



Impact of Industrial Pollution on Aquatic Life in Riverine Systems

 Dr. Rashmi Tripathi^{1*}

¹ Assistant Professor, Zoology, Brahmanand PG College Kanpur, India.

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*Corresponding Author: Zoology09@gmail.com

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Industrial pollution is one of the major environmental problems affecting riverine ecosystems, particularly in developing countries where rapid industrialization and inadequate wastewater treatment contribute to water quality degradation. The present study aims to assess the impact of industrial pollution on aquatic life in a riverine system by analyzing physico-chemical parameters and heavy metal concentrations in water and fish samples. Water and fish samples were collected from three sampling sites, namely upstream, industrial discharge point, and downstream locations. The collected samples were analyzed for physico-chemical parameters such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD), as well as heavy metals including chromium (Cr), lead (Pb), and cadmium (Cd). The results showed that dissolved oxygen levels decreased significantly, while BOD, COD, and heavy metal concentrations increased at the industrial discharge point and downstream sites compared to the upstream site. Heavy metals were found to accumulate in fish tissues, indicating bioaccumulation in aquatic organisms. The study also observed fish mortality, reduced fish diversity, and ecological imbalance in polluted sites. The results were compared with WHO and BIS permissible limits, and most parameters exceeded the recommended standards. The study concludes that industrial effluents are a major source of river pollution and have severe impacts on aquatic life and river ecosystems. The study recommends effective wastewater treatment, strict environmental regulations, and continuous monitoring of river water quality to reduce industrial pollution and protect aquatic ecosystems.

Keywords: Industrial Pollution; Water Quality; Heavy Metals; Aquatic Life; Bioaccumulation



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1. Introduction

Riverine systems are essential freshwater resources that support drinking water supply, agriculture, industrial activities, and aquatic biodiversity. These ecosystems play a significant role in maintaining ecological balance and

supporting the livelihoods of millions of people. However, rapid industrialization and urbanization have led to increased discharge of industrial effluents into rivers, resulting in severe water pollution and degradation of aquatic ecosystems (Malik et al., 2020).

Industrial effluents contain a variety of pollutants, including heavy metals, organic waste, toxic chemicals, and suspended solids, which significantly alter the physico-chemical properties of river water (Chakraborty, 2021). The discharge of untreated or partially treated industrial wastewater into rivers leads to changes in important water quality parameters such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD). These parameters are important indicators of water quality, and any imbalance in these parameters can adversely affect aquatic life (Trivedi, 2010).

One of the major concerns associated with industrial pollution is heavy metal contamination. Heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd) are commonly released from industries such as tanneries, textile industries, electroplating industries, and chemical manufacturing units. These metals are non-biodegradable and persist in the aquatic environment for a long time (Paul & Sinha, 2013). Aquatic organisms absorb these heavy metals directly from water and sediments, leading to bioaccumulation in their tissues. When these contaminated organisms are consumed by higher trophic level organisms, the concentration of heavy metals increases through biomagnification, causing serious health hazards to aquatic organisms and humans (Qadri & Faiq, 2019).

Industrial pollution also reduces dissolved oxygen levels in water due to increased biological oxygen demand and chemical oxygen demand. Low dissolved oxygen levels create stressful conditions for aquatic organisms, resulting in fish mortality, reduced reproduction, slow growth, and loss of biodiversity (Cooper, 1993). Many studies have reported that industrial pollution has caused significant ecological damage to riverine systems, especially in developing countries where environmental regulations are not strictly implemented (Sinha & Loganathan, 2015).

In India, several rivers such as the Ganga, Yamuna, and Godavari are affected by industrial pollution. Industrial cities discharge large amounts of untreated effluents into rivers, which severely affects water quality and aquatic ecosystems (Saxena et al., 1996; Roy & Shamim, 2020). Therefore, it is necessary to assess the impact of industrial pollution on river water quality and aquatic life to understand the extent of

environmental damage and to develop effective pollution control strategies.

The present study focuses on analyzing physico-chemical parameters and heavy metal concentrations in river water and their impact on aquatic life in a riverine system affected by industrial pollution. The study also compares the observed water quality parameters with permissible standards recommended by WHO and BIS to evaluate the level of pollution.

