CHAPTER 4

Industrial Effluents And Their Impact On Freshwater Fish Health

Dr. Mohd Shoeb

Department of Zoology, Gandhi Faiz E Aam College, Sahajahapur

Email- soabkhan92@gmail.com

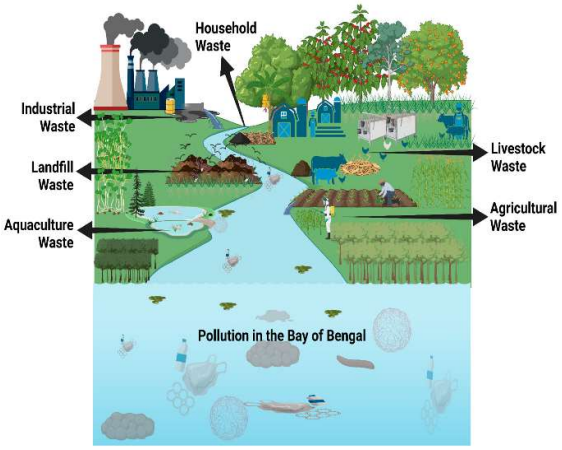
DOI- https://doi.org/10.59436/B978-81-971444-7-9/4

The growth of industries has had huge positive effects on the economy; however, the creation of a significant amount of industrial waste, which has also led to a large amount of pollutants being dumped into natural lakes and rivers, is one negative consequence of that growth. Industrial effluent, or wastewater, consists of a combination of different chemical compounds produced during various manufacturing processes like textiles, leather tanning, electroplating, pharmaceuticals, paper production, petrochemicals, and metal processing. Many of these effluents are discharged into freshwaters without any treatment or before they have been sufficiently treated (Authman, Zaki, Khallaf and Abbas, 2015) and contain toxic metals, organic compounds, dyes, solvents, acids, alkalis and suspended solids that affect the quality of the aquatic environment in which they are discharged. Freshwater ecosystems like rivers, lakes and reservoirs are particularly susceptible to industrial pollution due to the large quantity of untreated or partially treated wastewater that is released into these systems. The release of industrial effluent in to these freshwater ecosystems changes physical parameters of the water (pH, temperature and turbidity) and/or chemical parameters (dissolved oxygen concentration). The changes in the physical and/or chemical characteristics of the water create stresses on aquatic organisms, especially fish, which depend on stable water conditions for their survival and reproduction. Fish serve as excellent bio-indicators for assessing aquatic pollution because they respond quickly to changes in the aquatic environment and accumulate toxins that are found within the aquatic environment within their tissues (Fazio, 2019). Industrial pollution enters fish via three main pathways. First, fish will take in industrial pollution through their gills when they breathe. Second, fish ingest contaminated food. Third, industrial pollutants can diffuse into fish through the skin. After being incorporated into the fish's body, industrial pollutants are distributed throughout the body via the blood, concentrating in organs such as the liver, kidneys, gills, and

muscles. The accumulation of industrial pollutants has significant negative impacts on the physiology and biochemistry of fish, including oxidative stress, metabolic dysfunction, and physical damage to tissues (Jaishankar *et al.*, 2014). Industrial effluent exposure is one of several factors that may negatively impact fish health. Fish exposed to industrial effluents often experience poor respiration, changes in their blood chemistry, decreased enzyme activity, reproductive problems, and increased susceptibility to disease, among other adverse effects on fish health and well-being. Histological changes may occur in fish gills, liver, and kidneys in response to industrial pollution exposure. These toxicological impacts on fish not only threaten fish survival, but also disrupt aquatic biodiversity and the stability of aquatic ecosystems (Tchounwou *et al.*, 2012). Additionally, there are many different hazards that can arise from consuming the meat of contaminated freshwater fish. Fish, being such an important protein source for people all over the world, increases the level of risk to public health as a result of the accumulation of toxins in their tissues through the human food chain. As a result, a thorough understanding of how industrial runoff affects the health of freshwater fish is critical to environmental oversight, pollution management, and sustainable management of our freshwater fisheries.

