MICROBIOLOGY ARCHIVES
Original Research Article | ISSN: 3041-590X
Journal homepage: https://microjournal.researchfloor.org/

# Bacteriological Quality of Fresh Fish from a Riverine Water Body in Rivers State, Nigeria

**Aleru-Obogai, Constancy Prisca*** and **Ollor, Ollor Amba**

*Department of Medical Microbiology, Faculty of Medical Laboratory Science, Rivers State University, Nigeria*

ARTICLE INFO

**Citation:** Aleru-Obogai, Constancy Prisca and Ollor, Ollor Amba (2026). Bacteriological Quality of Fresh Fish from a Riverine Water Body in Rivers State, Nigeria.
*Microbiology Archives, an International Journal.*
**DOI: https://doi.org/10.51470/MA.2026.8.1.60**

Received 06 November 2025
Revised 10 December 2025
Accepted 09 January 2026
Available Online February 07, 2026

Corresponding Author: **Aleru-Obogai, Constancy Prisca**
E-Mail: **constancy.aleru1@ust.edu.ng**



ABSTRACT

*Fish is a major source of protein worldwide, and many communities living in riverine areas depend heavily on fish and aquatic resources for their livelihood and nutrition. Fresh fish is easily digested and possesses high nutritional value; however, it is susceptible to contamination by bacterial pathogens such as Escherichia coli, Staphylococcus aureus, Vibrio species, Clostridium species, Salmonella species and others, which are associated with diseases like food poisoning, cholera, typhoid fever and urinary tract infections. These microorganisms are often present when water bodies become contaminated with faecal materials. Poor sanitary practices, therefore, pose a serious public health concern, as sewage discharge and other domestic pollutants introduced into water bodies may contaminate aquatic ecosystems with bacterial pathogens. In this investigation, bacterial pathogens including Staphylococcus aureus, Escherichia coli, Vibrio species, Salmonella species and Pseudomonas species were isolated from fresh fish samples collected from a riverine water body using Nutrient agar, MacConkey agar, Thiosulfate Citrate Bile Salt Sucrose agar (TCBS), Salmonella–Shigella agar and CHROMagar Orientation. The findings revealed a high level of faecal contamination in the fresh fish obtained from the riverine environment. The physicochemical parameters of the water analysed showed that the pH (6.22) was slightly lower than the World Health Organisation (WHO) recommended value, while turbidity (9.97 NTU) was considerably higher than the WHO standard. Furthermore, the heavy metals detected at notable concentrations were iron and magnesium. These findings indicate potential environmental contamination and associated public health risks in riverine aquatic environments. Therefore, improved sanitary practices should be encouraged, fresh fish should be properly processed before consumption, and sanitation facilities such as toilets should not be located close to water bodies in order to prevent contamination.*

***Keywords:*** *Fish, public health risks, sanitation, as Escherichia coli, pollutants and water bodies.*

## INTRODUCTION

Fish represents one of the most important sources of dietary protein worldwide and constitutes a significant proportion of the protein intake of many populations, particularly in riverine regions such as Rivers State, Nigeria. Rivers State is characterized by extensive networks of rivers, creeks and estuaries, which support fishing activities and provide an important source of food and livelihood for many communities. According to [23] water covers approximately 70% of the Earth's surface, and aquatic ecosystems play a critical role in global food production. Fresh fish, which is one of the cheapest and most readily available sources of animal protein in Africa, contributes about 17% of the global protein supply and remains a major component of human nutrition in many developing countries [1-2]. Fresh fish is highly valued because it is easily digested, rich in essential amino acids, and provides important micronutrients such as vitamins A, D and B-complex vitamins, as well as essential fatty acids that are beneficial to human health [3-9]. Despite these nutritional benefits, fresh fish is highly susceptible to contamination by a wide range of bacterial pathogens.

When fish is improperly handled, processed, stored or transported, it may become contaminated with microorganisms capable of causing disease in humans. Consequently, fresh fish may serve as a vehicle for the transmission of bacterial pathogens, resulting in foodborne illnesses such as diarrhoea, dysentery and other gastrointestinal infections [6-8, 17]. The risk of contamination is particularly high in aquatic environments where sanitation practices are inadequate and where water bodies are exposed to domestic, agricultural or industrial pollution.

Several bacterial pathogens are associated with fresh fish and may colonise different anatomical parts of the fish, including the gills, gut, skin and mouth. The bacterial microflora associated with fish varies depending on the aquatic environment, the level of pollution, and post-harvest handling practices. Some of these microorganisms are psychrophilic (cold-loving microorganisms), such as *Vibrio* species and *Pseudomonas* species, which are capable of surviving and multiplying at relatively low temperatures. Other bacteria are thermophilic (heat-loving microorganisms), such as *Clostridium* species, while mesophilic bacteria such as *Escherichia coli* are commonly

associated with faecal contamination of water bodies. Certain bacterial pathogens associated with fish can be transmitted to humans through direct contact during handling, particularly through cuts, abrasions or open wounds. Examples of such pathogens include *Mycobacterium marinum* and *Streptococcus iniae*, both of which have been reported to cause infections in individuals exposed to contaminated aquatic environments [9-12; 42]

The bacteriological quality of fresh fish refers to the presence, diversity and abundance of bacteria capable of causing foodborne diseases or fish poisoning when fish is consumed without adequate processing or cooking. Freshwater fish species such as *Oreochromis* species (tilapia), *Sardinella* species, *Mugilidae* species (mullet), and other edible fish may harbour bacterial agents that are potentially pathogenic to humans, particularly when the aquatic environment is polluted. Contamination of fish may occur at various stages, including during harvesting, handling, processing, transportation or storage. In many developing regions where hygienic handling practices are limited, the microbial quality of fish may be compromised, thereby posing significant public health concerns [8;18-21].

