish pond water in Ondo state. It sampled pond water and analysed TDS, DO, pH, turbidity, and BOD. After analysis, most parameters met FAO aquaculture guidelines, except DO. It then concluded that Seasonal variations affect pond water quality; aeration systems recommended.

Olatunji & Aderibigbe (2017). They used Arithmetic Weightage Index to assess borehole water in Akure. They Analyzed 10 water parameters; computed WQI using WHO standards. After analysis, most boreholes classified as “Good” to “Poor. In their conclusion, they urged government monitoring of water safety.

Eze et al. (2021). This study computed the assessment of Water Quality in Catfish Farms, Anambra. It Analyze aquaculture water for sustainability, measured DO, ammonia, pH, and nitrate. Results obtained was High ammonia in poorly managed farms. It then concluded that frequent water exchange enhances quality.

Adefemi & Awokunmi (2011) assessed the water quality of River Oyun, Kwara State.They aimed to determine the river’s suitability for multiple sources. They Collected samples across seasons; evaluated pH, DO, conductivity. They found out that Dry season values exceeded safe limits. They concluded that Point-source pollution needs control.

Umeham (2015) assessed the Water Quality of Fish Ponds in Abia State. The aim was to evaluate health implications of pond water used domestically. He tested bacterial load, pH, color, TSS. The results obtained was High E. coli and poor turbidity. He then concluded that the fish pond water was not safe for domestic reuse without treatment.

Ukpong et al. (2013). This paper researched on Groundwater WQI Assessment in Akwa Ibom. It aimed to assess borehole quality using WQI. 10 were parameters tested; and Arithmetic WQI model was applied. After analysis, Over 60% samples were poor. It then concluded that Borehole maintenance programs are needed.

Edokpayi et al. (2016). This paper researched on Groundwater Quality in Limpopo, South Africa. It aimed to Apply WQI to assess borehole safety. It Collected samples from 20 boreholes; used arithmetic WQI model. The results obtained was that 30% of samples unsuitable without treatment. It then concluded and identified need for community filtration systems.

Sagir et al. (2023). This paper assessed the Pond Water Quality in Bauchi State. It aimed to evaluate suitability of ponds for fish culture. It measured temperature, pH, DO, BOD, TDS, EC, coliforms. Most parameters were compliant; DO and BOD sometimes zero. It then concluded that the pond water was suitable for fish but further improvements advised.

Ehiagbonare & Ogunrinde (2010) assessed Okada Fish Pond Physico-chemistry. They aimed to examine 21 water parameters in concrete and earthen ponds. The methodology employed was Standard lab analyses of water chemistry. After analysis, it was found that the parameter values within acceptable ranges; minor location-based variations. It then recommended that regular monitoring is required to prevent bioaccumulation.

Ibeaja & Ugorji (2024) carried out Comparative WQI across South-East Nigeria. They aimed to Compare WQIs of different water bodies using arithmetic model. They Measured physico-chemical parameters and computed WQI. They found that the WQI varied with human impacts and some sites below good threshold. They concluded that treatment and regulation are needed for affected sites.

Mbachu et al. (2023, IJECC). This paper assessed the WQI of Rural Ponds, Imo State. It desired to evaluate pond water for domestic use. It Measured physico-chemical & microbial parameters and calculated WQI. It was found that the ponds had extremely high WQI values (1338–3322), indicating poor quality and concluded that the Pond water are unsafe without treatment.

Mbachu & Nwaogazie (2023, JERR). They conducted WQI Modelling in Rural Ponds. They aimed to develop regression models for pond WQI. They PCA and multiple regression on >25 parameters. The Model predicted WQI with R^2 up to 0.99. it concluded that Predictive model aids rapid water quality assessments.

Iyiola et al. (2023). This research assessed the WQI & Fish Biodiversity in Owalla Reservoir. It aimed to assess fish diversity and water quality. They carried out Monthly sampling; WQI and biodiversity analysis. The results obtained were High WQI and ammonia; lower biodiversity in poor-quality areas. It then concluded that Water quality impacts fish diversity and monitoring is essential.

Adeosun et al. This researched assessed the Water Quality & Fish Catch in Ikere Gorge. It aimed to evaluate water quality and fish diversity in reservoir. It carried out Physico-chemical measurements; fish surveys over 18 months. The result gotten after analysis was Good water quality; identified 34 fish species. It then concluded that Reservoir supported diverse fish community; water quality adequate.

Adewumi et al. (2020). The researched evaluated Fish Farm Effluent & Stream Quality. It aimed to assess impact of effluent on Odo-Owa stream. The methodology employed was Seasonal sampling at multiple stations; measured water parameters and computated WQI via software. The result obtained was Reduced DO, higher nitrates downstream and the WQI fell from “good” to poorer classes. It concluded that Effluent degrades stream quality and treatment is recommended.

Orobator et al. (2020). This researched assessed the Water Quality of Benin City Aquaculture Ponds. It Evaluate pond water across Benin City. This researched Analyzed physico-chemical parameters. It found that the Water varied and some ponds suitable for non-potable uses. The researched then suggested regular monitoring and possible treatment.

Perera et al. (2023, Sri Lanka). This journal assessed the WQI Trends in River Basin. It aimed to track long-term WQI changes in Kelani River. It applied Weighted arithmetic WQI to 8-year data. The Quality ranged from fair to poor. The journal recommended the Need continuous monitoring and pollutant control.