Major Industrial Sources Of Aquatic Pollution

Aquatic pollution is exacerbated by industrial enterprises as one of the top causes of this type of pollution. As industrialisation and urbanisation continue to grow, the amount of untreated or partially treated wastewater discharged into waterways (such as rivers, lakes, and reservoirs) is also on the rise. There are many different types of toxic substances (heavy metals, synthetic dyes, organic chemicals, acids/alkalis and suspended solids) found within industrial effluents that can contaminate and degrade water quality and pose a threat to aquatic organisms (Tchounwou, Yedjou, Patlolla and Sutton 2012).



The textile dyeing and printing industries produce significant amounts of wastewater that contains synthetic dyes, bleaching agents and other toxic chemicals; as a result, these sectors are among the biggest contributors to aquatic pollution. Many synthetic dyes, bleaching agents and heavy metals (like chromium or copper) have been found to decrease the amount of light able to penetrate through water bodies, and thereby interfere with the photosynthetic processes

of aquatic vegetation. Moreover, the leather tanning industry is also a major source of aquatic pollution since its effluents contain large quantities of chromium salts and organic matter. Over time, these compounds can accumulate in sediments and result in long-term ecological harm (Jaishankar *et al.* 2014). Industrial sectors such as electroplating and metal finishing discharge wastewater containing hazardous heavy metals (copper, lead, nickel, and zinc). These metals are persistent in the environment and can bioaccumulate in fish tissue, causing physiological stress and organ injury. The paper and pulp industry is also a major contributor to aquatic pollution due to organic waste, lignin residues, and chlorinated compounds all of which contribute to elevated biological oxygen demand (BOD) and decrease the level of dissolved oxygen in the water (Authman *et al.*, 2015). Furthermore, the petrochemical and pharmaceutical industries are contributing hydrocarbons, solvents, and toxic by-products into freshwater systems. The continual discharge of these pollutants results in changes in water chemistry, the death of aquatic organisms, and the disruption of ecosystem stability. Therefore, adequate treatment of wastewater from the industries and strict environmental regulations are necessary to help reduce industrial pollution and protect the diversity of freshwater species.

Major Heavy Metals Affecting Freshwater Fishes

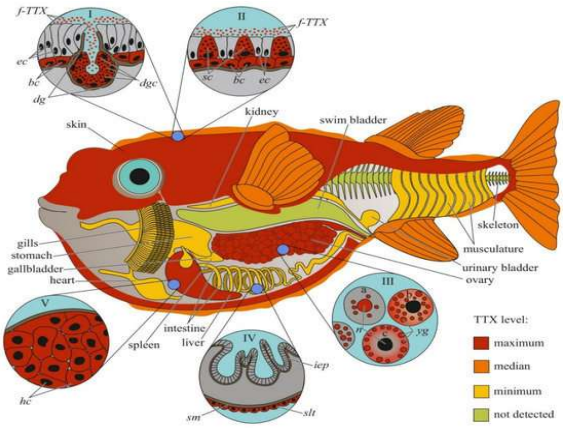
Heavy metals are among the most significant pollutants affecting freshwater fish health. These metals enter aquatic environments through industrial effluents, mining activities, agricultural runoff, and domestic waste. Once released into water bodies, heavy metals can accumulate in sediments and aquatic organisms. Freshwater fishes absorb these metals through gills, skin, and the digestive tract. Continuous exposure leads to bioaccumulation in vital organs such as liver, kidney, gills, and muscles, ultimately causing physiological and biochemical disturbances.

A. **Lead (Pb)**
   Lead is a highly toxic metal commonly released from batteries, paints, and industrial waste. In fishes, lead exposure can damage gills, liver, kidneys, and nervous systems. It interferes with enzyme activity and causes anemia, behavioral changes, and impaired growth.
B. **Cadmium (Cd)**
   Cadmium is released through mining, fertilizers, and industrial waste. It accumulates mainly in fish kidneys and liver. Chronic exposure causes kidney dysfunction, oxidative stress, and disruption of calcium metabolism.
C. **Mercury (Hg)**
   Mercury is one of the most dangerous heavy metals due to its high toxicity and bioaccumulation potential. In aquatic environments, mercury is converted into methylmercury, which easily accumulates in fish tissues and enters the food chain.
D. **Chromium (Cr)**
   Chromium contamination mainly originates from leather tanning industries and electroplating processes. Hexavalent chromium (Cr VI) is highly toxic and can cause DNA damage, oxidative stress, and histopathological alterations in fish organs.
E. **Copper (Cu) and Zinc (Zn)**

Copper and zinc are essential trace elements required in small quantities for metabolic functions. However, at higher concentrations, they become toxic and disrupt ion regulation, enzyme activity, and respiratory functions in fish.