The occurrence of bacterial pathogens in fresh fish is often closely associated with pollution of aquatic environments. Human activities, including industrial, agricultural and domestic practices, may introduce various pollutants into rivers and other water bodies, thereby altering the ecological balance of aquatic systems and creating favourable conditions for the proliferation of pathogenic microorganisms [13]. Major water pollutants include sewage effluents, plastics, fertilisers, pesticides, herbicides and heavy metals such as lead (Pb), copper (Cu) and zinc (Zn). Other sources of contamination include toxic waste disposal, eroded sediments, household chemicals, groundwater contamination resulting from drilling activities, oil spills and combustion products [14-16;22-24]. These pollutants may adversely affect both aquatic organisms and human populations that rely on these water bodies for domestic and economic activities.

Fresh fish is widely consumed as food in many riverine communities, while river water is frequently used for domestic purposes such as cooking, drinking, washing and bathing [25-29]. The presence of bacterial pathogens resulting from faecal contamination, combined with the accumulation of toxic chemical pollutants in aquatic environments, may render both fish and water unsuitable for human consumption. Consequently, the safety and quality of both fresh fish and aquatic environments may be compromised, thereby posing considerable public health risks to communities that depend heavily on these natural resources [30-34]. This situation is particularly relevant in riverine communities where fishing constitutes a major economic activity and where sanitation infrastructure may be limited. In view of these concerns, there is a need to evaluate the microbiological quality of fresh fish obtained from riverine aquatic environments. Such investigations provide important information regarding the potential health risks associated with fish consumption and the environmental conditions of the water bodies from which the fish are harvested [35-39]. Therefore, the present study was conducted to investigate the bacteriological contents of fresh fish obtained from a riverine water body in Rivers State, Nigeria. Specifically, the study aimed to isolate and identify bacteria associated with fresh fish, determine the antimicrobial susceptibility patterns of the isolated bacteria, and evaluate selected physicochemical parameters and heavy metal concentrations in the water body to assess the environmental quality of the aquatic ecosystem and the potential public health implications of fish consumption from the riverine environment.

## MATERIALS AND METHODS

### Study Area

The study was conducted in a riverine water body located within the Niger Delta region of Rivers State, Nigeria, on the west coast of Africa. The area is characterized by extensive aquatic ecosystems that support fishing activities and serve as important sources of fish production and livelihood for surrounding communities. The riverine environment also provides favorable conditions for fish breeding and aquaculture activities. The geographical location of the study area lies approximately between latitude 4°28′ N and corresponding longitudinal coordinates within the coastal zone of southern Nigeria. A map showing the study area is presented in Figure 1.

### Location of Sampling Stations

Sampling stations were established at selected waterfront locations within the riverine environment to facilitate the collection of fish and water samples for bacteriological analysis. The sampling points were selected based on accessibility and fishing activities within the study area.

### Sample Collection

Fresh fish samples were obtained from the riverine water body. The species collected included *Tilapia rendalli*, mullet (*Mugilidae* species), sardine (*Sardinella* species), catfish (*Clarias* species), mudskipper (*Periophthalmus* species), and mackerel (*Scomber* species). A total of thirty-eight fresh fish samples were collected for analysis.

All samples were collected aseptically using sterile containers (coolers), and ice blocks were added to maintain the freshness of the samples during transportation to the laboratory. Sterile dissecting instruments were used to obtain samples from the mouth, gills and digestive tract of the fish for microbiological analysis. The collected tissue samples were transferred into sterile bottles containing physiological saline. In addition, water samples were collected from the riverine water body for physicochemical analysis and heavy metal estimation in order to determine possible faecal or industrial contamination.

### Materials Used

The materials used for the study included wire loops, Petri dishes, Bunsen burners, aluminum foil, autoclaves, gloves, flat-bottom flasks, measuring cylinders, sterile dissecting knives, sterile sample bottles, pipettes, test tubes, cotton wool, alcohol, normal saline, glass slides, refrigerators, masking tape, bijou bottles and microscopes.

### Preparation of Culture Media

The culture media used for bacterial isolation included MacConkey agar, Nutrient agar, Salmonella–Shigella agar (SSA), Thiosulphate Citrate Bile Salt Sucrose agar (TCBS) and CHROMagar Orientation. MacConkey agar was used for the isolation of *Escherichia coli*, while Nutrient agar was used for the growth of bacteria such as *Staphylococcus* species, *Clostridium* species, *Proteus* species and *Serratia* species. Salmonella–Shigella agar was used for the isolation of *Salmonella* and *Shigella* species, while TCBS agar was used for the isolation of *Vibrio* species.

