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Bacteriological Quality and Public Health Implications of Selected Edible Seafood from a Coastal River in Rivers State, Nigeria

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Abstract

Seafood constitutes an important component of the human diet and includes a variety of aquatic invertebrates, such as molluscs, crustaceans and echinoderms. Common examples include crab, prawn, oyster, periwinkle, clams and other shellfish species. Although seafood contributes significantly to nutritional intake, its consumption is not entirely risk-free, as contaminated seafood has been implicated in a considerable proportion of food-borne illnesses worldwide. This study investigated the bacteriological quality of selected edible seafood obtained from coastal waters in Rivers State, Nigeria, and evaluated associated physicochemical and heavy metal parameters of the surrounding aquatic environment. Bacteriological analysis revealed the presence of several potential pathogenic microorganisms commonly associated with seafood contamination. These included Staphylococcus aureus, Salmonella spp., Shigella spp., Proteus spp., Serratia spp., Vibrio spp., Clostridium spp., Escherichia coli, Enterococcus spp., and Clostridium botulinum. These bacteria are known to cause a range of food-borne infections and intoxications, each characterised by distinct epidemiological patterns and clinical manifestations. Antimicrobial susceptibility testing further demonstrated varying levels of susceptibility of the isolated bacteria to commonly used antimicrobial agents. In addition to the microbiological assessment, several physicochemical parameters of the water environment were analysed, including pH, electrical conductivity, turbidity, salinity, temperature, total dissolved solids, phosphate, nitrate, sulphate, chloride, total alkalinity, total hardness and calcium. The concentrations of selected heavy metals such as mercury (Hg), arsenic (As), vanadium (V), iron (Fe), chromium (Cr), cadmium (Cd), lead (Pb), zinc (Zn), copper (Cu) and manganese (Mn) were also determined. The results indicated that some parameters, particularly iron and manganese, exceeded the recommended limits for safe water bodies as stipulated by the World Health Organisation (WHO), suggesting environmental pollution of the aquatic ecosystem. The findings highlight the potential public health risks associated with the consumption of contaminated seafood and emphasise the importance of continuous monitoring of seafood quality and aquatic environments. Effective control measures, improved environmental management and proper handling and processing of seafood are essential to minimise the risk of seafood-associated infections and ensure food safety.

Keywords: Seafood contamination; Bacteriological quality; Food-borne pathogens; Antimicrobial susceptibility; Physicochemical parameters; Heavy metal pollution

Introduction

Seafood is a broad culinary and fisheries term used to describe edible aquatic organisms, particularly exoskeleton-bearing invertebrates that inhabit marine and freshwater environments. These organisms include several species of molluscs, crustaceans and echinoderms. Common seafood varieties consumed worldwide include oysters, clams, mussels, prawns, crabs, lobsters, periwinkles and other shellfish species. Most seafood is harvested from marine and coastal environments, although some species are obtained from freshwater sources such as rivers, lakes and estuaries (Daniels et al., 2004). Owing to their high nutritional value, seafood products constitute an important component of human diets in many parts of the world, particularly in coastal regions where they serve as a major source of protein and essential micronutrients.

Seafood is widely recognised as a nutrient-rich food source that provides high-quality protein, essential fatty acids, vitamins and minerals that are beneficial to human health. Consumption of seafood has been associated with several health benefits, including improved neurological development during gestation and early childhood, as well as a reduced risk of cardiovascular diseases due to the presence of omega-3 fatty acids (Daniels et al., 2004). In many developing countries, seafood also contributes significantly to food security and economic livelihoods, particularly among communities that rely on fishing and seafood trading as major sources of income.

Despite its nutritional advantages, seafood consumption is not entirely without risk. Seafood harvested from contaminated aquatic environments may contain pathogenic microorganisms, chemical pollutants and environmental toxins that pose potential public health hazards. Aquatic environments are often exposed to various sources of pollution, including domestic sewage, agricultural runoff, industrial effluents and other anthropogenic activities that introduce harmful contaminants into water bodies. Consequently, seafood harvested from such environments may serve as vehicles for the transmission of infectious agents and toxic substances to humans (Ayers et al., 2006).