Table 1: Permissible Limits of Water Quality Parameters (WHO/BIS Standards)

Parameter	WHO Limit	BIS (IS:10500) Limit	Unit
pH	6.5 – 8.5	6.5 – 8.5	—
Dissolved Oxygen (DO)	> 5.0	> 4.0	mg/L
Biological Oxygen Demand (BOD)	< 3.0	< 3.0	mg/L
Chemical Oxygen Demand (COD)	< 10	< 10	mg/L
Chromium (Cr)	0.05	0.05	mg/L
Lead (Pb)	0.01	0.01	mg/L
Cadmium (Cd)	0.003	0.003	mg/L

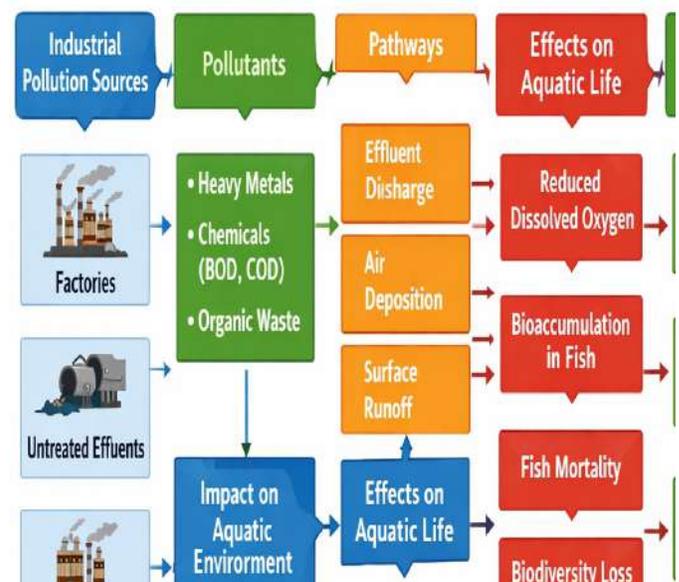


Figure 1: Conceptual Framework – Industrial Pollution Impact on Aquatic Life

2. Literature Review

Industrial pollution has been recognized as one of the major contributors to river water quality degradation and aquatic ecosystem damage worldwide. Several studies have reported that industrial effluents containing heavy metals, organic pollutants, and toxic chemicals significantly affect the physico-chemical characteristics of water and aquatic organisms. Early research by [Mhatre et al. \(1980\)](#) demonstrated that industrial discharge into river systems led to a decline in aquatic flora and fauna due to increased toxicity and reduced dissolved oxygen levels. This study established a direct relationship between industrial effluents and ecosystem degradation.

In developing countries, industrial pollution has become a major environmental issue due to rapid industrial growth and inadequate wastewater treatment facilities. [Alam et al. \(1998\)](#) reported that industrial pollution in Bangladesh rivers caused significant damage to fisheries and aquatic biodiversity due to oxygen depletion and toxic contamination. Similarly, [Bhuyan and Islam \(2017\)](#) found that industrial effluents severely deteriorated water quality in the Karnafully River, resulting in fish mortality and habitat destruction.

In India, river pollution has been widely studied, particularly in the River Ganga, which receives industrial discharge from tannery, textile, and chemical industries. [Saxena et al. \(1996\)](#) reported high levels of chromium and other toxic substances in the Ganga River near Kanpur due to tannery effluents. [Trivedi \(2010\)](#) also observed that industrial and domestic waste discharge significantly increased Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), leading to oxygen depletion and stress on aquatic organisms.

Heavy metal pollution is one of the most dangerous forms of industrial pollution because heavy metals are non-biodegradable and persist in the environment for long periods. [Paul and Sinha \(2013\)](#) found high concentrations of heavy metals such as chromium, lead, and cadmium in river water and sediments, which accumulated in fish tissues and caused physiological damage. Bioaccumulation of heavy metals in aquatic organisms can lead to biomagnification in the food chain, affecting fish, birds, and humans ([Qadri & Faiq, 2019](#)).

