



A Review on Impact of Water Pollution on Freshwater Fish Species and their Aquatic Environment

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ABSTRACT

Water pollution is a pressing global environmental issue with far-reaching consequences for freshwater ecosystem. This review paper examines the multifaceted impact of water pollution on freshwater fish species and their aquatic environments. We explore the various sources and types of pollutants, their effects on fish populations, and the broader consequences for aquatic biodiversity and ecosystem health. Additionally, we discuss mitigation strategies, regulatory measures & future research directions to address this critical challenge.

KEY WORDS

Water Pollution, Aquatic Environment, Freshwater Ecosystem.

INTRODUCTION

Water pollution is that pervasive and urgent global environmental concern that arises from the introduction of harmful or undesirable substances into bodies of water, including rivers, lakes, oceans and ground water. Water pollution originates from various sources, including industrial discharges, agricultural runoff, sewage and waste water, mining activities and urban storm water. Each source introduces a unique set of pollutants into aquatic environments.

Generally, the fish species are one of the most important aquatic communities concerning humans. The pollution generally denotes any unwanted alteration in the natural quality of any ecosystem brought around by the changes in their physical, chemical, as well as in biological factors (Subhendu, 2000). Freshwater fish represent a remarkable diversity of species, shapes, sizes and behaviours. They include well-known groups like salmon, trout, bass, catfish and

carp, as well as countless lesser-known species. They are vital source of protein for millions of people worldwide. They provide essential nutrition and livelihoods through subsistence and commercial fishing. Freshwater ecosystems and the fish they support have cultural significance for many communities. Fisheries, both commercial & recreational, generate substantial economic benefits. The health of freshwater ecosystem and fish population serves as a crucial indicator of broader environmental conditions. Decline in fish species or poor water quality can signal problems such as pollution, habitat degradation or climate change impacts.

The pollutants released from different types of industrial discharge and sewage not only pollute the surface water of rivers and reservoirs but also infiltrate into ground and also pollute the groundwater resources. Aquatic ecosystems are exposed to pollution loads is associated with the increase in urbanization and population growth (Edokpayi and Nkwoji, 2000; Nkwoji et al., 2010). These pollutants cause major threats to aquatic ecosystems, alter hydrology, physicochemical and faunal characteristics (Nkwoji et al., 2010). In contemporary times, developing nations face a critical set of challenges primarily centered around the mismanagement of vast volumes of waste materials generated through numerous human activities. One of the most formidable issues within this realm is the improper disposal of these pollutants into the surrounding natural environment. These activities, in particular, have a severe impact on water bodies, especially freshwater ecosystems such as rivers and reservoirs. As a result, these essential natural resources become compromised and unsuitable for both primary and secondary uses. Consequently the primary focus of this review article is to evaluate the repercussions of water pollution on the well-being of fish populations and their habitats.

Sources of Water Pollution

Water pollution arises from various sources, both natural and human- induced, that introduce contaminants into aquatic environments. Understanding these sources is crucial for effective pollution control and environmental protection. Here are the primary sources of water pollution:

1. Point Source Pollution

- **Industrial Discharges:** Factories and manufacturing facilities discharge pollutants directly into water bodies. These pollutants can include heavy metals, chemicals, and toxic substances.
- **Municipal Wastewater:** Municipal sewage treatment plants release treated or untreated sewage into rivers and streams, potentially carrying pathogens and nutrients.
- **Mining Activities:** Mining operations generate acidic runoff and introduce heavy metals and sediments into nearby waterways.
- **Power Plants:** Power plants, especially coal-fired ones, release thermal pollution and may discharge pollutants into water during cooling processes.
- **Chemical Plants:** Chemical manufacturing facilities can discharge a wide range of chemicals and hazardous materials into water bodies.

2. Non-Point Source Pollution

- **Agricultural Runoff:** Pesticides, herbicides, fertilizers, and animal waste from agricultural activities can wash into water bodies, contributing to nutrient pollution and chemical contamination.
- **Urban Runoff:** Stormwater runoff from urban areas carries pollutants like oil, heavy metals, trash, and chemicals from roads, parking lots, and industrial sites.
- **Construction Sites:** Soil erosion from construction sites can lead to sediment pollution, as well as the transport of construction-related chemicals into nearby water bodies.
- **Septic Systems:** Failing or poorly maintained septic systems can release pathogens, nutrients, and contaminants into groundwater and surface water.

3. Atmospheric Deposition

Airborne pollutants, including pollutants from industries and transportation, can settle into water bodies through rainfall and deposition. This process contributes to nutrient enrichment and chemical contamination.