Seafood-associated infections are commonly caused by a variety of microorganisms including bacteria, viruses and parasites. These pathogens may cause a wide spectrum of illnesses ranging from mild gastroenteritis to severe systemic infections and life-threatening conditions. Bacterial pathogens frequently associated with seafood contamination include species of *Vibrio*, *Salmonella*, *Shigella*, *Escherichia coli*, *Staphylococcus aureus* and *Clostridium* (Tranter, 1990; Desenclos et al., 1991). Outbreaks of seafood-borne illnesses have been reported in different parts of the world and are often linked to the consumption of contaminated or improperly handled seafood products. In addition to microbial contamination, seafood may also accumulate chemical contaminants such as heavy metals and marine toxins that originate from polluted aquatic environments (Martha et al., 2010).

Certain types of seafood are inherently more susceptible to contamination than others. For example, bivalve molluscs such as oysters, clams and mussels feed by filtering large volumes of surrounding water in order to obtain nutrients. During this filtration process, they can accumulate and concentrate microorganisms, including pathogenic bacteria and viruses that are present in their aquatic environment. Consequently, these organisms may harbour high concentrations of pathogens, particularly when harvested from polluted waters (Ayers et al., 2006). Similarly, crustaceans such as shrimp, crabs and lobsters may become contaminated through contact with polluted sediments, seawater or contaminated food sources.

Environmental contamination of aquatic ecosystems remains one of the most important factors influencing seafood safety (Summers & Rose, 2002). Pollution of water bodies through sewage discharge, agricultural runoff, industrial waste and urban activities can introduce a wide range of contaminants into aquatic environments. In particular, the discharge of untreated or poorly treated sewage into coastal and riverine environments can lead to contamination of seafood harvesting areas with human pathogens. Previous studies have reported outbreaks of seafood-associated illnesses linked to polluted waters contaminated with pathogens such as norovirus (calicivirus), hepatitis A virus and *Salmonella enterica* serotype Typhi (Desenclos et al., 1991).

In addition to environmental contamination, seafood may also become contaminated during post-harvest handling, processing, transportation and storage. Improper hygienic practices during seafood handling can introduce additional microbial contaminants. Contributing factors may include inadequate refrigeration, exposure to contaminated surfaces, cross-contamination during food preparation and handling by infected food handlers. Although adequate cooking can destroy most pathogenic microorganisms, seafood is frequently consumed raw or lightly cooked in many cultures, thereby increasing the risk of infection when contaminated seafood products are consumed (Martha et al., 2010).

Furthermore, aquatic environments may contain various physicochemical and heavy metal contaminants that may accumulate in seafood organisms. Heavy metals such as mercury, cadmium, lead and arsenic are of particular concern due to their persistence in the environment and potential toxicity to humans. Continuous monitoring of these contaminants in aquatic environments is therefore essential in order to assess environmental pollution levels and evaluate potential risks to public health.

Given the potential public health risks associated with contaminated seafood, it is essential to evaluate the microbiological quality of seafood harvested from aquatic environments. Such investigations provide important information on the types of bacteria associated with seafood and the potential health risks they pose to consumers. In addition, assessing the susceptibility of isolated bacteria to commonly used antimicrobial agents is necessary in order to understand their resistance patterns and implications for treatment of seafood-associated infections. It is also important to examine the physicochemical characteristics of aquatic environments and determine the presence of heavy metals that may contribute to environmental contamination and bioaccumulation in seafood organisms.

Therefore, this study *was conducted* to investigate the bacteriological quality of selected fresh seafood obtained from a coastal aquatic environment in Rivers State, Nigeria. The study also *evaluated* the antimicrobial susceptibility profiles of the isolated bacterial species, *analysed* selected physicochemical parameters of the aquatic environment and *determined* the presence and concentrations of selected heavy metals in the water body.

Materials and Methods

Study Area and Sample Collection

This study was conducted in a coastal community located in Rivers State, Nigeria. Fresh seafood samples were obtained from a coastal aquatic environment within the study area. Different varieties of seafood commonly consumed in the region were collected from multiple sampling points within the aquatic environment to ensure representative sampling.