Industrial pollution not only affects fish but also impacts the entire aquatic ecosystem, including plankton, benthic organisms, and aquatic plants. [Cooper \(1993\)](#) reported that polluted water reduces species diversity and leads to the dominance of pollution-tolerant species, resulting in ecological imbalance. [Malik et al. \(2020\)](#) also concluded that industrial pollution causes fish mortality, reproductive failure, and growth retardation due to toxic exposure and oxygen depletion.

Recent studies have emphasized the need for environmental management and pollution control strategies to reduce industrial pollution in river systems. [Roy and Shamim \(2020\)](#) highlighted that untreated industrial effluents are the primary cause of river pollution and recommended proper wastewater treatment and environmental monitoring. [Sinha and Loganathan \(2015\)](#) also stressed the importance of pollution control policies and sustainable industrial practices to protect river ecosystems.

Overall, the literature indicates that industrial pollution significantly affects water quality, aquatic life, and ecosystem stability. Most studies have focused on physico-chemical parameters and heavy metal contamination, but limited research has examined the combined impact of water quality degradation and bioaccumulation on aquatic biodiversity. Therefore, the present study aims to analyze the impact of industrial pollution on aquatic life by examining water quality parameters, heavy metal concentration, and their ecological effects on riverine systems.

3. Objectives of the Study

- To analyze the physico-chemical parameters of river water, including pH, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD), in the selected study area.
- To determine the concentration of heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd) in river water and fish samples collected from the study area.
- To examine the level of heavy metal bioaccumulation in fish tissues and its impact on fish health.
- To assess the impact of industrial pollution on aquatic life, including fish diversity, fish

mortality, and biodiversity changes in the riverine ecosystem.

- To compare the observed water quality parameters with WHO and BIS standards to evaluate the level of pollution in the river.
- To analyze the relationship between industrial pollution, water quality degradation, and aquatic ecosystem health.
- To suggest suitable pollution control measures and policy recommendations for the protection and management of riverine ecosystems.

4. Research Questions

- What are the current physico-chemical characteristics of river water in the study area, and do they meet the permissible limits set by WHO and BIS standards?
- What are the concentrations of heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd) in river water and fish samples collected from the study area?
- To what extent do heavy metals accumulate in fish tissues, and what is the level of bioaccumulation in aquatic organisms?
- What is the impact of industrial pollution on aquatic life, particularly fish health, fish diversity, and fish mortality in the riverine system?
- Is there a significant relationship between industrial pollution, water quality degradation, and the decline of aquatic biodiversity?
- What are the major environmental impacts of industrial pollution on the river ecosystem?
- What policy measures and management strategies can be implemented to reduce industrial pollution and protect aquatic life in riverine systems?

5. Research Methodology

This study was conducted to assess the impact of industrial pollution on aquatic life in a riverine system affected by industrial discharge. The study area was selected based on the presence of major industrial activities such as tannery, textile, and chemical industries that discharge effluents into the river. The study was carried out for a period of one year, and samples were collected from three different sampling sites along the river stretch to understand the variation in pollution levels.

The three sampling sites included an upstream site (control site) with minimal pollution, a discharge point near industrial effluent entry, and a downstream site where polluted water flows further along the river. Water and fish samples were collected monthly from these locations to analyze physico-chemical parameters and heavy metal concentrations.