CHRO Magar Orientation was used for the identification of bacteria, including *Escherichia coli*, *Enterococcus* species, *Klebsiella* species, *Proteus* species, *Pseudomonas* species and *Staphylococcus aureus*. All culture media were prepared according to the manufacturers' instructions and sterilised in an autoclave at 121 °C under a pressure of 15 kPa for 15 minutes [36].

**Sample Preparation**

Using sterile dissecting instruments, fish tissues, including the gills, digestive tract and mouth, were carefully removed. The samples were transferred into sterile bottles containing physiological saline and mixed thoroughly to obtain homogenised suspensions suitable for microbiological analysis.

**Inoculation of Culture Media**

Prepared culture media, including Nutrient agar, MacConkey agar, Salmonella–Shigella agar, TCBS agar and CHROMagar Orientation, were inoculated using the streak plate technique with a sterile wire loop. The inoculated plates were incubated at 37 °C for 24 hours before colony enumeration and isolation. This incubation temperature was selected to favour the growth of mesophilic bacteria, which include many pathogenic bacteria of medical importance [10].

**Enumeration of Bacterial Counts**

Bacterial colonies that developed on the culture plates after incubation were counted using the standard plate count method. Colony-forming units (CFU) were calculated by multiplying the number of colonies by the dilution factor.

CFU/ml = (Number of colonies × Dilution factor) / Volume of culture plated.

**Gram Staining**

Gram staining was carried out to differentiate Gram-positive bacteria from Gram-negative bacteria. The principle of Gram staining is based on differences in bacterial cell wall structure. Some bacteria retain the crystal violet primary stain after treatment with iodine, forming a crystal violet-iodine complex that resists decolourisation with alcohol. Gram-positive bacteria therefore retain the purple colour of the primary stain, whereas Gram-negative bacteria lose the primary stain during decolourisation and take up the counterstain (safranin), appearing pink when viewed under a microscope. The stained smears were examined under a light microscope using the ×100 oil immersion objective.

**Biochemical Tests**

Biochemical tests were carried out to identify and differentiate bacterial isolates based on their enzymatic activities and metabolic characteristics.

**Catalase Test**

The catalase test was used to detect the presence of the enzyme catalase, which breaks down hydrogen peroxide into water and oxygen. The appearance of bubbles following the addition of hydrogen peroxide indicated a positive reaction. This test was used to differentiate *Staphylococcus* species (catalase-positive) from *Streptococcus* species (catalase-negative).

**Coagulase Test**

The coagulase test was performed to identify *Staphylococcus aureus*. The enzyme coagulase converts fibrinogen in plasma into fibrin, resulting in clot formation. A portion of the test bacterium was emulsified in saline on a clean glass slide, after which a drop of human plasma was added. The presence of agglutination or clumping indicated a positive result.

**Indole Test**

The indole test was used to differentiate Gram-negative bacilli. Some bacteria can degrade the amino acid tryptophan to produce indole. The test bacterium was inoculated into tryptone broth and incubated overnight. After incubation, Kovac's reagent was added. The appearance of a red ring at the surface indicated a positive reaction. *Escherichia coli* is typically indole-positive due to the production of the enzyme tryptophanase.

**Antimicrobial Susceptibility Testing**

Antimicrobial susceptibility testing was carried out to determine the sensitivity of bacterial isolates to commonly used antibiotics. The test bacteria were first inoculated into peptone water and incubated for 24 hours. The bacterial suspension was then spread evenly over the surface of the nutrient agar plates using a sterile spreader. Antibiotic discs specific for Gram-positive and Gram-negative bacteria were placed on the inoculated agar using sterile forceps. The plates were incubated at 37 °C for 24 hours. Following incubation, zones of inhibition around the antibiotic discs were observed. The presence of a clear zone indicated susceptibility to the antibiotic, while the absence of a zone indicated resistance. The antibiotics tested included Septrin (SXT), Chloramphenicol (CH), Sparfloxacin (SP), Ciprofloxacin (CPX), Tarivid (OFX), Amoxicillin (AM), Augmentin (AU), Gentamicin (CN), Pefloxacin (PEF), Ampiclox (APX), Streptomycin (S), Zimacef (Z), Rocephin (R) and Erythromycin (E).

**Physicochemical Analysis and Heavy Metal Estimation**

Physicochemical parameters of the water samples were analysed using standard analytical techniques. Water samples were collected aseptically using sterile bottles, filtered into clean sterile containers and properly sealed to prevent contamination. The samples were transported immediately to the laboratory for analysis.

Parameters measured included pH, electrical conductivity, salinity, turbidity, nitrate concentration, total hardness, temperature, phosphate, sulphate, chloride, calcium content, magnesium content and total dissolved solids. Heavy metal analysis was also carried out to determine the concentrations of mercury (Hg), manganese (Mn), copper (Cu), zinc (Zn), lead (Pb), cadmium (Cd), chromium (Cr), iron (Fe), arsenic (As) and vanadium (V) in the water samples[22;30; 31].