All seafood samples were collected aseptically using sterile containers placed in insulated coolers containing ice packs to maintain low temperature during transportation to the laboratory. The samples were transported immediately for microbiological analysis. Using sterile dissecting instruments, portions of the seafood tissues, including the mouth and intestinal contents, were aseptically removed and transferred into sterile sample bottles containing sterile physiological saline for microbiological examination.

In addition to seafood samples, water samples were collected from the aquatic environment for the determination of physicochemical characteristics and the assessment of possible faecal and environmental contamination.

Culture Media Preparation

The culture media used for the isolation of bacterial organisms included Nutrient Agar, MacConkey Agar, Salmonella–Shigella Agar (SSA) and Thiosulphate Citrate Bile Salt Sucrose (TCBS) Agar. All media were prepared according to the manufacturer's instructions. The prepared media were sterilised and poured aseptically into sterile Petri dishes before use.

Sample Processing of Fresh Seafood

Using sterile dissecting instruments, samples from the mouth and intestinal regions of the seafood specimens were collected and placed in sterile bottles containing sterile physiological saline. The samples were homogenised and subsequently inoculated onto the prepared culture media for bacterial isolation.

Materials and Reagents

The materials used in this study included sterile knives, sterile bottles, swab sticks, Petri dishes, glass slides, microscopes, sterile wire loops, measuring cylinders and conical flasks. Additional materials included cotton wool, foil paper, peptone water, immersion oil, alcohol, masking tape and hand gloves.

The reagents used included Nutrient Agar, MacConkey Agar, Salmonella–Shigella Agar, Thiosulphate Citrate Bile Salt Sucrose Agar, sodium thiosulphate, Gram staining reagents, physiological saline and other laboratory chemicals required for microbial culture and identification.

Isolation of Bacteria

The swab technique was employed for the inoculation of seafood samples onto the culture media. Sterile swab sticks were used to streak the prepared Nutrient Agar, MacConkey Agar, Salmonella–Shigella Agar and TCBS agar plates. The inoculated culture plates were incubated **at** 37°C for 24 hours**,** after which bacterial colonies were observed and enumerated. The incubation temperature was selected because most pathogenic bacteria of medical importance are mesophilic organisms that grow optimally at this temperature (Baker and Silverton, 1983).

Distinct colonies were sub-cultured to obtain pure isolates, which were subsequently subjected to microscopic and biochemical identification procedures.

Gram Staining

Principle

Gram staining is a differential staining technique used to classify bacteria into Gram-positive and Gram-negative groups based on the structural differences in their cell walls. Gram-positive bacteria retain the primary stain (crystal violet) after treatment with iodine and alcohol due to the thick peptidoglycan layer in their cell wall. In contrast, Gram-negative bacteria lose the primary stain during decolourisation and subsequently take up the counterstain (safranin or neutral red), appearing pink or red under the microscope.

Procedure

A clean, grease-free glass slide was labelled appropriately. A small portion of a bacterial colony was picked using a sterile wire loop and smeared onto the slide. The smear was air-dried and heat-fixed by passing the slide briefly through a flame.

The smear was flooded with crystal violet for one minute and rinsed gently with water. Lugol's iodine was then applied as a mordant and allowed to act for one minute. The smear was subsequently decolourised using an acetone–alcohol solution for approximately 10–15 seconds. After decolourisation, the slide was counterstained with safranin for one minute and rinsed with water. The back of the slide was cleaned using cotton wool, and the slide was allowed to air dry. The stained smear was then examined under a microscope using the oil immersion objective (×100).

Biochemical Identification Tests

Several biochemical tests were performed to aid in the identification of bacterial isolates.

Catalase Test

The catalase test was carried out to differentiate catalase-positive organisms, such as *Staphylococcus* species, from catalase-negative organisms, such as *Streptococcus* species. The test is based on the ability of the enzyme catalase to break down hydrogen peroxide into water and oxygen.