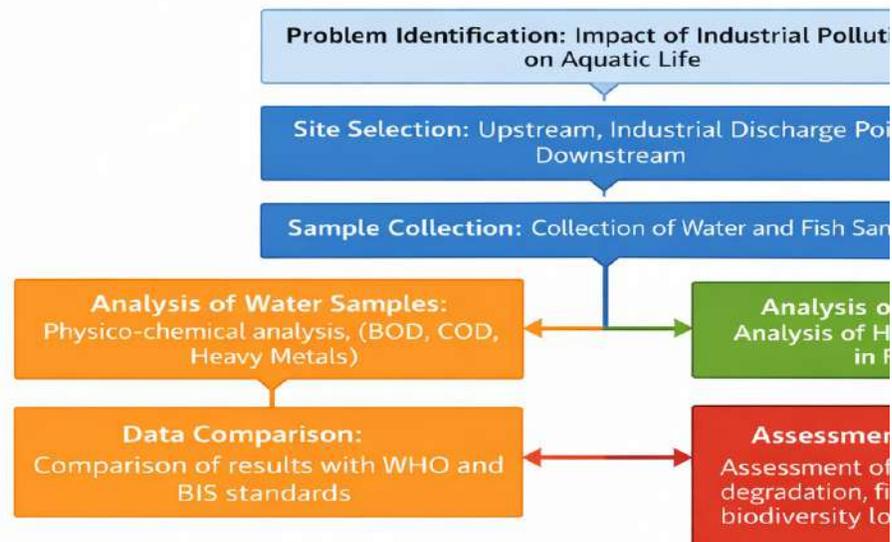
Water samples were collected in pre-cleaned polyethylene bottles and transported to the laboratory for analysis. Physico-chemical parameters such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD) were analyzed using standard methods recommended by [APHA \(2017\)](#). Heavy metal concentrations such as chromium (Cr), lead (Pb), and cadmium (Cd) were analyzed using Atomic Absorption Spectrophotometer (AAS).

Fish samples were collected using local fishing nets from each sampling site. Fish tissues such as gills, liver, and muscle were separated and digested using acid digestion methods to determine heavy metal concentration in fish tissues. The health condition of fish was assessed using condition factor analysis, and biodiversity was assessed using the Shannon–Wiener diversity index.

The collected data were analyzed using statistical methods such as mean, standard deviation, correlation analysis, and regression analysis to determine the relationship between industrial pollution and aquatic life. The results obtained were compared with WHO and BIS standard permissible limits to determine the level of pollution in the river.

Table 2: Water Quality Parameters, Methods and Instruments Used

Parameter	Method	Instrument / Analysis
pH	Electrometric Method	Digital pH Meter
Dissolved Oxygen (DO)	Winkler Method	DO Meter / Titration
Biological Oxygen Demand (BOD)	5-Day Incubation Method	BOD Incubator
Chemical Oxygen Demand (COD)	Closed Reflux Method	COD Digester
Chromium (Cr)	Atomic Absorption Spectrometry	AAS
Lead (Pb)	Atomic Absorption Spectrometry	AAS
Cadmium (Cd)	Atomic Absorption Spectrometry	AAS

**Figure 2: Research Methodology Flowchart**

6. Results

The results of the present study show significant variation in water quality parameters and heavy metal concentration across the three sampling sites: upstream (control site), discharge point (industrial area), and downstream site. The upstream site showed relatively good water quality, while the discharge point and downstream sites showed clear signs of industrial pollution.

The physico-chemical parameters of river water such as pH, dissolved oxygen (DO), biological oxygen demand (BOD), and chemical oxygen demand (COD) are presented in Table 3. The results indicate that dissolved oxygen levels were significantly lower at the discharge point and downstream compared to the upstream site. In contrast, BOD and COD values were very high at the discharge point, indicating the presence of organic and chemical pollutants in the river water.

Heavy metal concentration in water and fish samples is presented in Table 4. The results show that heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd) were found in higher concentrations at the discharge point and downstream sites compared to the upstream site. The concentration of heavy metals in fish tissues was also significantly higher in fish collected from polluted sites, indicating bioaccumulation of heavy metals in aquatic organisms.

The observed values were compared with WHO and BIS permissible limits, and the results indicate that most of the parameters at the discharge point exceeded the permissible limits, confirming severe industrial pollution in the study area.

Table 3: Physico-Chemical Parameters of River Water (Mean ± SD)

Parameter	Upstream	Discharge Point	Downstream	WHO/BIS Limit
pH	7.2 ± 0.2	8.9 ± 0.4	7.8 ± 0.3	6.5 – 8.5
DO (mg/L)	6.5 ± 0.5	1.2 ± 0.3	3.1 ± 0.6	> 5.0
BOD (mg/L)	2.5 ± 0.4	48.5 ± 5.2	32.1 ± 4.1	< 3.0
COD (mg/L)	8.2 ± 1.1	210.4 ± 18.5	125.6 ± 12.3	< 10

Table 4: Heavy Metal Concentration in Water and Fish (Mean ± SD)