Kar et al. (2017, India). This journal assessed the WQI in Loktak Lake. It aimed to apply WQI to assess lake water quality. It measured water parameters and computed the WQI. The WQI scores classified lake as poor to very poor. The journal then recommended urgent environmental protection needed.

Nagaraju et al. (2023, India). This journal assessed WQI & Ammonia Modeling in Aquaculture. It aimed to analyze WQI and predict ammonia levels. It employed WQI calculation on pond samples; ammonia modeling via machine learning. The results obtained include: Mean WQI = 126 (poor); high ammonia in 78% of samples. The journal concluded that Predictive tools improve proactive water quality management.

CHAPTER THREE

METHODOLOGY

3.1 Description of the Study Area

The study area is the fish pond at the Faculty of Agriculture, University of Benin, Benin City, and Edo State, Nigeria. This aquaculture facility is comprised of multiple connected chambers designed for teaching, research, and fish production activities. The main pond is a rectangular concrete structure with an approximate surface area of $246.74ft^2$ and a maximum depth of 1.5 m. It receives water from a nearby borehole and occasionally from municipal supply, making it representative of typical semi-urban farm ponds in southern Nigeria.

The pond supports tilapia (Oreochromis niloticus) and catfish (Clarias gariepinus), and is used for student training and research projects.

3.2 Site Location

University of Benin Main Campus.

Faculty of Agriculture compound: houses experimental plots and the fish pond facility.

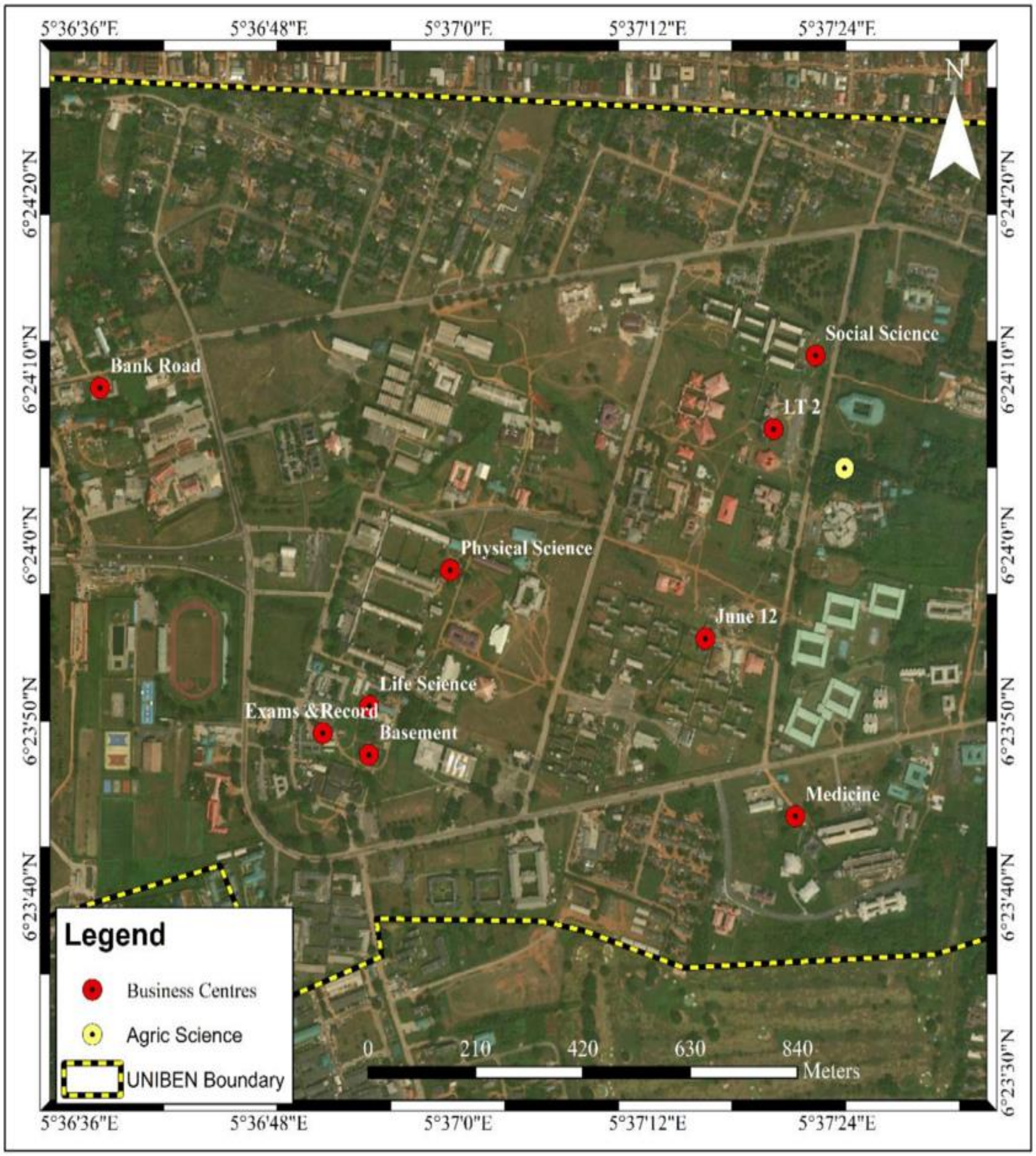

Figure 3.1: satellite map of University of Benin main campus highlighting the location of the fish pond at the Faculty of Agriculture, University of Benin.