Hydrogen peroxide (3%) was used as the reagent. A small portion of the bacterial colony was emulsified in distilled water on a clean glass slide. One to two drops of hydrogen peroxide were added to the suspension. The immediate production of gas bubbles indicated a positive catalase reaction (Ochei and Kolhatkar, 2000).

Coagulase Test

The coagulase test was performed to differentiate Staphylococcus aureus from other coagulase-negative Staphylococcus species. The enzyme coagulase causes plasma to clot by converting fibrinogen to fibrin.

Two drops of saline were placed on a clean glass slide. A colony of the organism was emulsified in each drop to form a thick suspension. A sterile wire loop was used to transfer a small amount of undiluted plasma into one of the bacterial suspensions and mixed gently. The appearance of visible clumping within 5–10 seconds indicated a positive coagulase reaction. The second suspension without plasma served as the negative control (Ochei and Kolhatkar, 2000).

Indole Test

The indole test was used to determine the ability of bacteria to break down the amino acid tryptophan to produce indole.

The test organism was inoculated into peptone water and incubated overnight. After incubation, a few drops of Kovac's reagent were added to the culture. The formation of a red ring on the surface of the medium indicated a positive indole reaction (Ochei and Kolhatkar, 2000).

Antimicrobial Susceptibility Testing

Antimicrobial susceptibility testing was carried out using the disc diffusion method in order to determine the sensitivity of the bacterial isolates to selected antimicrobial agents. Antimicrobial agents are chemical compounds used in the treatment of infectious diseases and may be derived from natural sources or synthesised in the laboratory.

In this study, commercially prepared antibiotic discs containing commonly used antimicrobial agents such as ampicillin, amoxicillin, cloxacillin, augmentin, tetracycline and chloramphenicol were used.

Disc Diffusion Method

The disc diffusion technique was performed according to standard microbiological procedures. A sterile swab was used to inoculate the test organism onto the surface of sensitivity test agar plates. Antibiotic-impregnated discs were then placed on the inoculated agar surface. During incubation, the antimicrobial agents diffused into the surrounding agar medium, creating a gradient of antibiotic concentration around each disc. After incubation, zones of inhibition appeared around discs where bacterial growth was inhibited. The diameter of the inhibition zone was measured and used to determine the susceptibility of the organism to the respective antimicrobial agent (Ochei and Kolhatkar, 2000).

Results

Physicochemical Properties of Water from the Study Environment

Table 1 presents the physicochemical characteristics of the water sample obtained from the study environment and compares them with the recommended limits of the World Health Organisation (WHO). Some parameters were found to fall within acceptable limits, while others exceeded the recommended standards. These results provide important information on the quality of the aquatic environment from which the seafood samples were obtained.

Table 1: Physicochemical Properties of Water from the Study Environment

S/N	Physicochemical Parameters	Sample value	WHO value
1.	Ph	6.22	6.5-8.5
2.	Electrical' conductivity µS/cm	31.200	-
3.	Turbidity, NTU	9.97	1.0
4.	Salinity %	1.96	-
5.	Temperature	29.4	6.0
6.	Total dissolved solids mg/l	21840	500
7.	Phosphate(PO43)mg/1	<0.05	-5
8.	Nitrate (NO3)mg/1	0.29	1.0
9.	Sulphate (SO42)mg/1	751.61	500
10	Chloride (Cl)mg/1	222.3	250
11	Total Alkalinity mg/l as CaCO3	14	-
12	Total hardness	960	200

13	Calcium, content mg/1	307.2	-
14	Magnesium mg/l	46.84	-

Concentrations of Selected Heavy Metals in Water from the Study Environment

Table 2 presents the concentrations of selected heavy metals detected in the water sample from the study environment and compares them with the permissible limits recommended by the World Health Organisation (WHO). Most of the heavy metals analysed were either not detected or present at very low concentrations, while iron and manganese were detected at measurable levels. The comparison with WHO standards indicates the level of heavy metal contamination in the aquatic environment.

