



# Freshwater Fish Safety and Bioaccumulation of Heavy Metals and Pesticides in South Dinajpur District

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**Abstract-** Freshwater fish safety has become an important issue at the intersection of aquatic ecology, food security, and public health in eastern India. This is especially true in agrarian districts where rivers, wetlands, canals, ponds, and aquaculture systems remain closely linked to agricultural landscapes. South Dinajpur district in West Bengal represents one such setting. Official district records describe a flood-sensitive agricultural district with a cropping intensity of 176 percent, substantial rainfed cultivation, and measurable freshwater resources including river, canal, and beel or baor areas. Earlier ichthyological work further recorded 49 fish species in the freshwater rivers of the district, indicating both ecological diversity and food-system relevance. Yet no integrated district-level study is readily available on fish safety in relation to both heavy metals and agricultural pesticides. This paper addresses that gap through a conceptual review. It synthesizes official district information, peer-reviewed research from West Bengal and the lower Gangetic region, and broader Indian literature on fish bioaccumulation, pesticide pollution, and food-safety regulation. The paper argues that South Dinajpur should be understood as a likely mixed-contaminant freshwater landscape in which agricultural runoff, hydrological connectivity, sediment transport, fish ecology, and local fish consumption interact to shape risk. It concludes that fish safety in the district cannot be assessed through single-contaminant or single-tissue approaches alone. Instead, a district-level framework linking habitat, species ecology, tissue accumulation, and human dietary exposure is required. The paper contributes a review-based conference model for future empirical study and for policy discussion on inland fish safety in eastern India.

**Keywords-** freshwater fish safety, bioaccumulation, heavy metals, pesticide residues, South Dinajpur, West Bengal.

## I. INTRODUCTION

Freshwater fish occupy a central position in aquatic food webs and in human diets, which is why fish contamination has become both an environmental and a food-safety concern. Fish can absorb contaminants from water, sediments, and prey organisms, and they can retain these contaminants in biologically important tissues over time. Recent review literature emphasizes that heavy metals in fish matter not only because they signal environmental degradation, but also because they transfer risk from water bodies to human consumers. Similar concerns now extend to pesticide residues, especially in



agricultural regions where surface runoff, drainage channels, and sediment movement connect cropland to fish habitats.

The South Dinajpur context makes this issue especially important. The district contingency plan identifies Dakshin Dinajpur as part of the Lower Gangetic Plain and the old alluvial zone. It records a cropping intensity of 176 percent, net irrigated area of 82.54 thousand hectares, rainfed area of 93.08 thousand hectares, and clear flood contingencies affecting both agriculture and aquaculture. The same document records freshwater fisheries-linked areas including 145.94 ha of river area, 114.18 ha of canal area, and 486.02 ha of beel or baor area, alongside district fish production of 36,528 tons in 2008-09. These figures indicate that South Dinajpur is not simply an agricultural district; it is an agriculture-water-fish district where rural production systems are closely interconnected.

The ecological base of this issue is also well established. Chakraborty and Bhattacharjee documented 49 fish species in the freshwater rivers of South Dinajpur, showing that the district's riverine systems support a meaningful range of edible and ecologically important species. That matters because fish safety cannot be reduced to one market sample or one farmed species. Different fish species vary by trophic level, habitat use, sediment contact, feeding strategy, and tissue chemistry, all of which influence contaminant uptake. In other words, fish safety is inseparable from fish ecology.

The wider regional evidence gives further reason for concern. In the East Kolkata Wetlands, Dutta et al. found measurable burdens of Pb, Cd, Cr, and Hg in edible fish and showed clear species-wise and seasonal differences, with monsoon accumulation exceeding post-monsoon, winter, and pre-monsoon levels and with tilapia showing higher overall burden than rohu and catla. In the lower Gangetic stretch, Kumar et al. evaluated potentially toxic elements in commercially important food fish and framed the issue directly in relation to food security and human health risk. Around Kolkata, Aktar et al. reported pesticide residues in fish from the Ganga, including HCH, DDT, endosulfan, dimethoate, and malathion. These studies do not prove that South Dinajpur fish are unsafe, but they make it unreasonable to assume safety in the absence of district-level evidence.