Figure 3.2: fish pond facility at the Faculty of Agriculture

3.3 Sample Collection

Water samples were collected from the main ponds which is a rectangular concrete structure. Water was sampled from two ponds, pond A and pond B. Water was collected in clean, labeled bottles. All samples were transported to the Hydraulics/Water Lab for analysis.

Figure 3.3: pond A which had a 5 – day retention period before water turnover

Figure 3.4: pond B which had a 13 – day retention period before water turnover.

3.4 Test Procedures

For each water quality parameter, the following details are described:

3.4.1 pH

Apparatus: pH meter

Procedure:

i. Calibrate the pH meter using standard buffers.

ii. Rinse electrode with distilled water.

iii. Immerse the electrode in the sample and wait for stabilization.

iv. Record the pH reading. (APHA, 2017).

3.4.2 Total Dissolved Solids (TDS)

Apparatus: TDS/conductivity meter

Procedure:

i. Switch on and calibrate the meter.

ii. Immerse the probe in a clean sample container.

iii. Wait for the reading to stabilize and record the TDS in mg/L.(APHA, 2017).

3.4.3 Total Suspended Solids (TSS)

Apparatus: Filter assembly, pre-weighed glass-fibre filters, drying oven at 105 °C

Procedure:

i. Weigh clean, dry filter paper and record the weight.

ii. Filter a known volume (100 mL) of the sample.

iii. Dry the filter paper in an oven for 24 hours.

iv. Cool in a desiccator and weigh.

v. TSS = (Final weight – Initial weight) / Sample volume × 10^6 (mg/L) (APHA, 2017).

3.4.4 Dissolved Oxygen (DO)

Apparatus: Dissolved oxygen meter.

Procedure:

i. calibrate the DO meter

ii. Immerse the probe in the sample. Take the reading.(APHA, 2017).

3.4.5 Temperature

Apparatus: Digital thermometer (±0.1 °C)

Procedure:

i. Immerse the thermometer in the water sample and

ii. Take the reading. (APHA, 2017).

3.4.6 Turbidity

Apparatus: Turbidity meter

Procedure:

i. Calibrate the turbidity meter using 0, 20, and 100 NTU standards.

ii. Rinse the cuvette with the sample water.

iii. Fill to the marked level, insert into the meter, and read NTU. (APHA, 2017).

3.4.7. Odour

Apparatus: 100 mL glass containers with lids, rely on human senses

Procedure:

i. Pour samples into the container.

ii. Remove lid and immediately sniff the sample to assess for abnormal odour.

iii. Record observations as acceptable/unacceptable. (APHA, 2017).

3.4.8. Colour

Apparatus: Colorimeter

Procedure: Calibrate the meter. Pour the sample into the colorimeter's sample cell and measure the color using the Platinum-Cobalt scale.(APHA, 2017).

3.5 Method of Analysis: Arithmetic Weightage Index Model

Final water quality assessment uses the Arithmetic Weightage WQI model. (Brown et al., 1970; Tyagi et al., 2013). Steps:

i. Constant of proportionality k

$$k = \frac{1}{\sum 1/Sn} \qquad \text{Eq. (3.2)}$$

K is proportionality constant

ii. Perimeter weightage Wn

$$Wn = \frac{k}{Sn} \qquad \text{Eq. (3.1)}$$

Where Wn = perimeter weightage; k = constant for proportionality; Sn = standard value (WHO guideline).

iii). Quality rating Qn

$$Qn = 100\ (\frac{Vn - Vi}{Sn - Vi}) \qquad \text{Eq. (3.3)}$$

Where Qn = quality rating, Vn = laboratory test result of parameters, Vi = ideal value of parameter (it is zero for all parameters except pH which is equal to 7.0 and dissolved oxygen which is equal to 14.6mg/L)

iv). Overall WQI

$$\text{WQI} = \frac{\sum(Qn\ x\ Wn)}{\sum(Wn)} \qquad \text{Eq. (3.4)}$$

Interpreted against thresholds:

0–25: Excellent

26–50: Good

51–75: Poor

76–100: Very poor

> 100: Unsuitable

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Physico-Chemical and Microbial Analysis of Pond Water Sample A

Sample A represents pond water that had remained in the fish pond for five (5) days before turnover. The physico-chemical and microbial parameters were analyzed in the laboratory and the results are interpreted below relative to WHO and aquaculture standards.

Table 4.1: Lab Results for the Physico-Chemical Parameters

S/N	PARAMETERS	STANDARD UNITS	RESULTS
1	pH		6.8
2	EC	MS/cm	582
3	Sal.	g/l	0.263
4	Col.	Pt.co	1.0
5	Turbidity	NTU	0.6
6	TSS	mg/l	1.8
7	TDS	mg/l	292
8	COD	mg/l	32.0
9	HCO_3	mg/l	112.0
10	Na^+	mg/l	5.10
11	K^+	mg/l	3.21
12	Ca^{2+}	mg/l	10.5

13	Mg^{2+}	mg/l	7.77
14	Cl^-	mg/l	101.5
15	P	mg/l	0.118
16	NH_4N	mg/l	0.325
17	NO_2	mg/l	0.084
18	NO_3	mg/l	0.214
19	SO_4	mg/l	0.118
20	Fe^{3+}	mg/l	0.610
21	Mn^{2+}	mg/l	0.181
22	Zn^{2+}	mg/l	0.332
23	Cu^{2+}	mg/l	0.105
24	Cr^{3+}	mg/l	0.082
25	Cd^{2+}	mg/l	0.008
26	Ni^{2+}	mg/l	Not detected
27	Pb^{2+}	mg/l	0.011
28	V	mg/l	Not detected
29	THC	mg/l	Not detected
30	Hardness		58.2

Table 4.2: lab results for the microbial parameters

S/N	PARAMETERS	STANDARD UNITS	RESULTS
1	Total Heterotropic Bacterial Counts	CFU/ML	3 × 10^3
2	Total Coliform Counts	CFU/ML	0 × 10^3
3	Total E.coli Counts	CFU/ML	0 × 10^3
4	Tentative isolates		Entero bacter sp. Bacillus sp.