Table 2: Concentrations of Selected Heavy Metals in Water from the Study Environment

S/N	Sample identity	Hg(mg/l)	As(mg/l)	1(mg/l)	Fe (mg/l)	Cr (mg/l)	Cd (mg/l)	Pb (mg/l)	Zn (mg/l)	Cu (mg/l)	Mn (mg/l)
1	Water Sample from Study Area	<0.001	<0.001	<0.001	0.996	<0.001	<0.001	<0.001	<0.001	<0.001	0.87
2	WHO	0.1	0.005-0.1	0.01	0.03	0.05	0.2-1.8	1.7	3.0	2-4	0.2

Bacterial Isolates and Colony Counts from Seafood Samples Obtained from the Study Area

Table 3 shows the bacterial isolates recovered from the analysed seafood samples together with their respective colony counts and colony-forming units (CFU). Several bacterial species of public health importance were identified, including Salmonella spp, Shigella spp., Vibrio, Staphylococcus aureus and Escherichia coli. The results indicate the presence of diverse bacterial contaminants in the seafood samples obtained from the study area.

Table 3: Bacterial Isolates and Colony Counts from Seafood Samples Obtained from the Study Area

Bacteria	Count	CFU
Salmonella spp.	31	1.5×10^3
Shigella spp.	29	1.4×10^3
Vibrio cholerae	20	1.0×10^2
Vibrio vulnificus	7	5.0×10^3
Vibrio parahaemolyticus	15	7.5×10^3
Serratia spp.	13	6.5×10^2
Klebsiella spp.	17	8.5×10^2
Staphylococcus aureus	21	1.0×10^3
Escherichia coli	25	1.3×10^3
Proteus spp.	6	3.0×10^2
Pseudomonas aeruginosa	6	3.0×10^2
Enterococcus spp.	7	3.5×10^2

Antimicrobial Susceptibility Patterns of Bacterial Isolates from Seafood Samples Obtained from the Study Area

The results show varying levels of resistance and susceptibility of the isolates to the antimicrobial agents tested. Several bacterial species demonstrated resistance to multiple antimicrobial drugs, while others showed varying degrees of susceptibility. These findings provide important information on the potential antimicrobial resistance patterns of bacteria associated with seafood from the study environment and highlight possible implications for public health and treatment of seafood-associated infections. The results show varying levels of resistance and susceptibility of the isolates to the antimicrobial agents tested. Several bacterial species demonstrated resistance to multiple antimicrobial drugs, while others showed varying degrees of susceptibility. These findings provide important information on the potential antimicrobial resistance patterns of bacteria associated with seafood from the study environment and highlight possible implications for public health and treatment of seafood-associated infections.

Table 4: Antimicrobial Susceptibility Patterns of Bacterial Isolates from Seafood Samples Obtained from the Study Area

		Antimicrobial drugs												
S/N	Bacteria	E	CA	SXT	OFX	SP	CPC	AM	PEF	APX	S	Z	R	CN
1	Staphylococcus aureus	R	R	R	R	R	R	R	R	R	H	R	R	R
2.	Escherichia coli	R	R	R	++	R	+++	R	++	R	R	R	R	++
3	Pseudomonas	R	R	R	++	R	+++	R	+++	R	R	R	R	+++
4.	Klebsiella	R	R	R	+++	R	+++	R	++	R	R	R	R	++
5.	Salmonella	R	R	R	++	R	+++	R	++	R	R	R	R	R
6.	Shigella	R	R	R	+++	+	++	R	++	R	R	R	R	+++
7.	Vibrio species	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	+++	+++	R	R	R	R	R	R	R	+++

Key

R - Resistance; + - Sensitive

Discussion

Seafood represents an important component of the human diet and is widely consumed due to its high nutritional value and economic importance, particularly in coastal regions. However, seafood harvested from contaminated aquatic environments may serve as a vehicle for the transmission of pathogenic microorganisms and environmental contaminants to humans. The findings of the present study demonstrate the presence of several bacterial species associated with seafood obtained from the study environment, highlighting potential public health concerns related to seafood consumption.