**Methods for Physicochemical Analysis**

Turbidity, electrical conductivity, salinity, temperature and total dissolved solids were measured using an Extech multiparameter instrument by immersing the probe into the water sample and recording the displayed readings. Phosphate concentration was determined by adding 0.5 ml of ammonium molybdate and 0.2 ml of stannous chloride to 25 ml of the water sample, followed by spectrophotometric measurement at a wavelength of 690 nm. Nitrate concentration was determined using the brucine method, in which sulphuric acid and brucine reagent were added to the sample followed by heating in a boiling water bath and spectrophotometric measurement at 410 nm. Sulphate concentration was determined by adding

conditioning reagent and barium chloride crystals to the water sample, followed by measurement at 420 nm using a spectrophotometer. Chloride concentration was determined by titration using potassium chromate as an indicator and 0.01 N silver nitrate as the titrant. Total hardness was determined by titration with 0.01 N EDTA using ammonium buffer and Eriochrome Black indicator. Calcium concentration was determined using sodium hydroxide and murexide indicator with EDTA titration. Magnesium concentration was obtained by subtracting calcium hardness from total hardness.

## RESULTS

### The Physicochemical Parameters of the Water Body

The physicochemical characteristics of the water body were analyzed to determine its quality and environmental condition. Key parameters assessed included pH, turbidity, electrical conductivity, salinity, temperature, total dissolved solids, and concentrations of major ions such as phosphate, nitrate, sulphate, and chloride. Additional parameters such as total alkalinity, total hardness, and calcium content were also evaluated to provide a comprehensive understanding of the chemical composition of the water. The results of these physicochemical measurements are presented in Table 1.

*Table 1: The physicochemical parameters of the Water Body*

| Parameters | Level |
|---|---|
| pH | 6.22 |
| Turbidity NTU | 9.97 |
| Electrical Conductivity µs/cm | 31200 |
| Salinity (%) | 1.96 |
| Temperature $^0C$ | 29.4 |
| Total dissolved solids mg/l | 21840 |
| Phosphate($PO_4^{3-}$)mg/l | <0.05 |
| Nitrate (NO3) mg/l | 0.29 |
| Sulphate($SO_4^{2-}$)mg/l | 757.61 |
| Chloride (Cl)mg/l | 2223 |
| Total Alkalinity (mg/l) as CaCO3 | 14 |
| Total Hardness (mg/l) | 960 |
| Calcium Content (mg/l) | 307.2 |

### Concentrations of Selected Heavy Metals Detected in the Water Body

The concentrations of selected heavy metals in the water samples were analyzed to evaluate the level of metal contamination in the riverine water body. The metals assessed included mercury (Hg), arsenic (As), vanadium (V), iron (Fe), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu), and manganese (Mn). The results obtained from the analysis of the riverine water sample are presented in Table 2.

*Table 2: Concentrations of Selected Heavy Metals Detected in the Water Samples*

| Sample Identity | Hg (mg/l) | As (mg/l) | V (mg/l) | Fe (mg/l) | Cr (mg/l) | Cd (mg/l) | Pb (mg/l) | Zn (mg/l) | Cu (mg/l) | Mn (mg/l) |
|---|---|---|---|---|---|---|---|---|---|---|
| Study the Water Body | <0.001 | <0.001 | <0.001 | 0.996 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | 0.087 |

### Distribution and Enumeration of Bacterial Isolates Recovered from the Water Samples

The bacteriological analysis of the fishes revealed the presence of several bacterial species of public health importance. The isolates were identified and quantified based on the number of colonies and their corresponding colony-forming units (CFU/ml). The distribution and abundance of the bacterial isolates recovered from the fish are presented in Table 3.

*Table 3: Distribution and Enumeration of Bacterial Isolates Recovered from the Fishes*

| Isolated Bacteria | Number of Colonies | Colony Forming Unit(cfu/ml) |
|---|---|---|
| *Staphylococcus aureus* | 29 | $2.9 \times 10^3$ |
| *Vibrio cholera* | 25 | $2.5 \times 10^3$ |
| *Vibrio parahaemolyticus* | 20 | $2.0 \times 10^3$ |
| *Vibrio vulnificus* | 11 | $1.1 \times 10^3$ |
| *Pseudomonas species* | 15 | $1.5 \times 10^3$ |
| *Escherichia coli* | 21 | $2.1 \times 10^3$ |
| *Klebsiella species* | 20 | $2.0 \times 10^3$ |
| *Salmonella species* | 22 | $2.2 \times 10^3$ |
| *Shigella species* | 12 | $1.2 \times 10^3$ |
| *Enterococcus faecalis* | 27 | $2.7 \times 10^3$ |
| *Proteus species* | 8 | $8.0 \times 10^2$ |
| *Serretia species* | 5 | $5.0 \times 10^2$ |
| *Clostridium species* | 18 | $1.8 \times 10^3$ |
| Total Number of Count | 233 | |

### Antibiotic Susceptibility Pattern of Bacterial Isolates from the Fishes

The antibiotic susceptibility patterns of the bacterial isolates recovered from the fishes were determined using selected commonly used antimicrobial agents. The isolates were tested against different antibiotics to evaluate their resistance and susceptibility profiles. The results of the antimicrobial sensitivity testing of the bacterial isolates are presented in Table 4.