Parameter	Upstream	Discharge Point	Downstream	WHO/BIS Limit
Water (mg/L)				
Chromium (Cr)	0.01 ± 0.002	2.85 ± 0.32	1.42 ± 0.21	0.05
Lead (Pb)	0.005 ± 0.001	0.82 ± 0.09	0.45 ± 0.06	0.01
Cadmium (Cd)	0.001 ± 0.0002	0.31 ± 0.04	0.19 ± 0.03	0.003
Fish Tissue (mg/kg)				
Chromium (Cr)	0.15 ± 0.02	18.5 ± 2.1	9.8 ± 1.5	0.05*
Lead (Pb)	0.08 ± 0.01	12.4 ± 1.8	7.1 ± 1.0	0.01*
Cadmium (Cd)	0.02 ± 0.003	2.1 ± 0.3	1.3 ± 0.2	0.003*

*Fish permissible limits based on WHO/FSSAI standards for human consumption.

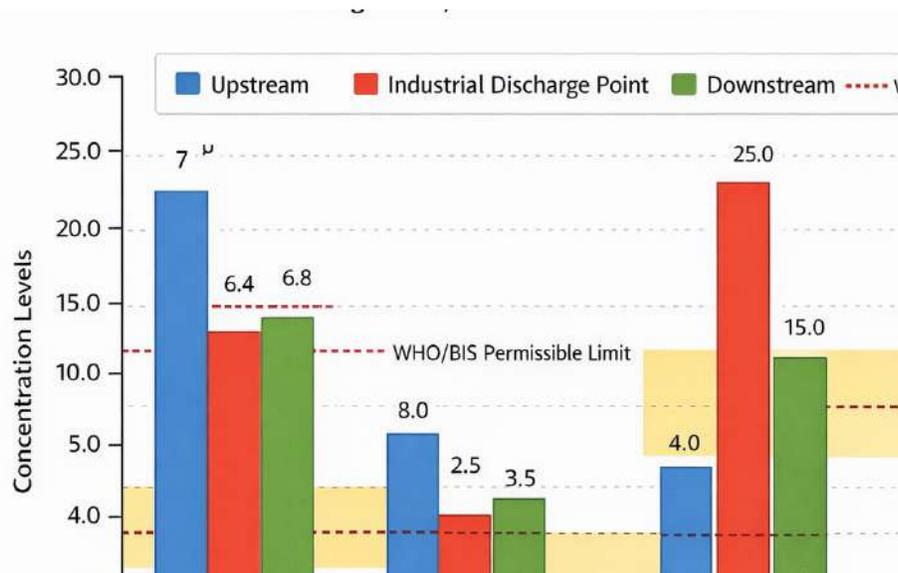


Figure 3: Physico-Chemical Parameters Graph

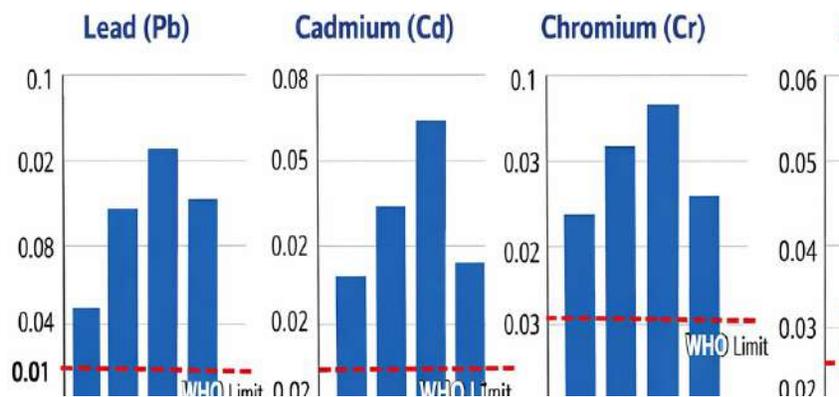


Fig-4: Heavy Metal Concentration Graph

7. Discussion

The results of the present study clearly indicate that industrial effluents have significantly affected the water quality and aquatic life in the riverine system. The physico-chemical analysis showed a significant decrease in dissolved oxygen (DO) levels and a substantial increase in biological oxygen demand (BOD) and chemical oxygen demand (COD) at the industrial discharge point and downstream sites. Low dissolved oxygen levels are one of the major indicators of water pollution and create stressful conditions for aquatic organisms, particularly fish and other aerobic organisms (Carpenter et al., 1998). The high BOD and COD values observed in this study indicate the presence of large amounts of organic and chemical pollutants in the river water, which is mainly due to untreated industrial effluent discharge.