The bacteriological analysis revealed the presence of several bacterial pathogens, including Staphylococcus aureus, Klebsiella *spp.,* Salmonella *spp.,* Shigella *spp.,* Vibrio *species*, Proteus *spp.,* Enterococcus spp., *Serratia* spp. and Escherichia coli. These organisms are widely recognised as important food-borne pathogens capable of causing a variety of gastrointestinal and systemic infections in humans. The detection of these organisms in seafood samples suggests possible contamination of the aquatic environment from which the seafood was harvested. Similar bacterial species have been reported in seafood and aquatic environments in previous studies, indicating that seafood can act as a reservoir for pathogenic microorganisms when harvested from polluted water bodies (Martha et al., 2010; Huss et al., 2000).

The occurrence of organisms such as *Escherichia coli*, *Salmonella* spp. and *Shigella* spp. is particularly significant because these bacteria are commonly associated with faecal contamination. Their presence in seafood samples may therefore indicate contamination of the aquatic environment by human or animal waste. Sources of such contamination may include discharge of untreated sewage, agricultural runoff, domestic waste disposal and other anthropogenic activities that introduce faecal materials into aquatic ecosystems. The presence of *Enterococcus* spp., which are also commonly used as indicators of faecal pollution in water, further supports the possibility of faecal contamination of the study environment (Cabelli, 1983; WHO, 2017).

The detection of *Vibrio* species such as *Vibrio cholerae*, *Vibrio vulnificus* and Vibrio parahaemolyticus in the seafood samples is also noteworthy. Species of the genus *Vibrio* are naturally occurring bacteria in marine and estuarine environments and are frequently associated with seafood-borne infections. These organisms are known to cause a range of illnesses in humans, including gastroenteritis, wound infections and septicaemia, particularly when contaminated seafood is consumed raw or undercooked (Oliver, 2005). The presence of these organisms in seafood samples therefore represents a potential risk to consumers if adequate food safety practices are not observed.

The antimicrobial susceptibility results obtained in this study revealed varying levels of resistance and susceptibility among the bacterial isolates. Several isolates demonstrated resistance to multiple antimicrobial agents, while others showed varying degrees of sensitivity. The occurrence of antimicrobial resistance among bacteria isolated from seafood is an issue of growing global concern. The presence of resistant bacteria in aquatic environments may be linked to the indiscriminate use of antimicrobial agents in human medicine, veterinary practice and aquaculture, as well as the discharge of antimicrobial residues into aquatic ecosystems. Such environmental exposure may promote the development and spread of antimicrobial-resistant bacteria within aquatic microbial communities (Cabello et al., 2013). Consequently, seafood contaminated with resistant bacteria may contribute to the dissemination of antimicrobial resistance to humans.

The physicochemical analysis of the water sample from the study environment revealed variations in several parameters when compared with the recommended limits established by the World Health Organization (WHO). The pH value of the water was slightly below the recommended range, indicating mildly acidic conditions. In addition, turbidity levels exceeded the WHO recommended limit, suggesting the presence of suspended particles or organic matter within the water. Elevated turbidity may be associated with microbial growth and organic pollution in aquatic environments (WHO, 2017).

A notably high level of total dissolved solids (TDS) was recorded in the water sample, which may indicate the presence of dissolved inorganic salts, organic matter or other pollutants in the aquatic environment. Similarly, sulphate concentration and total hardness were found to exceed recommended limits. High concentrations of these parameters may be influenced by environmental factors such as industrial discharge, mineral dissolution, agricultural runoff and other anthropogenic activities affecting the aquatic ecosystem. Such conditions may create favourable environments for microbial proliferation and may influence the microbial composition of the water body.

The heavy metal analysis revealed that most of the analysed metals were either absent or present at extremely low concentrations in the water sample. However, iron and manganese were detected at measurable levels that exceeded the recommended WHO guideline values. Elevated concentrations of these metals in aquatic environments may result from both natural geological processes and anthropogenic activities such as industrial discharge, petroleum exploration, mining operations and urban runoff (Tchounwou et al., 2012). Although iron and manganese are essential trace elements, excessive concentrations in water bodies may affect water quality and contribute to environmental pollution.