*Table 4: Antibiotic Susceptibility Pattern of Bacterial Isolates from the Fishes*

| S/N | Microorganism | E | CH | SXT | OFX | SP | CPX | AM | PEF | APX | S | Z | R | CN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | *Staphylococcus* | R | R | R | R | R | R | R | R | R | | R | R | R |
| 2 | *E.coli* | R | R | R | ++ | R | +1+ | R | ++ | R | R | R | R | +1+ |
| 3 | *Pseudomonas* | R | R | R | +1+ | R | +1+ | R | +1+ | R | R | R | R | +1+ |
| 4 | *Klebsiella* | R | .R | R | R | R | +1+ | R | ++ | R | R | R | R | ++ |
| 5 | *Salmonella* | R | R | R | + | R | ++ | R | +1+ | R | R | R | R | R |
| 6 | *Shigella* | R | R | R | +1+ | R | +1+ | R | H+ | R | R | R | P | +1+ |
| 7 | *Vibrio* | R | R | R | R | R | + | R | R | R | R | R | R | + |
| 8 | *Proteus* | R | R | R | R | R | R | R | R | R | R | R | R | ++ |
| 9 | *Enterococcus* | R | + | R | +1+ | +1+ | R | R | R | R | R | R | R | ++ |

***Key:***

*R=Resistance*
*+=Susceptible*
*Septrin(SXT)*
*Chloramphenicol (CH)*
*Spartoxacin (SP)*
*Ciprofloxacin (CPX)*
*Tarivid (OFX)*
*Amoxacillin (AM)*
*Augmentin (AU)*
*Gentamycin (CN)*
*Perfloxacin (PEF)*
*Ampiclox (APX)*
*Streptomycin (S)*
*Zimacef(Z)*
*Rocephin(R)*
*Erythromycin(E).*

## DISCUSSION

The bacteriological analysis of fresh fish samples obtained from the riverine water body revealed the presence of several bacterial pathogens of public health importance, including *Staphylococcus aureus*, *Escherichia coli*, *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Klebsiella* species, *Proteus* species, *Enterococcus faecalis*, *Salmonella* species, *Shigella* species, *Serratia* species, *Vibrio vulnificus* and *Clostridium* species. The occurrence of these microorganisms suggests that the riverine aquatic environment from which the fish were harvested may be subject to microbial contamination, particularly from sewage and other anthropogenic sources. The presence of such bacteria in fish samples indicates that the aquatic ecosystem may be impacted by faecal pollution, which could compromise the microbiological quality of fish intended for human consumption. In many riverine communities, water bodies serve multiple domestic and economic purposes, including fishing, drinking, cooking, washing and bathing. Such activities increase the likelihood of microbial contamination, particularly where sanitation infrastructure is limited and where human waste disposal practices may allow sewage to enter aquatic environments. Consequently, faecal materials may be washed into water bodies through runoff or sewage discharge, thereby introducing pathogenic microorganisms into the aquatic ecosystem. The isolation of bacteria such as *Escherichia coli* and *Enterococcus faecalis* in the present study is particularly significant, as these bacteria are widely recognised indicators of faecal contamination in water and aquatic food sources [39].

The detection of *Staphylococcus aureus* in fresh fish samples further suggests possible contamination arising from human handling or environmental exposure. *Staphylococcus aureus* is a common component of the normal flora of the human skin, nose and throat, and its presence in food products often reflects contamination during processing or handling [32]. Similarly, the isolation of *Vibrio* species from fish samples may be associated with the natural microflora of aquatic environments; however, the presence of pathogenic species such as *Vibrio cholerae* and *Vibrio parahaemolyticus* raises concerns regarding potential risks of foodborne infections, particularly where fish are inadequately cooked before consumption [8].

Previous studies have reported similar findings regarding the microbial contamination of fish harvested from aquatic environments. For instance, [23] isolated *Staphylococcus aureus*, *Escherichia coli* and *Lactobacillus plantarum* from frozen mackerel samples obtained in Nsukka, Nigeria. In the present study, *Staphylococcus aureus* and *Escherichia coli* were also isolated from fresh fish samples collected from the riverine environment, although *Lactobacillus plantarum* was not detected. Furthermore, [41-42] reported the isolation of *Escherichia coli*, *Pseudomonas aeruginosa*, *Shigella dysenteriae*, *Staphylococcus aureus*, *Vibrio cholerae*, *Enterococcus faecalis* and *Salmonella typhi* from edible fish obtained from Fletcher Dam in Zimbabwe. The presence of similar bacterial species in the present investigation suggests that microbial contamination of fish in aquatic environments is a widespread issue that may have important implications for food safety and public health. Comparable findings were also reported by [39] who isolated *Salmonella typhi*, *Shigella* species, *Escherichia coli*, *Streptococcus faecalis*, *Vibrio cholerae* and *Clostridium perfringens* from fish samples collected from aquatic environments. The similarity between these findings and those observed in the present study reinforces the notion that aquatic ecosystems may serve as reservoirs of pathogenic microorganisms capable of contaminating fish and other aquatic organisms.

Interestingly, the present investigation also revealed the presence of *Serratia* species and *Proteus* species, bacteria that were not reported in some previous studies of fish-associated microflora. Their presence may further indicate environmental pollution resulting from human activities and sewage contamination.

The detection of these pathogenic microorganisms suggests potential health risks to individuals who consume fresh fish harvested from contaminated aquatic environments, particularly when fish are consumed raw or inadequately cooked. Many of the bacterial species isolated in this study are known to cause foodborne illnesses, including gastroenteritis, typhoid fever, cholera and other gastrointestinal infections. Individuals who are immunocompromised or suffering from underlying health conditions may be particularly susceptible to such infections. *Pseudomonas* species identified in the samples are recognised opportunistic pathogens that may cause infections in individuals with weakened immune systems [42]. The presence of these microorganisms also suggests that the microbial load of fish may depend largely on the quality of the aquatic environment rather than on the size or weight of the fish itself. Environmental contamination resulting from sewage discharge, agricultural runoff or other anthropogenic activities may significantly influence the microbial composition of aquatic ecosystems and the organisms inhabiting them.