The measured pH of 6.8 falls within the WHO recommended range (6.5–8.5). The value represents slight acidification which occurs due to organic matter decomposition, but the value still supports biological productivity.

The Electrical Conductivity value of 582 µS/cm suggests moderate mineralization, since for aquaculture, EC values between 200–1,500 µS/cm are acceptable (Boyd & Tucker, 1998). The salinity level of 0.263 parts per thousand (ppt) confirms that the pond water is not saline and is within limits 0–0.5 ppt (FAO, 2006).

The measured Turbidity value 0.6 NTU is far below the WHO aesthetic limit of 5 NTU, signifying good clarity. The color of 1.0 Pt-Co units indicates very clear water with little to no dissolved organic or inorganic coloration. No foul smell/odour was detected.

The TSS value of 1.8 mg/L is very low, showing minimal particulate matter. In aquaculture, TSS below 30 mg/L is acceptable (FAO, 2011). This indicates good sediment control and little waste accumulation after 5 days of water retention.

The TDS level of 292 mg/L falls within the WHO recommended aesthetic limit of <1,000 mg/L (Boyd, 1990). This level signifies adequate nutrient availability and low salinity.

The COD value of 32 mg/L suggests moderate organic load, likely due to feed residue or fish excreta. Although WHO does not specify a COD limit for potable water, in aquaculture, lower COD (<40 mg/L) is preferable to maintain high dissolved oxygen levels (Tyagi et al., 2013).

The bicarbonate level (HCO_3) at 112 mg/L shows the water possesses moderate alkalinity, ensuring pH stability and resilience to acidification. Both sodium and potassium values are low, indicating absence of saline intrusion.

Chloride concentration is within the WHO aesthetic limit (200 mg/L). The detected value of Phosphorus indicates low nutrient enrichment, avoiding eutrophication risks. The recorded ammonium level is slightly above the desirable range (<0.2 mg/L) but still acceptable for short-term exposure. Both Nitrite and Nitrate are within safe limits for aquaculture (NO_2 < 0.2 mg/L; NO_3 < 50 mg/L per WHO). Sulfate (SO_4) is very low and well below the WHO guideline (250 mg/L). This shows minimal mineral pollution or industrial intrusion.

All heavy metals detected (Fe = 0.61, Mn = 0.181, Zn = 0.332, Cu = 0.105, Cr = 0.082, Cd = 0.008, Pb = 0.011 mg/L) are within WHO permissible limits and below toxic thresholds for fish (WHO, 2017). Nickel, vanadium, and total hydrocarbons were not detected, further confirming the absence of industrial contamination. For Total Hardness, WHO does not impose a health-based limit, but hardness between 50–200 mg/L is considered ideal for aquaculture.

The Total Heterotrophic Bacterial Count (THBC) was 3×10^3 cfu/mL, indicating a moderate microbial load typical of healthy pond ecosystems. The Enterobacteria indicate mild organic pollution but not pathogenic levels (WHO, 2011).

4.2 Physico-Chemical and Microbial Analysis of Pond Water Sample B

Sample B represents the pond water that had remained in the fish pond for thirteen (13) days before discharge or turnover. Compared to Sample A (5-day water), this sample reflects more prolonged biological activity, feed accumulation, and waste decomposition, which typically influence the water's physical, chemical, and microbial composition. The lab results are interpreted below relative to WHO (2017) and FAO (2011) standards for water quality and aquaculture suitability.

Table 4.3: Lab Results for the Physico-Chemical Parameters

S/N	PARAMETERS	STANDARD UNITS	RESULTS
1	pH		7.41
2	EC	MS/cm	720
3	Sal.	g/l	0.320
4	Col.	Pt.co	2.0
5	Turbidity	NTU	0.8
6	TSS	mg/l	3.0
7	TDS	mg/l	350
8	COD	mg/l	40.0
9	HCO_3	mg/l	140.0
10	Na^+	mg/l	8.0
11	K+	mg/l	4.0
12	Ca^{2+}	mg/l	12.0

13	Mg^{2+}	mg/l	9.5
14	Cl^-	mg/l	130.0
15	P	mg/l	0.210
16	NH_4N	mg/l	0.593
17	NO_2	mg/l	0.120
18	NO_3	mg/l	0.425
19	SO_4	mg/l	0.200
20	Fe^{3+}	mg/l	0.100
21	Mn^{2+}	mg/l	0.233
22	Zn^{2+}	mg/l	0.496
23	Cu^{2+}	mg/l	0.150
24	Cr^{3+}	mg/l	0.098
25	Cd^{2+}	mg/l	0.020
26	Ni^{2+}	mg/l	Not detected
27	Pb^{2+}	mg/l	0.022
28	V	mg/l	Not detected
29	THC	mg/l	Not detected
30	Hardness		75.3

Table 4.4: Lab Results for the Microbial Parameters

S/N	PARAMETERS	STANDARD UNITS	RESULTS
1	Total Heterotropic Bacterial Counts	CFU/ML	1.2×10^4
2	Total Coliform Counts	CFU/ML	0×10^3
3	Total E.coli Counts	CFU/ML	0×10^3
4	Tentative isolates		Entero bacter sp. Bacillus sp.