This paper therefore addresses a specific research problem: how should freshwater fish safety in South Dinajpur be understood when the district's agrarian and hydrological structure makes mixed contamination plausible, but integrated district-level evidence remains limited? The paper asks four linked questions. First, what pathways are most likely to move heavy metals and pesticides into fish habitats in South Dinajpur? Second, how do fish species and tissues shape bioaccumulation patterns? Third, what can regional evidence from West Bengal and the lower Gangetic system tell us about likely risk in the district? Fourth, what research framework is needed to move from plausible concern to defensible district evidence? The paper argues that fish safety in South Dinajpur should be treated as a mixed-contaminant problem requiring integrated attention to landscape, species ecology, tissue analysis, and human dietary exposure.

## II. LITERATURE REVIEW

The literature on fish contamination is built around the concept of bioaccumulation. Heavy metals such as lead, cadmium, chromium, and mercury can enter aquatic systems through agricultural runoff, sewage, household waste, soil erosion, and other anthropogenic sources. Once in water bodies, they may dissolve, bind to particles, settle in sediments, or enter food webs. Fish then accumulate these metals through branchial uptake, ingestion of contaminated particles or prey, and contact with sediments. Review literature emphasizes that fish contamination is shaped not only by the concentration of metals in the environment but also by species, age, exposure duration, habitat, and organ function. Pesticides complicate this picture because they follow partly different pathways. Kashyap et al. show that intensive agriculture in India has resulted in widespread pesticide use, with residues detected in



soil, surface water, and groundwater and with continuing policy concern over monitoring and control. In fish systems, some compounds are persistent and lipophilic, while others are less persistent but still toxic under repeated exposure. The key point is that agricultural landscapes generate both direct and indirect routes of pesticide entry into aquatic food webs, especially where drainage, flood pulses, and water reuse create repeated contact between field and water body.

A major debate in this literature concerns tissue selection. From a toxicological perspective, liver and gills are often important because liver is associated with metabolism and detoxification, while gills are in direct contact with the aquatic medium. From a food-safety perspective, however, muscle matters most because it is the primary edible tissue. Review literature on heavy-metal bioaccumulation repeatedly stresses this distinction. A study that focuses only on muscle may understate ecological exposure, while a study that focuses only on liver or gills may overstate consumer exposure if edible tissue is not also assessed. This makes tissue selection a conceptual issue rather than a laboratory detail.

A second debate concerns species differences. The East Kolkata Wetlands study is particularly useful because it shows that metal accumulation is species-specific even within the same system. Tilapia, rohu, and catla did not accumulate metals uniformly. This is consistent with wider review evidence that species ecology, trophic position, sediment contact, growth rate, and physiology all affect contaminant burden. For South Dinajpur, where the district's fish diversity includes multiple ecological guilds, this suggests that any meaningful fish-safety assessment must go beyond a single commercially convenient species.

A third debate concerns the separation of heavy-metal and pesticide studies. Much of the literature treats them independently, even though real freshwater systems expose fish to mixtures rather than isolated contaminant classes. This creates a practical and analytical problem. A district may appear relatively safe if only metals are tested, while pesticide burdens remain unknown, or vice versa. The problem is particularly acute in agrarian districts, where both metal and pesticide pathways can operate at once. Recent review literature on fish and human health risk supports moving toward an integrated "water to plate" perspective, while the Indian pesticide review underscores the need for stronger monitoring and regulatory attention.

A fourth debate concerns governance and food safety. India has an active regulatory framework through the Food Safety and Standards (Contaminants, Toxins and Residues) Regulations, 2011, as updated in 2025. These regulations define contaminants and residues within the food system and establish the legal basis for controlling them. Yet regulation alone does not guarantee district-level surveillance. Inland fish often move through informal or semi-formal channels, and residue monitoring is rarely visible to local consumers. The literature therefore suggests a recurring gap between regulatory existence and practical detection. Fish safety in districts such as South Dinajpur depends not only on contamination levels but also on whether local surveillance systems can detect, interpret, and communicate those levels.

### **III. METHODOLOGY OR CONCEPTUAL APPROACH**

This paper is conceptual in method and structured as a review-based district case study. It does not present original laboratory or field data from South Dinajpur. A true empirical paper on this topic would require fish-tissue analysis, water and sediment testing, seasonal sampling, and local consumption data. Since such data are not provided here, the strongest and most defensible conference-paper format is a conceptual review that synthesizes district context, regional evidence, and current toxicological literature into a district-specific framework.