Antimicrobial susceptibility testing revealed varying resistance patterns among the bacterial isolates. *Staphylococcus aureus* demonstrated resistance to several antibiotics, including chloramphenicol, septrin, erythromycin, pefloxacin, gentamicin, ampiclox, zimacef, amoxicillin, rocephin and ciprofloxacin. Similarly, *Vibrio* species exhibited resistance to chloramphenicol, sparfloxacin, pefloxacin, tarivid, septrin, streptomycin, augmentin and amoxicillin. *Proteus* species also demonstrated resistance to several antimicrobial agents including ciprofloxacin, sparfloxacin, chloramphenicol, pefloxacin, tarivid, streptomycin, septrin, amoxicillin and augmentin. However, some isolates showed susceptibility to selected antibiotics such as chloramphenicol, gentamicin, ciprofloxacin and augmentin. These findings indicate the potential presence of antimicrobial resistance among bacteria associated with fish in aquatic environments, which may complicate the treatment of infections resulting from contaminated food sources. The physicochemical characteristics of the water body also provide important information regarding the environmental quality of the aquatic ecosystem. The pH value of 6.22 recorded in this study was slightly lower than the recommended range of 6.5–8.5 established by the Federal Environmental Protection Agency (FEPA) for water quality [34]. Variations in pH may influence the survival and proliferation of microorganisms in aquatic environments. Similarly, the recorded water temperature of 29.4 °C may favour the growth of many mesophilic bacterial pathogens commonly associated with aquatic environments [31].

The turbidity value of 9.97 NTU recorded in the present study was considerably higher than the World Health Organisation (WHO) recommended value of 1.0 NTU for potable water. Elevated turbidity levels often indicate the presence of suspended particles, organic matter or microbial contamination within the water body. Increased turbidity may also promote microbial growth by providing nutrients and surfaces for bacterial attachment.

Although the nitrate concentration recorded in this study (0.29 mg/L) was below the WHO permissible limit of 10 mg/L, the sulphate concentration exceeded the recommended limit of 500 mg/L, indicating possible environmental pollution. Additionally, total dissolved solids and hardness values recorded in the study were relatively high compared with recommended standards.

Heavy metal analysis revealed that iron (Fe) and manganese (Mn) were present at concentrations of 0.996 mg/L and 0.087 mg/L, respectively. According to WHO guidelines for drinking water quality, the permissible concentration for iron is 1.0 mg/L, while manganese should not exceed 0.05 mg/L. Although the iron concentration recorded in this study fell within acceptable limits, the manganese concentration slightly exceeded the recommended value. Heavy metals present in aquatic environments may originate from geological sources, mining activities, industrial discharges or other anthropogenic activities. These metals may accumulate in aquatic organisms, including fish, through bioaccumulation processes and may subsequently pose health risks to humans consuming contaminated fish [43], the findings of the present study highlight the potential microbiological and environmental risks associated with fish harvested from contaminated aquatic environments. The presence of pathogenic bacteria, antimicrobial resistance patterns and elevated physicochemical parameters underscores the importance of monitoring the microbial quality of fish and aquatic environments in order to safeguard public health.

## CONCLUSION

The findings of the present investigation demonstrate that a diverse range of bacterial pathogens are associated with fresh fish obtained from a riverine water body. A total of twelve microorganisms were isolated from the fish samples using various culture media, particularly selective media designed for the recovery of pathogenic bacteria. The presence of these microorganisms indicates a relatively high microbial load in the fish samples and suggests possible contamination of the aquatic environment. Such contamination is often associated with faecal pollution and other anthropogenic activities that introduce microbial pathogens into water bodies. The results further suggest that fresh fish harvested from riverine aquatic environments may serve as reservoirs of human pathogens when the surrounding water body is exposed to environmental pollution. In many riverine communities, water bodies are frequently used for several domestic activities, including drinking, cooking, washing and bathing. Where sanitation facilities are inadequate or poorly located, sewage or other waste materials may be discharged into nearby water bodies, thereby increasing the risk of microbial contamination of aquatic organisms. Such practices may compromise the microbiological quality of fish and other aquatic food sources harvested from these environments.

The isolation of pathogenic bacteria such as *Salmonella* species, *Vibrio* species and other opportunistic pathogens highlights the potential public health risks associated with the consumption of fish from contaminated aquatic environments. These microorganisms are known to be responsible for several foodborne illnesses, including gastroenteritis, typhoid fever and cholera. Consequently, individuals who consume fish that is improperly handled, inadequately processed or insufficiently cooked may be at increased risk of infection, the findings of this study indicate that the riverine water body investigated may be impacted by domestic and sewage-related pollution, which in turn affects the microbiological quality of fresh fish inhabiting the aquatic environment. The presence of bacterial pathogens in the fish samples therefore suggests that fish obtained from such environments may pose potential health risks if appropriate hygienic handling, processing and cooking practices are not strictly followed. These results underscore the importance of monitoring the microbial quality of aquatic environments and fish products in order to safeguard public health and ensure the safety of fish consumed by communities living in riverine regions.