The pH value of 7.41 lies within the recommended aquaculture range (6.5–9.0) (FAO, 2011). The slight increase in pH, compared to Sample A (6.8), indicates more carbon dioxide accumulation over the 13-day period.

The EC value 720 µS/cm signifies higher ionic concentration. This rise indicates the gradual accumulation of dissolved salts, ions, and metabolic by-products due to longer water retention. It remains within acceptable limits for aquaculture (200–1,500 µS/cm). A slight rise in salinity to 0.320 ppt further confirms ion build-up during the extended pond retention although still within acceptable limits.

The turbidity value (0.8 NTU) remains low and within WHO's ideal limit. This value implies slight organic matter accumulation, which is expected with longer retention. The color value 2.0 Pt-Co units indicate a slight increase in dissolved organic matter. An unpleasant smell/odour was detected.

The TSS value to 3.0 mg/L, still falls far below the 30 mg/L aquaculture limit (FAO, 2011). This minor increase as compared to sample A suggests mild sediment resuspension or waste accumulation.

The TDS concentration shows a moderate increase from 292 mg/L to 350 mg/L as compared to sample A, still comfortably below the WHO aesthetic limit of 1,000 mg/L. This rise mirrors the conductivity increase, representing progressive mineral and nutrient enrichment over time.

The COD value of 40 mg/L is slightly higher than Sample A (32 mg/L), reflecting increased organic load due to prolonged decomposition of feed residues, fecal matter, and plankton.

The bicarbonate concentration (HCO_3) 140 mg/L, indicate higher alkalinity and buffering capacity. The increase in Na and K concentrations corresponds with higher conductivity and is still within tolerable limits.

Chloride concentration increased slightly, yet it remains below the WHO aesthetic limit (200 mg/L). Phosphorus levels nearly doubled compared to Sample A (0.118 mg/L), indicating gradual nutrient enrichment which poses eutrophication risks. This increase of NH_4–N from 0.325 mg/L in Sample A to 0.593 mg/L signifies organic waste buildup and incomplete nitrification and approaches toxicity level. Both nitrogen species, NO_2 and NO_3 increased, reflecting active nitrification but also greater organic decomposition over the 13-day period. Sulfate levels remain very low and within WHO permissible levels (<250 mg/L).

The trace metal concentrations generally remain within WHO safe limits and far below aquaculture toxicity thresholds. The total hardness increased from 58.2 to 75.3 mg/L as compared to sample A, indicating moderate hardness.

The Total Heterotrophic Bacterial Count (THBC) rose from 3×10^3 cfu/mL to 1.2×10^4 cfu/mL, showing a significant increase in microbial activity due to extended organic matter retention. The increase suggests a nutrient-rich environment with higher bacterial turnover, though not yet pathogenic or harmful.

In general, Sample B shows moderate organic enrichment and slightly elevated nutrient and ion levels compared to Sample A, primarily due to longer retention (13 days). While most parameters remain within WHO and FAO acceptable ranges, the increases in COD, ammonia, nitrate, and microbial counts indicate that prolonged water retention reduces quality and oxygen balance.

4.3. Environmental risk/implication of discharge

a. Organic and Nutrient Enrichment: Sample B showed higher concentrations of ammonium, nitrate, phosphate, and COD (40 mg/L) than Sample A. If discharged untreated, these nutrients could lead to eutrophication of nearby rivers, streams, or wetlands. Eutrophication promotes excessive algal growth, depleting dissolved oxygen levels and disrupting aquatic ecosystems (FAO, 2006; Akinbile & Yusoff, 2011).

b. Heavy Metal Accumulation: Both samples contained trace metals such as iron, manganese, zinc, chromium, cadmium, and lead, all within WHO permissible limits for drinking water. However, repeated or large-scale discharge of such water into soil or natural watercourses can lead to bioaccumulation and heavy metal buildup in sediments (Ehiagbonare & Ogunrinde, 2010). Although Sample A poses minimal risk due to its low concentrations and short retention period, the higher metal levels in Sample B (Cd = 0.020 mg/L; Pb = 0.022 mg/L; Cr = 0.098 mg/L) could create cumulative toxicity if disposal is frequent or continuous.

c. Microbial Contamination: The Total Heterotrophic Bacterial Count (THBC) increased from 3×10^3 cfu/mL in Sample A to 1.2×10^4 cfu/mL in Sample B, reflecting greater microbial activity and organic matter decomposition. If such water is released untreated, it may cause microbial pollution of soil and surface water, increasing biochemical oxygen demand (BOD) and favoring the proliferation of pathogenic bacteria (WHO, 2011). While Bacillus species are largely beneficial, Enterobacteria can include opportunistic pathogens, posing public health risks in areas where the effluent reaches wells, hand-dug water sources, or vegetable farmlands (Ayeni et al., 2019). This highlights the need for pre-treatment or controlled reuse before disposal.