The presence of elevated physicochemical parameters and detectable levels of certain heavy metals in the aquatic environment may influence the growth and survival of microorganisms. Environmental conditions such as nutrient availability, pH, temperature and dissolved substances can significantly affect microbial activity and diversity in aquatic ecosystems. Consequently, changes in these environmental parameters may facilitate the proliferation of pathogenic microorganisms capable of contaminating seafood harvested from such environments (Huss et al., 2000).

Overall, the findings of this study demonstrate that seafood obtained from the study environment harbours a variety of bacterial species, including several organisms of public health importance. The presence of faecal indicator organisms, potential food-borne pathogens and detectable environmental contaminants highlights the need for improved monitoring of aquatic environments used for seafood harvesting. In addition, proper handling, processing and adequate cooking of seafood are essential measures to minimise the risk of seafood-associated infections among consumers.

Continuous environmental surveillance, improved waste management practices and effective public health interventions are therefore necessary to reduce microbial and chemical contamination of aquatic ecosystems. Such measures will contribute to improved seafood safety and help protect public health in communities that depend on seafood as a major source of nutrition.

Conclusion

The findings of this study demonstrate that seafood obtained from the study environment is associated with a diverse range of bacterial species, including several organisms of public health importance. The bacterial isolates identified in the seafood samples included Staphylococcus aureus, Klebsiella *spp.*, Salmonella *spp.*, Shigella *spp.*, Vibrio *species*, Proteus *spp.*, Enterococcus *spp.*, Serratia *spp. and* Escherichia coli. The occurrence of these microorganisms suggests possible contamination of the aquatic environment from which the seafood was harvested.

The presence of faecal indicator organisms such as Escherichia coli *and* Enterococcus spp. indicates that the aquatic environment may be exposed to faecal contamination, most likely resulting from anthropogenic activities such as sewage discharge, agricultural runoff and domestic waste disposal. Such contamination can significantly compromise the microbiological quality of seafood and increase the risk of food-borne infections among consumers.

The antimicrobial susceptibility results further revealed varying levels of resistance among the bacterial isolates to the antimicrobial agents tested. The occurrence of antimicrobial-resistant bacteria in seafood is of considerable public health concern, as these organisms may contribute to the spread of antimicrobial resistance through the food chain. This highlights the importance of continuous monitoring of antimicrobial resistance patterns in bacteria associated with aquatic environments and seafood products.

In addition to the microbiological findings, the physicochemical analysis of the water sample indicated that some parameters exceeded the recommended limits established by the World Health Organization (WHO). Elevated levels of turbidity, total dissolved solids, sulphate and total hardness suggest possible environmental pollution of the aquatic ecosystem. The heavy metal analysis also revealed detectable concentrations of iron and manganese above the recommended guideline values, further indicating potential environmental contamination of the water body.

Overall, the results of this study suggest that seafood harvested from the study environment may serve as a potential vehicle for the transmission of pathogenic microorganisms to humans if proper handling and preparation practices are not observed. These findings emphasise the need for effective environmental monitoring, improved sanitation practices and strict adherence to food safety measures in order to minimise the risk of seafood-associated infections.

Recommendations

Based on the findings of this study, the following recommendations are proposed:

1. Regular Monitoring of Aquatic Environments Continuous microbiological and physicochemical monitoring of aquatic environments used for seafood harvesting should be carried out in order to detect contamination early and prevent potential public health risks.
2. Improved Waste Management Practices Government agencies and environmental regulatory bodies should implement stricter measures to control the discharge of untreated sewage, industrial effluents and other pollutants into aquatic environments.
3. Public Health Education Communities involved in seafood harvesting, processing and marketing should be educated on proper hygiene practices and safe handling procedures in order to reduce microbial contamination of seafood.
4. Proper Cooking of Seafood Consumers should be encouraged to cook seafood thoroughly before consumption, as adequate cooking can significantly reduce the risk of infection from pathogenic microorganisms.
5. Antimicrobial Resistance Surveillance Routine surveillance of antimicrobial resistance among bacteria isolated from seafood and aquatic environments should be encouraged in order to monitor emerging resistance patterns.
6. Further Research Additional studies should be conducted to investigate seasonal variations in microbial contamination of seafood, as well as the potential bioaccumulation of environmental contaminants in different seafood species.

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