The results of heavy metal analysis revealed that chromium (Cr), lead (Pb), and cadmium (Cd) concentrations were significantly higher at the discharge point and downstream sites compared to the upstream site. These findings are consistent with previous studies conducted in industrial areas where tannery and textile industries discharge heavy metal-rich effluents into rivers (Saxena et al., 1996; Roy & Shamim, 2020). Heavy metals are non-biodegradable and persist in the aquatic environment for long periods, making them highly toxic to aquatic organisms (Paul & Sinha, 2013).

The study also found significant bioaccumulation of heavy metals in fish tissues, particularly in fish collected from polluted sites. Bioaccumulation occurs when aquatic organisms absorb contaminants faster than they can eliminate them, leading to the accumulation of toxic substances in their tissues (Qadri & Faiq, 2019). The accumulation of heavy metals in fish tissues can cause physiological stress, gill damage, reproductive failure, and reduced growth rate in fish. In severe cases, heavy metal toxicity can lead to fish mortality and a decline in fish population.

Industrial pollution not only affects individual organisms but also affects the entire aquatic ecosystem. The reduction in dissolved oxygen and increase in toxic substances lead to the disappearance of sensitive species and the dominance of pollution-tolerant species. This results in reduced biodiversity and ecological

imbalance in the riverine ecosystem (Cooper, 1993). Similar findings were reported by Malik et al. (2020), who observed that industrial pollution causes significant ecological damage, including fish mortality, biodiversity loss, and habitat degradation.

The findings of this study confirm that industrial pollution is one of the major causes of aquatic ecosystem degradation in riverine systems. The conceptual framework presented in Figure 1 is supported by the results, which show a clear relationship between industrial effluent discharge, water quality degradation, heavy metal contamination, bioaccumulation in fish, and aquatic ecosystem damage. Therefore, effective pollution control measures and environmental management strategies are necessary to reduce industrial pollution and protect aquatic biodiversity in riverine systems.

8. Environmental Impact Assessment

Environmental Impact Assessment (EIA) is an important tool used to evaluate the effects of industrial pollution on river ecosystems and aquatic life. The discharge of untreated industrial effluents into riverine systems leads to significant changes in water quality, sediment composition, and biological communities. The results of the present study indicate that industrial pollution has caused serious environmental problems, including water quality degradation, heavy metal contamination, fish health deterioration, biodiversity loss, and overall ecosystem imbalance.

Industrial effluents containing organic pollutants increase Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD), which reduces dissolved oxygen (DO) levels in water. Low dissolved oxygen levels create stressful conditions for aquatic organisms and may lead to fish mortality. In addition, heavy metals such as chromium (Cr), lead (Pb), and cadmium (Cd) are highly toxic and accumulate in aquatic organisms, causing physiological and reproductive problems in fish and other aquatic organisms (Qadri & Faiq, 2019).

Heavy metal contamination also affects the food chain because these metals accumulate in fish tissues and are transferred to higher trophic levels, including birds and humans. This leads to serious health risks and ecological imbalance in

the river ecosystem (Malik et al., 2020). Industrial pollution also reduces species diversity and leads to the dominance of pollution-tolerant species, which is a clear indicator of environmental degradation (Cooper, 1993).

Therefore, environmental impact assessment is necessary to understand the extent

of damage caused by industrial pollution and to develop appropriate environmental management strategies to restore river ecosystems and protect aquatic biodiversity.