4.4. Determination of WQI using Arithmetic weightage index model

4.4.1. Sample A

S/N	**Parameter**	**Sn**	**Vn**	**1/Sn**	$\boldsymbol{Wn = \frac{k}{Sn}}$	$\boldsymbol{Qn = 100\,(\frac{Vn-Vi}{Sn-Vi})}$	**Qn x Wn**
1	pH	8.5	6.8	0.118	${}^{4.9}/_{8.5} = 0.576$	$100[\frac{6.8-7}{8.5-7}] = -13.33$	-7.678
2	Turbidity	30	0.6	0.033	${}^{4.9}/_{30} = 0.16$	$100[\frac{0.6-0}{30-0}] = 2$	0.32
3	TSS	200	1.8	0.005	${}^{4.9}/_{200} = 0.0245$	$100[\frac{1.8-0}{200-0}] = 0.9$	0.022
4	TDS	500	292	0.002	${}^{4.9}/_{500} = 0.0098$	$100[\frac{292-0}{500-0}] = 58.4$	0.572

5	Cl	50	101.5	0.02	$^{4.9}/_{50}$ $= 0.098$	100[$\frac{101.5-0}{50-0}$] = 203	19.894
6	COD	50	32	0.02	$^{4.9}/_{50}$ $= 0.098$	100[$\frac{32-0}{50-0}$] = 64	6.272
7	Hardness	180	58.2	0.006	$^{4.9}/_{180}$ $= 0.027$	100[$\frac{58.2-0}{180-0}$] = 32.33	0.873
$\sum$				0.204	0.9933		20.275

K = $\frac{1}{\sum^{1}/_{Sn}}$ = $\frac{1}{0.204}$ = 4.9

WQI = $\frac{\sum Qn\ x\ Wn}{\sum Wn}$ = $\frac{20.275}{0.9933}$ = 20.41.

Interpretation according to Arithmetic Weightage WQI Scale: EXCELLENT.

Possible usage recommendation/safe discharge procedure to mitigate environmental risk: Since the pond water is of excellent quality, it can be discharged directly to the environment without treatment. The pond water is also suitable for continued aquaculture use. It is also suitable for irrigation of sensible use. Brown et al. (1970); FAO (2011); WHO (2017).

4.4.2. Sample B.

S/N	Parameter	Sn	Vn	1/Sn	$Wn = \frac{k}{Sn}$	$Qn = 100\ (\frac{Vn-Vi}{Sn-Vi})$	Qn x Wn
1	pH	8.5	7.41	0.118	${}^{4.9}/_{8.5}$ $= 0.576$	100[$\frac{7.41-7}{8.5-7}$] = 27.33	15.742
2	Turbidity	30	0.8	0.033	${}^{4.9}/_{30}$ $= 0.16$	100[$\frac{0.8-0}{30-0}$] = 2.67	0.427
3	TSS	200	3.0	0.005	${}^{4.9}/_{200}$ $= 0.0245$	100[$\frac{3-0}{200-0}$] = 1.5	0.037
4	TDS	500	350	0.002	${}^{4.9}/_{500}$ $= 0.0098$	100[$\frac{350-0}{500-0}$] = 70	0.686
5	Cl	50	130	0.02	${}^{4.9}/_{50}$ $= 0.098$	100[$\frac{130-0}{50-0}$] = 260	25.48
6	COD	50	40	0.02	${}^{4.9}/_{50}$ $= 0.098$	100[$\frac{40-0}{50-0}$] = 80	7.840
7	Hardness	180	75.3	0.006	${}^{4.9}/_{180}$ $= 0.027$	100[$\frac{75.3-0}{180-0}$] = 41.83	1.129
$\sum$				0.204	0.9933		51.341

K = $\frac{1}{\sum {}^{1}/_{Sn}}$ = $\frac{1}{0.204}$ = 4.9

WQI = $\frac{\sum Qn\ x\ Wn}{\sum Wn} = \frac{51.341}{0.9933}$ = 51.69.

Interpretation according to Arithmetic Weightage WQI Scale: POOR WATER.

Possible usage recommendation/safe discharge procedure to mitigate environmental risk: since the water quality is poor, it should undergo and sedimentation to allow particles settle in order to reduce bacterial load, and disinfection using chlorine (chlorination) or UV light to kill bacteria, before discharged or reuse. After treatment, it is suitable for restricted irrigation. Ramakrishnaiah et al. (2009); FAO (2011)

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

This study assessed the water quality of a fish pond located within the Faculty of Agriculture, University of Benin, through detailed physicochemical and microbial analyses of two pond water samples—Sample A (5 days retention) and Sample B (13 days retention)—to evaluate their quality, potential environmental impact upon discharge, and possible reuse applications.

The laboratory results revealed that both pond water samples exhibited acceptable water quality, though Sample A demonstrated better quality than Sample B. From the results, we could see that If Sample B water were to be discharged directly into the natural environment without treatment, it could cause nutrient enrichment (eutrophication), oxygen depletion, and microbial contamination of nearby soil and water systems (FAO, 2011; WHO, 2017). In contrast, Sample A water, being less polluted, poses minimal environmental risk upon controlled discharge.

Also from the arithmetic weightage index model, we saw that Sample A water exhibited excellent water quality and could be discharged directly into the environment or be reuse for continued aquaculture or agricultural purposes or for irrigation. Sample B, on the other hand exhibited poor water quality and was concluded that the pond water can be safely reused after simple treatment processes such as settling, filtration, or aeration (Tyagi et al., 2013). Potential safe reuses include agricultural irrigation (for non-edible crops), or controlled aquaculture recycling. These options not only minimize environmental pollution but also support sustainable water resource management within the university and beyond (UNEP, 2019; Boyd and Tucker, 1998).