4. Natural Sources

- **Volcanic Eruptions:** Volcanic activity can release ash, minerals, and gases into water bodies, affecting water quality.
- **Erosion:** Natural erosion processes can introduce sediments and natural pollutants into water, especially in areas with fragile ecosystems.
- **Microbial Activity:** Natural microbial decomposition processes can lead to the release of organic matter and nutrients into water bodies.

5. Inadequate Waste Disposal

- **Improper Solid Waste Disposal:** Illegal dumping of solid waste, including plastics, can contaminate water bodies and disrupt aquatic ecosystems.
- **Improper Hazardous Waste Disposal:** Incorrect disposal of hazardous materials, such as chemicals and electronic waste, can result in contamination of groundwater and surface water.

6. Ship and Boat Operations

- **Ballast Water:** Ballast water from ships can introduce invasive species and pathogens into new environments.
- **Oil Spills:** Accidental oil spills from vessels can lead to severe oil pollution in oceans and coastal areas.

7. Climate Change

Climate change can exacerbate water pollution by altering precipitation patterns and increasing the frequency and severity of extreme weather events, which can lead to the runoff of pollutants from various sources.

Types of Water Pollutants

Water pollutants encompass a wide range of substances that, when introduced into aquatic environments, can degrade water quality and harm aquatic ecosystems. These pollutants can originate from various sources, both natural and human-induced.

1. Nutrients

- **Nitrogen:** Excess nitrogen from sources like agricultural runoff and wastewater can lead to nutrient pollution. It promotes excessive algal growth, which depletes oxygen in water, causing “dead zones” harmful to aquatic life.
- **Phosphorus:** Phosphorus, often from agricultural runoff and detergents, contributes to eutrophication, causing algal blooms and oxygen depletion in aquatic ecosystems.

2. Sediments

Soil erosion from construction sites, agriculture, deforestation, and urban runoff can introduce sediments into water bodies. Sedimentation can cloud water, smother aquatic habitats, and hinder sunlight penetration, affecting plant and animal life.

3. Pathogens

Bacteria, viruses, and parasites from human and animal waste can contaminate water, causing waterborne diseases. Inadequate sewage treatment and failing septic systems are common sources of pathogenic pollution.

4. Heavy Metals

Mercury, lead, cadmium, and arsenic are examples of heavy metals that can enter water bodies through industrial discharges, mining, and atmospheric deposition. These metals can accumulate in aquatic organisms, posing health risks to both wildlife and humans.

5. Toxic Chemicals

Industrial and agricultural chemicals, such as pesticides, herbicides, and synthetic compounds, can leach into water bodies, affecting aquatic life. Some chemicals, like polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs), are persistent and highly toxic.

6. Oil and Petroleum Products

Oil spills from transportation accidents and industrial activities can coat water surfaces, harming aquatic organisms and fouling habitats. The toxicity of oil and its long-lasting effects make it a severe pollutant.

7. Thermal Pollution

Discharge of heated water from power plants and industrial processes can raise water temperatures, affecting aquatic ecosystems. Elevated temperatures can reduce dissolved oxygen levels and stress aquatic organisms, particularly cold-water species.

8. Acid Rain

Sulphur dioxide (SO₂) and nitrogen oxides (NO_x) emissions from industrial activities and transportation can react with atmospheric moisture, leading to acid rain. Acidic precipitation can lower the pH of water bodies, harming aquatic life, especially sensitive species like trout.

9. Plastics and Microplastics

Plastics, including single-use plastics and microplastics (tiny plastic particles), can enter water bodies through littering and runoff. They pose threats to aquatic organisms through ingestion, entanglement, and the release of harmful chemicals.

10. Radioactive Substances

Radioactive pollutants, such as uranium and radium, can enter water bodies from natural sources or nuclear accidents. They may accumulate in aquatic organisms and pose long-term health risks.

11. Emerging Contaminants

This category includes pharmaceuticals, personal care products, and endocrine-disrupting compounds, which can enter water systems through wastewater discharge and agricultural runoff. Their impact on aquatic ecosystems and human health is an emerging area of concern.

Impact on Freshwater Fishes

The impact of water pollution on freshwater fish is significant and multifaceted, affecting both individual fish species and entire aquatic ecosystems.

1. Altered Water Quality

- **Chemical Contaminants:** Pollutants such as heavy metals (e.g., mercury, lead), pesticides, industrial chemicals, and nutrients can enter freshwater ecosystems, altering water quality. Elevated levels of these contaminants can be toxic to fish, affecting their health, growth, and survival.

2. Habitat Degradation

- **Sedimentation:** Excessive sediment runoff from construction, agriculture, and urban areas can smother fish habitats, including spawning grounds and areas where fish seek shelter.
- **Nutrient Enrichment:** Nutrient pollution from agricultural runoff and sewage can lead to the overgrowth of algae, which can reduce water clarity and disrupt aquatic habitats.