## RECOMMENDATIONS

Based on the findings of this investigation, several measures are recommended to minimise microbial contamination of fresh fish and improve the sanitary conditions of riverine aquatic environments. Public health education should be prioritised in communities that depend on riverine water bodies for fishing and other domestic activities. Community members should be sensitised to the potential health risks associated with poor sanitation practices around water bodies, particularly the disposal of human waste and other pollutants into aquatic environments. Increased awareness of these risks will encourage behavioural changes that can help reduce environmental contamination and improve food safety.

Good sanitary practices should also be promoted among individuals involved in fishing, fish processing and fish handling. Hygienic handling of fish during harvesting, transportation and preparation is essential in order to minimise contamination with pathogenic microorganisms. Public health authorities and local environmental agencies should therefore implement programmes that encourage proper hygiene and environmental management in riverine communities, it is advisable that certain parts of the fish that are more likely to harbour bacterial pathogens, such as the gills and digestive tract, should be removed and discarded before consumption. These organs are frequently exposed to environmental contaminants and may contain higher concentrations of microorganisms due to their direct contact with the surrounding aquatic environment. Proper processing and preparation of fish before consumption is also essential for reducing the microbial load associated with fresh fish. Fish intended for consumption should be thoroughly washed with clean water, properly scaled, and carefully eviscerated in hygienic conditions. In addition, adequate cooking should always be ensured, as proper heat treatment can effectively destroy many pathogenic microorganisms present in fish tissues. Adopting these processing practices will significantly reduce the risk of foodborne infections associated with contaminated fish.

Environmental sanitation around riverine water bodies should also be improved. Sanitary facilities such as toilets should not be constructed directly over or close to water bodies, as this increases the likelihood of faecal contamination through sewage discharge or surface runoff. Activities such as open defecation in or near water bodies should be strongly discouraged. Appropriate waste management systems should be established to prevent the introduction of human waste and other pollutants into aquatic ecosystems, regular monitoring of the microbiological and physicochemical quality of riverine water bodies is recommended. Such monitoring will enable early detection of environmental contamination and provide useful information for the development of effective environmental management strategies.

Strengthening regulatory frameworks and enforcing environmental protection policies will also play an important role in safeguarding aquatic ecosystems and ensuring the safety of fish consumed by communities that depend on riverine resources.