Routes Of Pollutant Entry Into Fish

Industrial pollutants enter fish bodies through several pathways. Freshwater fishes are continuously exposed to contaminants present in their surrounding aquatic environment, making them highly vulnerable to toxic substances released from industrial activities. Pollutants dissolved in water or present in sediments and food particles can easily enter the fish body through multiple biological routes. Once absorbed, these toxic substances are distributed through the circulatory system and may accumulate in different tissues, leading to physiological stress and toxicological effects.



Gill absorption:

Gills are the primary site of pollutant uptake due to their large surface area and direct contact with water. The thin epithelial membranes of gill lamellae allow dissolved chemicals and heavy metals to diffuse rapidly into the bloodstream. Pollutant exposure can damage gill tissues, reducing oxygen exchange and causing respiratory stress.

Digestive tract:

Fish ingest contaminated food, plankton, and sediments containing industrial chemicals. These pollutants are absorbed through the intestinal lining and transported to vital organs. Continuous ingestion of contaminated food may lead to bioaccumulation of toxic substances in fish tissues.

Skin diffusion:

Certain pollutants may also enter through skin tissues, particularly when the protective mucus layer is damaged. The skin acts as a secondary route of exposure, especially in polluted waters with high concentrations of dissolved chemicals. Once inside the body, pollutants are transported through the bloodstream and accumulate in organs such as liver, kidneys, gills, brain, and muscles.

Biochemical And Molecular Effects

Fish tissue biochemical parameters can be altered by exposure to industrial effluents. Industrial wastewater contains a variety of contaminants (such as heavy metals, organic pollutants and toxins) that may change how aquatic organisms metabolize materials. The toxic materials enter the fish through three principal routes, their gills, the gastrointestinal tract (GI), and skin; where they will ultimately affect vital biochemical pathways. The presence of these pollutants results in the disruption of enzymatic activity, damage cellular structures, and create metabolic imbalance resulting in physiological stress to the fish (Jaishankar *et al.*, 2014) and decreased chance of survival.

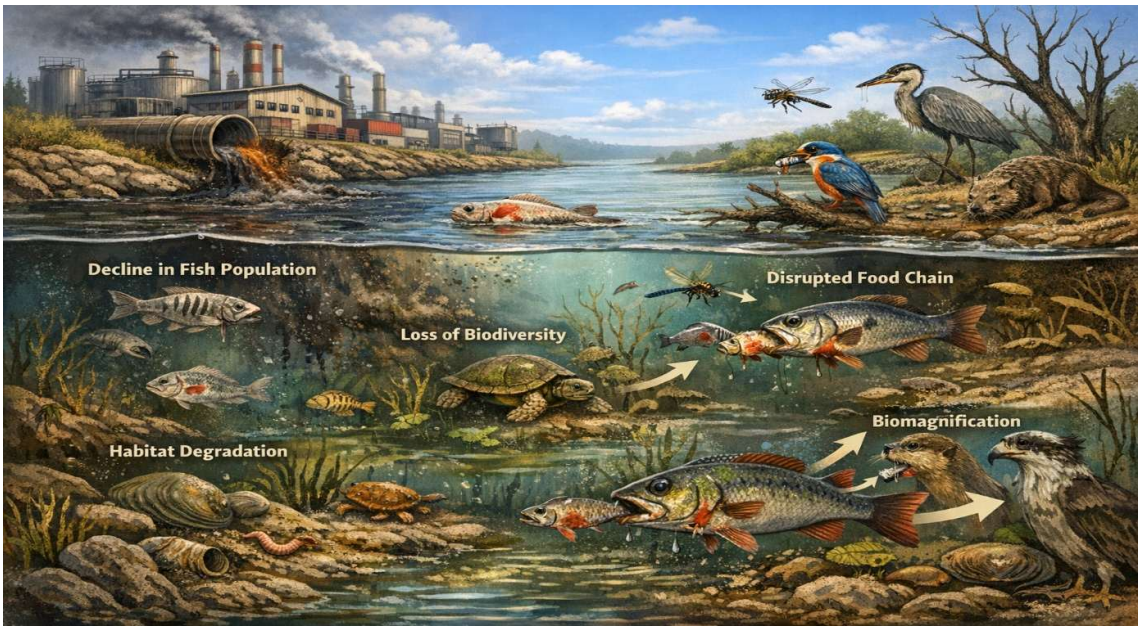
Common biochemical changes include:

- Increased oxidative stress
- Elevated liver enzymes (ALT, AST, ALP)
- Altered protein and carbohydrate metabolism
- Lipid peroxidation in cell membranes

Excessive industrial pollution creates increased amounts of reactive oxygen species (ROS) throughout the tissues of fish, resulting in oxidative stress. This oxidative stress damages proteins, nucleic acids and membrane lipids. Common signs of liver dysfunctions and tissue damage in fish exposed to pollutants include increased activity of the liver enzymes (alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase). Disruptions to protein synthesis and carbohydrate metabolism can cause issues with growth, energy balance and immune responses to occur in fish (Authman *et al.*, 2015). Biochemical disruptions caused by toxic industrial pollutants indicate a disruption in metabolic balance or damage to cells through toxic pollutants. In ecotoxicology studies, biochemical biomarkers are commonly used to evaluate the effects of industrial pollution on the health of freshwater fish.

Ecological Consequences

The way in which industrial effluents influence individual fish will have a much larger effect on overall aquatic ecosystems. Continuous discharging of untreated (or only partially treated) industrial waste products into freshwater (lakes, rivers, ponds), introduces toxic substances including heavy metals and organic compounds to our freshwater bodies. Such contaminants can change physical properties of water (e.g. pH); alter water's chemical composition (e.g. dissolved oxygen, turbidity); thus, creating potentially harmful environments for aquatic organisms. Ultimately, if pollutants accumulate for a long enough period, they can destroy the ecological balance of a freshwater ecosystem and greatly decrease the overall productivity of freshwater ecosystems.



Major ecological impacts include:

- Decline in fish population
- Loss of aquatic biodiversity
- Disruption of food chains
- Habitat degradation

By impairing fish growth, reproduction and survival, toxic industrial waste can contribute to declining fish populations. Sensitive fish species may completely vanish from polluted places, resulting in lower levels of species diversity and the remodelling of community structure. In addition, industrial pollutants can also affect plankton, aquatic vegetation, and benthic animals that form the base of the aquatic food chain. When these primary producers and consumers are damaged, energy transfer between the trophic levels is disrupted, thereby destabilising the whole ecosystem. The presence of industrial waste in the tissues of fish may also result in biomagnification through the food chain. This occurs when a predator fish consumes prey fish that are contaminated by the presence of industrial waste, which causes the predator fish to accumulate higher levels of toxins due to the higher level of industrial waste present in the prey fish. This presents a substantial threat not only to the aquatic environment but also to birds, mammals and humans that rely on fish, reptiles and amphibians as food.

Human Health Implications

Freshwater ecosystems are severely impacted by the pollution generated by industrial activity, which threatens the health of humans, particularly through the consumption of contaminated fish and water. Industrial factories emit large amounts of wastewater—called effluents—into rivers, lakes, and other freshwater systems. The effluents often contain toxic organic compounds, heavy metals, and persistent pollutants that accumulate in aquatic organisms.