The source base for this paper consists of three categories. First, official district records were used to establish South Dinajpur's agro-hydrological and fisheries context. Second, peer-reviewed studies from



West Bengal and the lower Gangetic region were used to identify evidence already available from ecologically relevant settings. Third, broader review and policy sources were used to build the conceptual link between aquatic contamination, fish tissue accumulation, and food safety. This combination makes it possible to interpret South Dinajpur not as a blank space, but as a district where the conditions for mixed contamination can be evaluated conceptually even before a full empirical survey is undertaken.

Figure 1 presents the paper's conceptual framework. It shows fish safety as the end product of a linked sequence rather than a single laboratory event.

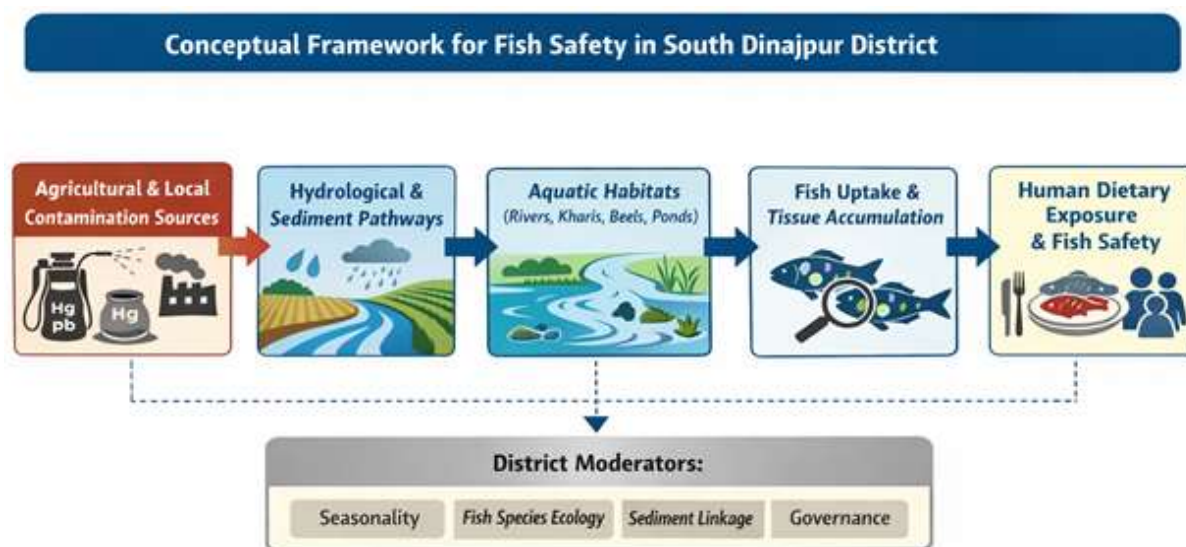


Figure 1. Conceptual framework for fish safety in South Dinajpur district

District moderators: seasonality, fish species ecology, sediment linkage, and governance

This framework is useful because it avoids two common errors. The first is reducing fish contamination to a single source, such as current pesticide use on cropland. The second is treating fish contamination only as an environmental issue without connecting it to human consumption. In South Dinajpur, fish safety must be understood through the relationship between landscape, aquatic pathways, fish biology, and food systems.

Table 1 summarizes the most relevant studies for building a South Dinajpur framework. It is not a substitute for district evidence, but it shows what kinds of findings already exist in nearby or conceptually similar systems.

Study	Location	Main focus	Relevance to South Dinajpur
Dutta et al. (2022)	East Kolkata Wetlands, West Bengal	Pb, Cd, Cr, Hg in edible fish	Shows species-specific and seasonal metal accumulation in a West Bengal wetland system
Kumar et al. (2024)	Lower Gangetic stretch	Potentially toxic elements in food fish	Connects fish contamination directly to food security and health-risk assessment
Aktar et al. (2009)	Ganga around Kolkata	Pesticide residues in fish	Demonstrates residue occurrence in West Bengal fish, including HCH, DDT, endosulfan, dimethoate, and malathion



Study	Location	Main focus	Relevance to South Dinajpur
Kashyap et al. (2024)	India-wide review	Pesticide pollution and policy	Establishes intensive agriculture as a continuing contamination driver in India
Ray and Vashishth (2024)	Review	Heavy-metal bioaccumulation and human risk	Provides a strong "water to plate" conceptual framework
Emon et al. (2023)	Review	Heavy-metal uptake and tissue accumulation	Clarifies source pathways and organ-level accumulation patterns

#### IV. RESULTS OR ANALYSIS

The first analytical result is that South Dinajpur should be treated as an exposure landscape rather than as a neutral district background. The district's agricultural intensity, rainfed dependence, river and beel resources, flood contingencies, and aquaculture vulnerabilities all increase the plausibility of contaminant transfer into fish habitats. This does not prove contamination by itself, but it establishes that the district has the structural conditions under which mixed contamination can occur and persist. In districts like this, fish safety cannot be assumed in the absence of evidence.

