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Intrusion of Mercury and Micro Plastics in the Aquatic Food Chain Its Effects on Fish Consumption Risks, Realities, and Policy Implications

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Abstract: Aquatic ecosystems are increasingly threatened by pollutants such as mercury and micro plastics, both of which disrupt food web dynamics. Mercury, a persistent and bio accumulative heavy metal, enters aquatic systems through industrial discharge and atmospheric deposition, accumulating in organisms and biomagnifying across trophic levels. Micro plastics, defined as plastic fragments smaller than 5 mm, are ingested by a wide range of aquatic organisms, impairing feeding, growth, and reproduction. Moreover, micro plastics act as vectors for toxic substances, including heavy metals like mercury, facilitating their transfer through the food chain. The combined presence of mercury and micro plastics poses synergistic risks, intensifying toxic effects and threatening biodiversity, ecosystem services, and human health via seafood consumption. This paper explores the pathways, interactions, and consequences of mercury and micro plastics in aquatic food chains, highlighting the urgent need for integrated pollution management and policy interventions to safeguard aquatic resources and food security.

I. Introduction

Public concern over mercury and microplastics in fish has grown in recent years, fueled by media headlines and social debates. Fish, once universally praised for its nutritional value, is now often viewed with suspicion. This paper examines the reality of these risks, with a focus on India, where fish is both a staple food and a major livelihood resource. Mercury, primarily introduced through human activities such as coal burning and industrial discharge, bioaccumulates and biomagnifies in aquatic food chains, posing health risks in large predatory fish. However, Indian diets largely rely on small fish species with short lifespans, which generally contain mercury levels well within safe international limits. Microplastics, another emerging pollutant, are widespread in aquatic environments but are mostly located in fish digestive tracts, which are typically removed during preparation. Recent Indian studies reveal measurable levels of microplastics and heavy metals in seafood and freshwater species, but evidence suggests that risks remain manageable if consumers choose small, low-mercury fish and avoid highly polluted waters. This study argues for balanced consumer awareness, strengthened pollution control policies, and improved waste management to mitigate environmental impacts while ensuring safe and nutritious fish for consumers.

Fish has long been recognized as a vital source of high-quality protein, omega-3 fatty acids, and essential vitamins and minerals. Yet in recent years, rising awareness of contaminants such as mercury and microplastics has led to confusion among consumers regarding the safety of fish consumption. While these pollutants pose real challenges, the degree of risk varies significantly by species, environment, and preparation methods. This paper investigates mercury and microplastic contamination in fish, with a special focus on India, and examines how scientific evidence compares to public perceptions.

Mercury Contamination in Fish and Its Source

Mercury occurs naturally in air, soil, and water, but human activities such as coal combustion, mining, and industrial waste discharge have significantly increased environmental concentrations. Once in aquatic systems, mercury is converted by microorganisms into methyl mercury, its most toxic form.

Bioaccumulation and Biomagnification

Methyl mercury enters aquatic food webs through plankton and small organisms, gradually concentrating as larger fish consume smaller ones. Large, long-lived predators such as sharks, swordfish, and certain tuna species exhibit the highest mercury levels due to bio magnification.