Freshwater fish absorb the pollutants through their gills, digestive systems, and skin, creating a bioaccumulation of toxic substances. Therefore, when humans consume contaminated fish, these toxic substances can enter the human body and produce a variety of long-term health problems (Jaishankar *et al.*, 2014). Of all of the heavy metals, mercury, cadmium, lead, and chromium are known to be extremely dangerous to human tissue because of their ability to accumulate in the body's organs over time. Mercury exposure (particularly via methylmercury) is widely known to damage the nervous system and negatively affect the development of the brains of developing children. Cadmium exposure has been linked to renal dysfunction, damage to bone, and problems with heart and blood vessels, while lead toxicity can manifest as neurological disorders, anemia, and delays in normal growth and development (Tchounwou, Yedjou, Patlolla, & Sutton, 2012). In addition to heavy metals, industrial effluents may contain carcinogenic chemicals such as polycyclic aromatic hydrocarbons (PAHs) and industrial solvents that increase the risk of cancer and endocrine disruption. Continuous exposure to contaminated aquatic food sources may therefore contribute to chronic diseases and immune system disorders in humans (Briffa, Sinagra, & Blundell, 2020).Therefore, monitoring industrial pollutants in freshwater ecosystems is essential for protecting public health. Strict environmental regulations, effective wastewater treatment systems, and regular assessment of contaminant levels in fish are necessary to ensure food safety and reduce health risks associated with aquatic pollution.

Conclusion

The main source of freshwater pollution is industrial waste, which also has a serious impact on fish and other aquatic life. Rapid industrialization, lack of treatment for wastewater, and the continuous release of toxic materials like heavy metals, organic chemicals, dyes, and industrial solvents into rivers, lakes, and reservoirs are all contributing factors to this large amount of freshwater pollution. These pollutants change the chemical and physical properties of water (i.e. pH, temperature, turbidity, and oxygen levels), causing stress to aquatic organisms. Freshwater fish are particularly susceptible to industrial pollution because they come into contact with polluted water and may absorb toxic materials through gills, skin, and digestion. Industrial pollution can lead to a number of toxic effects on fish physiology, biochemistry, and histopathology, which include respiratory problems, disruption of normal metabolism, oxidative stress, and damage to tissues. Lengthy exposure can lead to decreased growth and fewer offspring produced, resulting in lower fish populations and loss of biodiversity, as well as disrupting aquatic food webs. Furthermore, because of the accumulation of toxic materials in their bodies, fish that are exposed to these contaminants may suffer biomagnification through multiple levels of the food web, thus creating potential health risks to any consumers (e.g. wildlife or people) of these contaminated fish. Therefore, effective management of industrial wastewater is essential for protecting freshwater ecosystems. Implementation of advanced wastewater treatment technologies, strict environmental regulations, and continuous monitoring of aquatic pollution are crucial steps toward reducing industrial contamination and ensuring the sustainability of freshwater biodiversity and fisheries resources.

References

Authman, M. M. N., Zaki, M. S., Khallaf, E. A., & Abbas, H. H. (2015). Use of fish as bio-indicator of the effects of heavy metals pollution. *Journal of Aquaculture Research and Development*, 6(4), 1–13. https://doi.org/10.4172/2155-9546.1000328

Briffa, J., Sinagra, E., & Blundell, R. (2020). Heavy metal pollution in the environment and their toxicological effects on humans. *Heliyon*, 6(9), e04691. https://doi.org/10.1016/j.heliyon.2020.e04691

Fazio, F. (2019). Fish hematology analysis as an important tool of aquaculture: A review. *Aquaculture*, 500, 237–242. https://doi.org/10.1016/j.aquaculture.2018.10.030

Jaishankar, M., Tseten, T., Anbalagan, N., Mathew, B. B., & Beeregowda, K. N. (2014). Toxicity, mechanism and health effects of some heavy metals. *Interdisciplinary Toxicology*, 7(2), 60–72. https://doi.org/10.2478/intox-2014-0009

Singh, B., Maheshwari, M., & Sharma, H. (2024). Nutritional studies on fish *Catla catla* found in Ganga River with hydrobiological studies. *Journal of Science Innovations and Nature of Earth*, 4, 17–22. https://doi.org/10.59436/ht5mmg32

Singh, B., Sharma, H. N., Prveen, & Singh, S. (2024). *A review on effect of cypermethrin on hematology of fresh water fish Channa punctatus (Bloch.)*. Journal of Science Innovations and Nature of Earth, 4. https://doi.org/10.59436/jsiane.271.2583-2093

Tchounwou, P. B., Yedjou, C. G., Patlolla, A. K., & Sutton, D. J. (2012). Heavy metal toxicity and the environment. *Experientia Supplementum*, 101, 133–164. https://doi.org/10.1007/978-3-7643-8340-4_6