3. Toxic Effects

- **Bioaccumulation:** Fish can accumulate pollutants in their tissues over time, a process known as bioaccumulation. This can result in high concentrations of toxins in predator fish, making them unsafe for consumption by both wildlife and humans.

- **Sub lethal Effects:** Even sub lethal exposure to pollutants can have detrimental effects on fish behaviour, reproduction, and immune systems, making them more vulnerable to diseases and predators.
- 4. Disrupted Reproduction**
Pollutants can interfere with fish reproductive cycles, leading to decreased fertility, deformities in developing fish embryos, and skewed sex ratios among fish populations.
- 5. Disease and Pathogens**
Water pollution can create favorable conditions for the proliferation of disease-causing pathogens, leading to disease outbreaks among fish populations. This can result in mass mortality events and population declines.
- 6. Altered Behavior and Physiology**
Pollutants can disrupt fish behavior, affecting feeding patterns, migration, and reproduction. Changes in physiology, such as altered gill function, can impair a fish's ability to respire and regulate bodily functions.
- 7. Loss of Biodiversity**
Water pollution can disrupt the balance of aquatic ecosystems, favouring pollution-tolerant species over others. This can lead to a decline in native fish species, reducing overall biodiversity.
- 8. Economic Impact**
The decline of fish populations due to water pollution can have significant economic consequences, especially in regions where fishing is a major industry. Loss of fish stocks can lead to unemployment and economic hardship.
- 9. Regulatory Measures**
Many countries have implemented regulations and environmental protection measures to mitigate water pollution and its impacts on fish species. These include wastewater treatment, agricultural best practices, and pollution monitoring programs.
- 10. Long-Term Consequences**
The impacts of water pollution on freshwater fish can have long-term consequences, with some pollutants persisting in the environment for years. This can result in chronic health issues for fish populations and continued degradation of aquatic ecosystems.

Impact on Aquatic Ecosystems

Instantly after organic pollution comes in contact with water bodies results in a decrease or even purging of algae due to de-oxygenation and little amount of light present. Further, this is followed by a gradual increase in algae abundance once situations improve. This gradual increase is stirred by the bulky concentrations of nutrients that are probable to be present (Mason, 1991). Planktons (phytoplankton and zooplankton), macrobenthos, fish species, and macrophytes are badly affected by biodegradable organic pollution (Hynes, 1960; Malik et al., 2018; Kumar et al., 2018). Generally, De-oxygenation decreases the light levels, increases TSS and settling material thus results in the reduction or loss of aquatic species which are most sensitive to the pollution (Hawkes, 1962; Haslam, 1987). Mainly in the downstream regions of rivers tends to be more of a problematic from biodegradable organic pollution (Mason, 1991).

This causes certain glitches for migratory fish species with high DO requirements i.e. in the case of *Salmo salar* and *Salmo trutta*. In a few cases, the levels of DO and organic pollutants can prompt avoidance behavior and acts as a barrier which averts them reaching highly oxygenated breeding and spawning grounds (Richardson et al., 2001).

Human Health Implications

The impact of water pollution on freshwater fish can have significant human health implications, particularly when people consume contaminated fish or use polluted water sources. When fish in polluted waters accumulate

toxins and pollutants in their tissues through a process known as bioaccumulation, consuming these contaminated fish can pose health risks to humans. Contaminants such as heavy metals (e.g., mercury, lead), persistent organic pollutants (POPs), and industrial chemicals can harm human health when ingested.

Mercury is a common contaminant in some freshwater fish, particularly larger predatory species. Chronic exposure to high levels of mercury through fish consumption can lead to mercury poisoning, which can cause neurological and developmental issues, especially in children and developing fetuses. Lead contamination in freshwater ecosystems can affect fish populations. Consumption of lead-contaminated fish can lead to lead poisoning in humans, causing a range of health problems, including cognitive impairments and developmental issues in children.

Fish exposed to chemical pollutants like pesticides, industrial chemicals, and endocrine-disrupting compounds can pass these contaminants on to humans when consumed. Some of these chemicals have been linked to various health concerns, including cancer, reproductive disorders, and hormonal disruptions.

If fish are exposed to waterborne pathogens in polluted waters, consuming undercooked or raw fish can transmit waterborne diseases to humans, leading to gastrointestinal illnesses and other health issues. Polluted water bodies can release airborne pollutants into the atmosphere, which can affect air quality and lead to respiratory problems in nearby communities.

Health issues resulting from the consumption of contaminated fish can place a financial burden on healthcare systems and individuals, including medical costs and potential lost productivity due to illness.