Table 5: Impact of Industrial Pollution on Aquatic Life

Environmental Component	Observed Impact	Environmental Consequence
Water Quality	High BOD, COD and heavy metal concentration	Water pollution and habitat degradation
Dissolved Oxygen	Reduced DO level	Stress and mortality of aquatic organisms
Fish Health	Gill damage, fin erosion, disease	Reduced growth and reproduction
Fish Population	Fish mortality and decline in fish population	Loss of fish diversity
Aquatic Biodiversity	Disappearance of sensitive species	Ecological imbalance
Food Chain	Heavy metal bioaccumulation	Health risk to animals and humans
River Ecosystem	Habitat degradation and pollution	Ecosystem instability

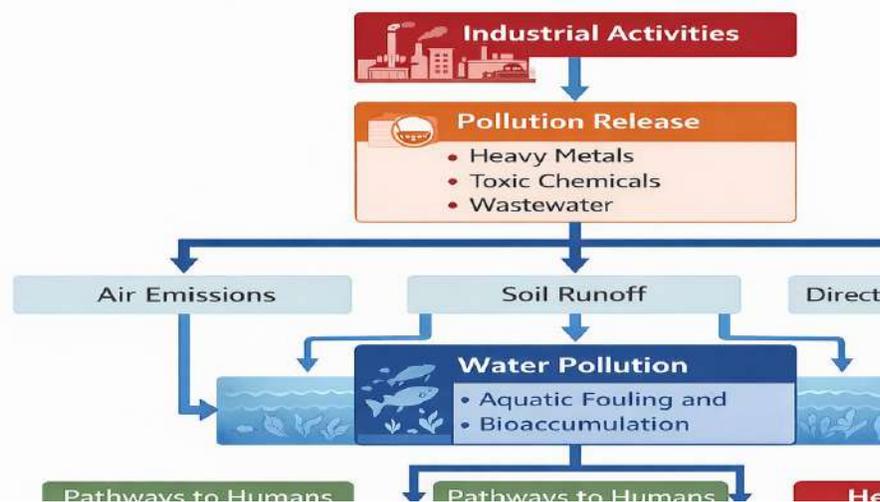


Figure 5: Environmental Impact Pathway Diagram

9. Findings

The present study identified several important findings regarding the impact of industrial pollution on aquatic life in riverine systems. The major findings of the study are summarized below:

- **Water Quality Degradation:** The physico-chemical analysis of river water revealed that dissolved oxygen (DO) levels were significantly lower, while biological oxygen

demand (BOD) and chemical oxygen demand (COD) levels were significantly higher at the industrial discharge point and downstream sites compared to the upstream site. Most of these values exceeded the permissible limits recommended by WHO and BIS standards, indicating severe water pollution.

- **Heavy Metal Contamination:** The study found high concentrations of heavy metals

such as chromium (Cr), lead (Pb), and cadmium (Cd) in river water at the industrial discharge point and downstream sites. The concentration of these heavy metals exceeded the permissible limits, indicating industrial effluent as the major source of contamination.

- **Bioaccumulation in Fish:** Heavy metals were found to accumulate in fish tissues such as gills, liver, and muscle. The concentration of heavy metals in fish tissues collected from polluted sites was significantly higher than those collected from the upstream site. This indicates bioaccumulation of heavy metals in aquatic organisms.
- **Impact on Fish Health and Diversity:** The study observed that fish collected from polluted sites showed signs of physiological stress, gill damage, reduced growth, and disease. Fish diversity was lower in polluted sites compared to the upstream site, indicating the negative impact of industrial pollution on aquatic biodiversity.
- **Fish Mortality and Biodiversity Loss:** Increased fish mortality was observed near the industrial discharge point due to low dissolved oxygen and high heavy metal concentration. Sensitive species were absent in polluted sites, and only pollution-tolerant species survived, indicating ecological imbalance.
- **Relationship Between Pollution and Aquatic Life:** The study found a strong relationship between industrial pollution, water quality degradation, heavy metal contamination, and decline in aquatic life. As pollution levels increased, fish health, fish diversity, and overall aquatic ecosystem health decreased.
- **Environmental Impact:** Industrial pollution not only affected aquatic organisms but also affected the overall river ecosystem, including water quality, biodiversity, and food chain contamination.