5.2 Recommendations

Based on the findings and conclusions of this research, the following recommendations are made:

a. Adoption of Water Quality Index (WQI): Aquaculture farms should employ the Water Quality Index (WQI) system using the Arithmetic Weightage Index Model to evaluate and grade their pond water periodically. This aids in quick decision-making on whether the water should be reused or discharged (Tyagi et al., 2013).

b. Effluent Treatment Before Discharge: Before releasing pond effluent into the environment, simple filtration, sedimentation, and aeration treatments should be applied to remove suspended solids and reduce organic load (Boyd and Tucker, 1998; WHO, 2017).

c. Reuse of Pond Effluent: Treated pond water can be reused for non-edible crop irrigation, minimizing freshwater consumption and promoting sustainable practices (FAO, 2011; Akinbile and Yusoff, 2011).

d. Environmental Awareness: The University of Benin and other tertiary institutions should promote awareness and training on sustainable aquaculture practices, water conservation, and effluent management among students and small-scale fish farmers (UNEP, 2019).

REFERENCES

Adefemi, S.O. & Awokunmi, E.E. (2011). 'The assessment of the water quality of River Oyun in Kwara State, Nigeria', Research Journal of Environmental Sciences, 5(1), pp. 1–7.

Adeosun, F.I., Yusuf, K.A. & Alade, O.A. (2021). 'Assessment of water quality and fish catch in Ikere Gorge, Nigeria', Nigerian Journal of Fisheries, 18(1), pp. 56–65.

Adewumi, A.A., Ayinla, O.A., & Ugwumba, A.A.A. (2020). 'Assessment of fish farm effluent impact on stream water quality', Journal of Environmental Protection, 11(4), pp. 389–399.

Akinbile, C.O. & Yusoff, M.S. (2011). ‘Environmental impact of fish pond effluent on water quality and soils in Ibadan, Nigeria’. Journal of Environmental Technology, 32(3), 285–294.

Akinrotimi, O.A., Abu, O.M.G., & Aranyo, A.A. (2010). 'Environmental friendly aquaculture key to sustainable fish farming development in Nigeria', Continental Journal of Fisheries and Aquatic Science, 4(2), pp. 17–31.

Akinrotimi, O.A., Uedeme-Naa, B., & Orokotan, O.O. (2010). Environmental implications of aquaculture practices in Nigeria. Journal of Agricultural and Environmental Ethics, 23(6), pp.561–570.

Akinsulire, O.R., Adegbite, M.A., & Dada, A.O. (2019). 'Evaluation of water quality for aquaculture viability in Eriwe fish farm', Journal of Aquatic Science and Engineering, 34(2), pp. 89–98.

American Public Health Association (APHA). (2017). ‘Standard Methods for the Examination of Water and Wastewater’. 23rd ed. Washington, D.C.: American Water Works Association and Water Environment Federation.

Ayeni, A.O., Ojo, M.O., & Agboola, T.O. (2019). 'Physicochemical properties of fish pond water in Ondo State', Nigerian Journal of Environmental Sciences, 13(3), pp. 132–140.

Ayeni, A.O., Fagbohunka, B.S. & Okoh, A.I. (2019). ‘Microbial pollution in surface waters: sources, risks and control’. African Journal of Environmental Science and Technology, 13(4), 145–156.

Ayers, R.S. & Westcot, D.W. (1985). Water Quality for Agriculture. FAO Irrigation and Drainage Paper No. 29. Rome: FAO.

Ayoola, S.O. (2002). Fish Pond Management and Aquaculture Practices in Nigeria. Ibadan: Agbo Areo Publishers.

Bitton, G. (2011). Wastewater Microbiology. 4th ed. Hoboken: Wiley.

Boyd, C.E. (1990). ‘Water Quality in Ponds for Aquaculture’. Auburn University, Alabama: Birmingham Publishing Company.

Boyd, C.E. & Tucker, C.S. (1998). 'Pond Aquaculture Water Quality Management', Boston: Springer.

Brown, R.M., McClelland, N.I., Deininger, R.A., & Tozer, R.G. (1970). 'A water quality index – do we dare?', Water and Sewage Works, 117(10), pp. 339–343.

Chapman, D. (ed) (1996). 'Water Quality Assessments: A Guide to the Use of Biota, Sediments and Water in Environmental Monitoring', 2nd ed. London: E&FN Spon.

Chatterjee, C. & Raziuddin, M. (2002). 'Determination of Water Quality Index of a degraded river in Asansol Industrial Area, India', Nature Environment and Pollution Technology, 1(2), pp. 181–189.

Edokpayi, J.N., Odiyo, J.O., Popoola, O.E., & Msagati, T.A.M. (2016). 'Assessment of groundwater quality in rural areas of Limpopo Province, South Africa', Environmental Earth Sciences, 75(1), pp. 1–14.

Ehiagbonare, J.E. & Ogunrinde, Y.M. (2010). 'Physico-chemical analysis of fish pond water in Okada, Edo State, Nigeria', African Journal of Biotechnology, 9(36), pp. 5922–5928.

Eze, V.C., Nwanguma, B.C., & Agba, M.I. (2021). 'Assessment of water quality in catfish farms in Anambra State', Journal of Aquatic Sciences, 36(1), pp. 33–41.

FAO. (2006). 'Environmental Impact Assessment and Monitoring in Aquaculture', FAO Fisheries Technical Paper No. 527, Rome: Food and Agriculture Organization.