Mercury in Indian Fish Species

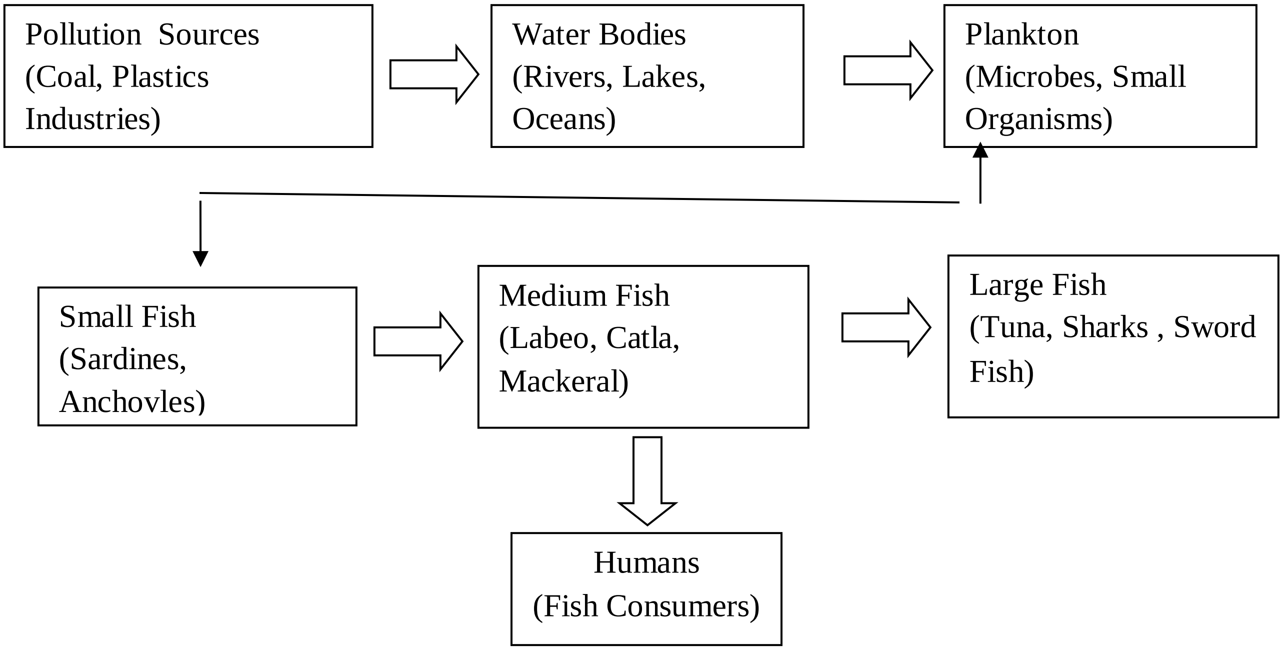
In India, the most commonly consumed fish include sardines, mackerel, anchovies, rohu, and catla. These are smaller, short-lived, and lower on the food chain, leading to relatively low mercury concentrations. Studies confirm that mercury levels in these species remain within limits set by the World Health Organization (WHO) and the Food and Agriculture Organization (FAO). Health agencies recommend avoiding large, high-mercury fish for vulnerable groups, while encouraging regular consumption of low-mercury species for their nutritional benefits.

Microplastics in Fish and Sources and Characteristics

Microplastics, defined as plastic particles smaller than 5 mm, result from the degradation of plastic waste or originate directly from synthetic textiles, personal care products, and industrial processes. These pollutants are now pervasive in oceans, rivers, and lakes.

Pathways into the Food Chain

Fish ingest microplastics either by mistaking them for food or indirectly through prey species. Studies show that microplastics are most commonly found in fish stomachs and intestines and other organs that are generally removed before consumption.



Risks to Consumers

For most Indian consumers, who eat cleaned and gutted fish, microplastic ingestion is minimal. Exceptions include traditional dishes that use whole small fish or dried fish, where limited exposure may occur. While short-term health risks appear low, the long-term effects remain uncertain. More concerning is the environmental role of microplastics, which can carry toxic chemicals and damage aquatic ecosystems.

Case Studies from India

Micro plastics in Seafood along the Vizag Coast

A 2025 study under the EU's Eco Marine project analyzed 100 specimens from 15 edible marine species including shrimp, crabs, squid, and fish caught off the Visakhapatnam (Vizag) coast. Researchers found micro plastics in every sample, mostly polyethylene, polypropylene, PVC, and nylon, with particle sizes below 120 µm. While most were located in non-edible organs, the study highlighted potential risks for consumers who eat whole small fish or dried fish.