## REFERENCES


1. Ahmed, M. K., Islam, S., Rahman, S., Haque, M. R., & Islam, M. M. (2010). Heavy metals in water, sediment and some fishes of the Buriganga River, Bangladesh. *International Journal of Environmental Research*, 4(2), 321–332.
2. Akoto, O., Bruce, T. N., & Darka, G. (2008). Heavy metal pollution profiles in streams serving the Owabi Reservoir. *African Journal of Environmental Science*, 2(11), 354–359.
3. Alikunhi, N. M., Batang, Z. B., Aljahdali, H. A., Aziz, M. A. M., & Al-Suwaitem, A. M. (2016). Culture-dependent bacteria in commercial fishes: qualitative assessment and molecular identification using 16S rRNA gene sequencing. *Saudi Journal of Biological Sciences*, 23, 1–12.
4. American Public Health Association (1992). *Standard Methods for the Examination of Water and Wastewater*. Washington DC: APHA.
5. Apu, K., Yusof, A. M., & Jugang, K. (1999). Distribution of bacteria in tropical freshwater fish and ponds. *International Journal of Environmental Health Research*, 9, 285–292.
6. Ashford, R. V., Sargeant, P. D., & Lum, G. D. (1998). Septic arthritis of the knee caused by *Edwardsiella tarda* after a catfish puncture wound. *Medical Journal of Australia*, 168, 443–444.
7. Association of Reproductive Health Professionals (2004). Fish consumption to promote good health and minimise contaminants: A quick reference guide for clinicians.
8. Austin, B. (2006). The bacterial microflora of fish. *The Scientific World Journal*, 6, 931–945.
9. Baffone, W., Pianetti, A., Bruscolini, F., Barbieri, E., & Citterio, B. (2000). Occurrence and expression of virulence-related properties of *Vibrio* species isolated from widely consumed seafood products. *International Journal of Food Microbiology*, 54, 9–18.
10. Baker, F. J., & Silverton, R. E. (1985). *Introduction to Medical Laboratory Technology*. Toronto: Butterworths.
11. Bayles, D. O., Annous, B. A., & Wilkinson, B. J. (1996). Cold stress proteins induced in *Listeria monocytogenes* in response to temperature down-shock and growth at low temperatures. *Applied and Environmental Microbiology*, 62, 1116–1119.
12. Benson, A. S. (1990). *Control of Communicable Diseases in Man*. Washington DC: American Public Health Association.
13. Cahill, M. M. (1990). Bacterial flora of fishes. *Journal of Microbial Ecology*, 19(1), 21–41.
14. Censi, P., Spoto, S. E., Siano, F., Sprovieri, M., & Mazzola, S. (2006). Heavy metals in coastal water systems: A case study from the north-western Gulf of Thailand. *Chemosphere*, 64, 1167–1176.
15. Chattopadhyay, P. (2000). Fish catching and handling. In: *Encyclopedia of Food Microbiology*. London: Academic Press.
16. Cheesbrough, M. (2002). *District Laboratory Practice in Tropical Countries (Part II)*. Cambridge: Cambridge University Press.
17. Claucas, I. J., & Ward, A. R. (1996). *Post-Harvest Fisheries Development: A Guide to Handling, Preservation, Processing and Quality*. Chatham Maritime, United Kingdom.
18. Colwell, R. R. (1996). Global climate and infectious disease: The cholera paradigm. *Science*, 20, 2025–2031.
19. Cordos, E., Rautiu, R., Roman, C., et al. (2003). Characterisation of the river system in a mining and industrial area of Baia Mare, Romania. *European Journal of Mineral Processing and Environmental Protection*, 3(3), 324–335.
20. Daniels, N. A., Mackinnon, L., Bishop, R., et al. (2000). *Vibrio parahaemolyticus* infections. *Journal of Infectious Diseases*, 181, 1661–1666.
21. Dhawan, A., & Kaur, S. (2002). Pig dung as pond manure: Effects on water quality, pond productivity and growth of carps in polyculture systems.
22. Ekhaise, F. O., & Omoigberale, M. O. (2011). Bacteriological and physicochemical qualities of Ebutte River in Edo State, Nigeria. *Journal of Applied Sciences and Environmental Management*, 15(4), 663–673.
23. Eze, E. I., Echezona, B. C., & Uzodinma, E. C. (2011). Isolation and identification of pathogenic bacteria associated with frozen mackerel fish (*Scomber scombrus*) in a humid tropical environment. *African Journal of Agricultural Research*, 6(8), 1947–1951.
24. Food and Drug Administration (2004). What you need to know about mercury in fish and shellfish.
25. Gbamaniji, S. P. T. (1998). Pollution. *Journal of Environmental Education Series*, 2, 43.
26. Ghaly, A. E., Dave, D., Budge, S., & Brooks, M. S. (2010). Fish spoilage mechanisms and preservation techniques: Review. *American Journal of Applied Sciences*, 7(7), 859–877.
27. Hansen, G. H., & Olafsen, J. A. (1999). Bacterial interactions in early life stages of marine cold-water fish. *Microbial Ecology*, 38, 1–26.
28. Harth, M., Ralph, E. D., & Faraawi, R. (1994). Septic arthritis due to *Mycobacterium marinum*. *Journal of Rheumatology*, 21, 957–960.
29. Horsfall, M., & Spiff, A. I. (2001). *Principles of Environmental Pollution*. Port Harcourt: Metroprints.
30. Ideriah, T. J. K., David-Omiema, S., & Ogbonna, D. N. (2012). Distribution of heavy metals in water and sediment along Abonnema shoreline, Nigeria. *Resources and Environment*, 2(1), 33–40.
31. Iroha, I. R., Okonta, M., Ele, G., et al. (2016). Bacteriological and physicochemical parameters of selected borehole water sources in Abakaliki metropolis, Nigeria. *International Journal of Community Medicine and Public Health*, 3(11), 3271–3277.
32. Jay, J. M., Loessner, M. J., & Golden, D. A. (2005). *Modern Food Microbiology*. New York: Springer.
33. Kam, K. M., Leung, T. H., Ho, Y. Y., et al. (1995). Outbreak of *Vibrio cholerae* in Hong Kong related to contaminated fish tank water. *Public Health*, 109, 389–395.
34. Kern, W., Vanek, E., & Jungbluth, H. (1989). Fish breeder granuloma: Infection caused by *Mycobacterium marinum*. *Medizinische Klinik*, 84, 578–583.
35. Matthews-Amune, O. C., & Kakulu, S. (2012). Physicochemical parameters and heavy metals in River Pompom, Nigeria. *International Research Journal of Biotechnology*, 3(8), 134–140.
36. Merlino, J., & Alonso, K. (1996). CHROMagar orientation: A chromogenic detection medium. *Journal of Clinical Microbiology*, 34, 1788–1798.
37. Novotny, L., Dvorska, L., Lorencova, A., Beran, V., & Pavlik, I. (2004). Fish: A potential source of bacterial pathogens for humans. *Veterinary Medicine*, 49(9), 343–358.
38. Ochei, J., & Kolhatkar, A. (2000). *Medical Laboratory Science: Theory and Practice*. New Delhi: Tata McGraw-Hill.
39. Olugbojo, J. A., & Ayoola, S. O. (2015). Comparative studies of bacterial load in fish species of commercial importance. *International Journal of Fisheries and Aquaculture*, 7(4), 37–46.
40. Owa, F. W. (2014). Water pollution: Sources, effects, control and management. *International Letters of Natural Sciences*, 3, 1–6.
41. Petrinollah, R. S., Robert, K. G., John, V. M., & Ngoni, S. (2013). Isolation and identification of pathogenic bacteria in edible fish. *International Journal of Science and Research*, 2(9), 269–273.
42. Ryan, K. J., & Ray, C. G. (2004). *Sherris Medical Microbiology*. New York: McGraw-Hill.
43. Wemedo, S. A., & Wachukwu, C. K. (2004). Occurrence of *Vibrio* species in the gut of *Sardinella madrensis*. *Journal of Medical Laboratory Science*, 13(2), 62–66.