Food and Agriculture Organization (FAO). (2006). ‘Aquaculture Development: Ecosystem Approach to Fisheries and Aquaculture’. FAO Technical Guidelines for Responsible Fisheries No. 5. Rome: FAO.

FAO. (2011). 'Water Quality for Agriculture', FAO Irrigation and Drainage Paper 29 Rev.1. Rome: Food and Agriculture Organization.

FAO (2021). National Aquaculture Sector Overview: Nigeria. Rome: Food and Agriculture Organization of the United Nations. Available at: http://www.fao.org/fishery / [Accessed 25 June 2025].

Ibeaja, C.A. & Ugorji, P.N. (2024). 'Comparative WQI assessment across water bodies in South-East Nigeria', Nigerian Journal of Environmental Management, 28(1), pp. 59–67.

Iyiola, A.O., Bello, Y.A., & Fagade, S.O. (2023). 'Water quality index and fish biodiversity in Owalla Reservoir', African Journal of Ecology, 61(2), pp. 159–169.

Kar, D., Sur, P., Mandal, S.K., Saha, T., & Kole, R.K. (2017). 'Assessment of water quality index in Loktak Lake, North-East India', Ecotoxicology and Environmental Safety, 59(2), pp. 241–248.

Kpikpi, W.M. & Bubu-Davies, J.E. (2021). 'Assessment of water quality index of artificial aquatic environments in Port Harcourt', International Journal of Environmental Studies, 78(6), pp. 965–975.

Mbachu, O.E. & Nwaogazie, I.L. (2023). 'Regression modeling of water quality index for rural ponds', Journal of Environmental Research and Review, 14(1), pp. 22–34.

Mbachu, O.E., Okoye, C.O., & Nwaogazie, I.L. (2023). 'Assessment of rural pond water quality index in Imo State, Nigeria', International Journal of Environment, Climate Change and Ecology, 12(4), pp. 113–122.

Murphy, A. (2001). 'Understanding globalism through a rural locale', in McGregor, T. (ed) Globalism, Localism and Identity. London: Earthscan, pp. 100–110.

Nagaraju, B., Sharma, S., & Kumar, V. (2023). 'Ammonia prediction and water quality modeling in aquaculture ponds using WQI', Journal of Water and Health, 21(2), pp. 150–162.

Njoku, O.E., Ekpo, K.E., & Eze, V.C. (2015). 'Physico-chemical and bacteriological analysis of Niger Delta fish ponds', Nigerian Journal of Microbiology, 29(1), pp. 3122–3132.

Odesiri-Eruteyan, E. & Urhibo, J.O. (2022). 'Bacteriological and physicochemical analysis of fish pond effluents in Warri, Nigeria', Journal of Aquatic Pollution and Toxicology, 10(2), pp. 88–97.

Ofojekwu, P.C., Onah, D.N., & Ezenwaji, N.E. (2016). 'Waste discharge from aquaculture and its environmental implications in Nigeria', Journal of Aquaculture Research, 48(3), pp. 345–352.

Ofojekwu, P.C., Ayotunde, E.O. & Ezeri, G.N.O. (2016). Effect of aquaculture effluent on water quality of the receiving stream in Nigeria. Journal of Fisheries and Aquatic Science, 11(1), pp.45–51.

Olatunji, M. T., & Aderibigbe, A. (2017). Water Quality Index Application in Borehole Water. Journal of Environmental ProtectionOrobator, A.N., et al., 2020. Water quality of Benin City aquaculture ponds.

Oyelude, E.O. & Ahenkorah, Y. (2012). Water quality assessment of fish ponds in the University of Cape Coast, Ghana. Journal of Applied Science and Environmental Management, 16(3), pp.275–280.

Perera, M., et al., 2023. WQI analysis in Kelani River, Sri Lanka.Ramakrishnaiah, C.R., Sadashivaiah, C. & Ranganna, G. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry, 6(2), pp.523–530.

Ramakrishnaiah, C.R., Sadashivaiah, C. & Ranganna, G. (2009). *Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India*. E-Journal of Chemistry, 6(2), 523–530.

Sagir, M., et al., 2023. Assessment of pond water quality in Bauchi State.

Sawyer, C.N., McCarty, P.L. & Parkin, G.F. (2003). Chemistry for Environmental Engineering and Science. 5th ed. New York: McGraw-Hill.

Spellman, F.R. (2014). Handbook of Water and Wastewater Treatment Plant Operations. 3rd ed. Boca Raton: CRC Press.

Tyagi, S., Sharma, B., Singh, P. & Dobhal, R. (2013). Water quality assessment in terms of water quality index. American Journal of Water Resources, 1(3), pp.34–38.

Ukpong, E. C., et al. (2013). WQI of Groundwater in Akwa Ibom. African Journal of Environmental Science.

Umeham, A. N. (2015). Health Risk of Domestic Use of Fish Pond Water. *African Journal of Health & Safety.

UNEP (2010). Clearing the Waters: A Focus on Water Quality Solutions. Nairobi: United Nations Environment Programme

United Nations Environment Programme (UNEP). (2019). Sustainable Water Management for Aquaculture and Agriculture. Nairobi: UNEP Publications.

USGS (2020). Water Quality Information. United States Geological Survey. Available at: http://www.usgs.gov/ [Accessed 25 June 2025].

WHO (2017). Guidelines for Drinking-water Quality. 4th ed. Geneva: World Health Organization.