Heavy Metals and Micro plastics in Gujarat Rivers

Two independent studies conducted in the Narmada and Mahi rivers (2024) found alarming levels of heavy metals such as nickel, chromium, lead, manganese, and arsenic in water, sediments, and fish tissues (e.g., *Labeo rohita* and *Salmostoma phulo*). Microplastics ranging from 0.5 to 4 mm, made of polypropylene and nylon, were also detected in both fish and river water. These findings raise concerns about inland freshwater fish safety in highly industrialized regions.

Microplastics in Freshwater Mussels in West Bengal

A 2024 market-based study in West Bengal examined 373 freshwater mussels (*Lamellidens marginalis*), of which 302 contained microplastics. Fiber-shaped plastics were the most common form detected. Researchers warned of potential human health risks, including inflammation, oxidative stress, and genetic damage if exposure accumulates over time.

Table: Mercury and Microplastic Risks in Commonly Consumed Indian Fish

Fish/Seafood	Trophic Level	Mercury Risk	Microplastic Risk	Consumption Safety
Sardines (*Sardinella longiceps*)	Low	Very Low	Moderate (digestive tract only)	Safe; rich in omega-3; commonly eaten in Kerala & Goa.
Indian Mackerel (*Rastrelliger kanagurta*)	Low–Mid	Low	Moderate	Safe; WHO/FAO data show mercury within limits.

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Anchovies (*Stolephorus spp.*)	Low	Very Low	Moderate (whole fish dishes may increase exposure)	Safe when gutted; caution if eaten whole/dried.
Rohu (*Labeo rohita*)	Mid	Low	High (freshwater rivers like Gujarat show contamination)	Safe in general, but avoid fish from heavily industrialized rivers.
Catla (*Catla catla*)	Mid	Low	High (similar to Rohu)	Safe in clean water sources; risks rise in polluted areas.
Shrimp/Prawns	Low	Very Low	Moderate–High (microplastics common in intestines)	Safe when cleaned/deveined.
Squid & Crabs	Mid	Low	High (Vizag study detected microplastics in all specimens)	Edible tissues safer than gut content.
Tuna (large oceanic species)	High	High bioaccumulation)	Moderate	Should be limited, especially for pregnant women & children.
Shark/ Swordfish	Very High	Very High	Low–Moderate	Avoid; mercury often exceeds safety limits.
Freshwater Mussels (*Lamellidens marginalis*)	Low (filter feeder)	Low	Very High (West Bengal study showed 81% contaminated)	Potentially unsafe if consumed regularly.

II. Discussion

The Indian case studies demonstrate that while mercury levels in commonly consumed small fish remain within safe limits, microplastic contamination is widespread in both marine and freshwater environments. Importantly, most microplastics are localized in digestive tracts and are removed during food preparation, reducing direct risks to consumers. However, the adsorption of heavy metals onto microplastics, as observed in Gujarat, suggests a compounded toxicity that could affect food safety if pollutants migrate into edible tissues. From a public health perspective, the benefits of eating small, low-mercury fish (sardines, mackerel, Rohu, Catla) still outweigh potential risks. The larger threat lies in long-term ecosystem degradation caused by plastic pollution and heavy metal accumulation, which may compromise future fish stocks and livelihoods of fishing communities.

III. Conclusion

Mercury and microplastics highlight the complex intersection of environmental pollution, food safety, and public health. In India, current risks from commonly consumed fish are generally low and manageable, provided consumers make informed choices and avoid highly polluted fishing areas. Case studies from Vizag, Gujarat, and West Bengal confirm contamination trends but also suggest that risks are species and region-specific. Tackling the root causes industrial emissions, poor plastic waste management, and inadequate pollution monitoring is essential. Stronger regulations, public awareness campaigns, and sustainable fisheries management will ensure that fish continue to be a safe, nutritious, and culturally vital food source.

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