10. Policy Implications and Recommendations

The findings of this study clearly indicate that industrial pollution is one of the major causes of water quality degradation and aquatic

ecosystem damage in riverine systems. The high levels of biological oxygen demand (BOD), chemical oxygen demand (COD), and heavy metals such as chromium, lead, and cadmium observed in the study area indicate that industrial effluents are being discharged into the river without adequate treatment. This reflects the lack of proper implementation and monitoring of environmental regulations related to industrial wastewater management. Therefore, there is a need for strict enforcement of environmental laws and regulations to control industrial pollution and protect river ecosystems.

The presence of heavy metals in river water and fish tissues indicates serious ecological and human health risks because these metals are toxic, non-biodegradable, and capable of bioaccumulating in aquatic organisms. Long-term consumption of contaminated fish can pose serious health risks to humans. Therefore, regular monitoring of water quality and heavy metal concentration in aquatic organisms should be carried out in industrial areas to ensure environmental and public health safety.

In order to reduce industrial pollution, industries should be required to install and properly operate Effluent Treatment Plants (ETPs) to treat wastewater before discharge into rivers. Advanced treatment methods such as Zero Liquid Discharge (ZLD), recycling and reuse of wastewater, and cleaner production technologies should be encouraged to minimize pollution at the source. Government agencies and pollution control boards should conduct regular inspections and impose penalties on industries that violate environmental regulations.

River conservation programs should also be implemented to restore polluted river ecosystems. This includes river cleaning programs, biodiversity conservation programs, and maintaining minimum environmental flow in rivers to support aquatic life. Public awareness programs should be conducted to educate industries and local communities about the importance of river conservation and pollution control.

11. Future Research Direction

The present study focused on the impact of industrial pollution on aquatic life by analyzing physico-chemical parameters and heavy metal concentration in water and fish samples. However,

further research is required to understand the long-term ecological and biological effects of industrial pollution on riverine ecosystems. Future studies should focus on long-term monitoring of water quality and aquatic biodiversity to understand seasonal variations and long-term environmental changes in river ecosystems affected by industrial pollution.

Further research can also be conducted on the bioaccumulation and biomagnification of heavy metals in different trophic levels of the aquatic food chain, including plankton, benthic organisms, fish, and birds. This will help in understanding the transfer of toxic substances through the food chain and the potential risks to human health. In addition, future studies should focus on histopathological and biochemical analysis of fish tissues to understand the physiological and cellular damage caused by heavy metal toxicity.

Another important area for future research is the development of effective and low-cost wastewater treatment technologies for industries to reduce pollution at the source. Studies can be conducted on bioremediation, phytoremediation, and microbial treatment methods for removing heavy metals and toxic pollutants from industrial wastewater.

Future research should also focus on ecological risk assessment and environmental impact modeling to predict the long-term effects of industrial pollution on river ecosystems. The use of Geographic Information Systems (GIS) and remote sensing techniques can help in monitoring river pollution and identifying pollution hotspots.

12. Conclusion

The present study examined the impact of industrial pollution on aquatic life in a riverine system by analyzing physico-chemical parameters and heavy metal concentrations in water and fish samples. The results of the study revealed that industrial effluents significantly deteriorate river water quality by increasing biological oxygen demand (BOD), chemical oxygen demand (COD), and heavy metal concentration, while reducing dissolved oxygen (DO) levels. The observed values of several water quality parameters exceeded the permissible limits recommended by WHO and BIS standards, indicating severe water pollution in the study area.

The study also found that heavy metals such as chromium, lead, and cadmium accumulated in fish tissues collected from polluted sites, indicating bioaccumulation of toxic substances in aquatic organisms. This bioaccumulation not only affects fish health, growth, and reproduction but also poses serious risks to human health through the food chain. The reduction in fish diversity, fish mortality, and disappearance of sensitive species in polluted areas clearly indicate that industrial pollution has caused significant ecological damage and ecosystem imbalance in the riverine system.

The environmental impact assessment conducted in this study shows that industrial pollution affects water quality, aquatic organisms, biodiversity, and overall river ecosystem health. The findings of the study confirm that untreated industrial effluents are one of the major causes of aquatic ecosystem degradation in riverine systems. Therefore, effective pollution control measures, strict environmental regulations, and sustainable industrial practices are necessary to reduce industrial pollution and protect aquatic life.

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