For communities that rely on fishing for sustenance and livelihoods, the contamination of fish populations due to water pollution can undermine food security and economic stability.

Mitigation and Management Strategies

Mitigating and managing the impact of water pollution on freshwater fish is essential to protect aquatic ecosystems and ensure the sustainability of fisheries.

1. Pollution Prevention

- **Regulatory Measures:** Enforce and strengthen regulations on industrial discharges, wastewater treatment, and agricultural runoff to limit the release of pollutants into water bodies.
- **Best Management Practices (BMPs):** Promote BMPs in agriculture, construction, and industry to reduce pollutant runoff. These practices include soil conservation, reduced pesticide use, and proper waste disposal.

2. Sustainable Land Use

- **Watershed Management:** Implement comprehensive watershed management plans to protect and restore the health of freshwater ecosystems. This includes land-use planning, riparian buffer zones, and wetland preservation.
- **Urban Planning:** Encourage responsible urban planning that minimizes impervious surfaces, employs green infrastructure, and manages stormwater to prevent pollution in urban areas.

3. Wastewater Treatment

- **Upgrading Infrastructure:** Invest in modernizing and upgrading wastewater treatment facilities to effectively remove pollutants and pathogens from sewage before discharge into water bodies.
- **Advanced Treatment Technologies:** Explore advanced treatment technologies, such as membrane filtration and ultraviolet disinfection, to improve water quality.

4. Monitoring and Assessment

- **Water Quality Monitoring:** Establish monitoring programs to regularly assess water quality in freshwater ecosystems. This includes tracking pollutant levels and ecosystem health indicators.

- **Fish Health Assessment:** Monitor fish populations for signs of pollution-related stress or disease. This can serve as an early warning system for water quality issues.

5. Habitat Restoration

- **Revegetation:** Restore riparian zones and buffer areas with native vegetation to reduce sediment runoff and provide habitat for aquatic life.
- **Fish Passages:** Build or improve fish passages, like fish ladders and culverts, to facilitate fish migration and access to spawning habitats.

6. Fisheries Management

- **Regulation and Enforcement:** Implement and enforce sustainable fishing regulations, including catch limits and size restrictions, to prevent overfishing and maintain healthy fish populations.
- **Stocking Programs:** Consider stocking fish populations in degraded areas to help restore fish populations, but do so cautiously to avoid unintended consequences.

7. Education and Outreach

- **Public Awareness:** Educate communities, industries, and policymakers about the importance of water quality and its impact on fish and aquatic ecosystems.
- **Safe Fish Consumption Guidelines:** Provide clear and up-to-date guidelines on the safe consumption of fish from polluted waters, especially for vulnerable populations like pregnant women and children.

8. Research and Innovation

- **Scientific Research:** Support research into the effects of pollution on freshwater fish and ecosystems to inform management decisions and mitigation strategies.
- **Technological Solutions:** Explore innovative technologies for water treatment, pollution detection, and ecosystem restoration.

9. International Collaboration

Collaborate with neighboring countries and international organizations to address transboundary water pollution issues and develop coordinated strategies for pollution control.

10. Environmental Advocacy

Encourage and support environmental advocacy groups and NGOS working to raise awareness about water pollution issues and advocate for policy changes.

CONCLUSIONS

Various impurities and toxins find their way into aquatic ecosystems, severely affecting water quality and disrupting the life cycles of aquatic organisms. Some pollutants exhibit a potent capacity to harm aquatic life both structurally and metabolically. Despite this, there is limited concrete evidence to directly link water impurities and pollutants to the proliferation of diseases among aquatic animals. Prolonged exposure of aquatic animals to pollutants poses an ongoing health risk, placing them in a vulnerable position. Hence, it is evident that various human activities pose a direct and indirect threat to aquatic creatures. To address these issues, it is imperative that everyone takes proactive steps to safeguard aquatic communities. Researchers have consistently documented a wide array of impacts from pollutants on the populations of various fish species over time. These effects are often associated with chronic exposure levels that bring about a range of consequences for aquatic life. These consequences encompass alterations in histopathological conditions, physiological harm, adjustments in migration patterns, as well as embryonic and developmental changes, particularly among fish species.

Numerous pollutants present in the atmosphere contain a variety of toxic compounds, such as organophosphate compounds, which exert fatal impacts on fish species. Consequently, there is a pressing need to devise methods using molecular biology techniques that can advance cost-effective toxicological assessments without relying on aquatic animals to detect environmental stressors. Further research endeavours

should be undertaken to determine the specific concentration levels and duration of exposure to all pollutants. Equally vital is the task of substantiating significant lethal and sub-lethal effects on aquatic organisms.

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