The second analytical result is that heavy-metal bioaccumulation in South Dinajpur should be expected to vary by species, tissue, and season if the district is studied empirically. The East Kolkata Wetlands study gives a clear regional example: metal accumulation followed both a seasonal pattern and a species pattern. Review literature supports the same conclusion more generally. Fish absorb metals through water and sediments, but bioaccumulation becomes visible through biological processes such as organ function, trophic level, and exposure duration. This means that a South Dinajpur study limited to one species or one season would likely miss much of the actual variability in fish safety.

The third analytical result is that pesticide risk in South Dinajpur is likely to be both contemporary and legacy-based. The Indian pesticide review makes clear that intensive agriculture remains a major source of environmental pesticide load. The West Bengal fish-residue study around Kolkata shows that multiple pesticide groups have already been detected in fish within the state. This means that a district like South Dinajpur may face contamination from current agricultural use, past residues in soils and sediments, and possibly chemical use within aquaculture itself. The West Bengal aquaculture survey strengthens this concern by documenting 109 different aquaculture-related products across freshwater farms in 15 districts of the state and reporting that many farmers lacked adequate knowledge about dosage, use, and residue implications. Even though South Dinajpur was not singled out in that survey, the study shows that chemical complexity in West Bengal aquaculture is real.

The fourth analytical result is that fish safety in South Dinajpur cannot be interpreted properly through single-contaminant studies alone. A district may appear relatively safe if only metals are assessed, while pesticide residues remain unmeasured, or vice versa. But fish in agrarian landscapes are exposed to mixtures. Sediments can carry metals and legacy pesticides at the same time. Flooding can remobilize both. Fish species can move between habitats and accumulate contaminants through more than one route. This is why an integrated approach is conceptually stronger than separate studies conducted in isolation. Fish safety is a cumulative question even when regulation is organized by separate contaminant categories.

The fifth analytical result concerns the relationship between fish safety and public health. Regional studies now routinely move beyond concentration reporting toward health-risk interpretation. The



lower Gangetic fish study explicitly links tissue contamination to food security and human health risk, while broader reviews emphasize the transfer of contaminants from water bodies into consumers. In a fish-dependent food culture such as West Bengal, this is especially important. The problem is not only whether contamination exists, but whether commonly consumed species, edible tissues, and local dietary frequency create meaningful exposure over time. Fish safety is therefore not an abstract laboratory concern. It is part of everyday food security.

The sixth analytical result is that governance remains a weak link. India has food-safety regulations and a legal basis for contaminant control, but regulation is not the same as active surveillance. Inland fish markets rarely provide species-wise residue information, and district-level consumer advisories are uncommon. This means that fish safety often depends on research studies rather than routine public communication. In South Dinajpur, the governance question is therefore straightforward: without district-level residue monitoring, neither consumers nor policymakers can know which fish species, habitats, or seasons deserve greater caution or confidence.

## V. DISCUSSION

The evidence reviewed here supports a clear interpretation: South Dinajpur is not merely a district lacking data. It is a district where the ecological and agricultural conditions make fish-safety research especially necessary. The combination of rivers, canals, beels, aquaculture systems, flood sensitivity, and intensive cultivation means that contaminants can move through multiple pathways before entering fish tissues. This is why the district should be approached as an interconnected aquatic landscape rather than as a set of isolated water bodies.

The paper also clarifies that fish safety is both an ecological and a food-system issue. From an ecological point of view, contamination affects fish health, habitat quality, and species-specific vulnerability. From a food-system point of view, contamination influences the safety of edible fish moving through local markets and households. The significance of this dual perspective is that it prevents a narrow reading of contamination. A district may maintain fish production and still face food-safety uncertainty if residue surveillance is absent. Conversely, a district may have contamination hotspots without all fish being uniformly unsafe. Good research is needed to distinguish between these outcomes.

Another important implication concerns research design. The conceptual literature and the regional case evidence both suggest that the next stage of South Dinajpur research should be mixed-contaminant and mixed-media. Muscle data alone are not enough for ecological interpretation. Water data alone are not enough for food safety. Sediment data alone cannot explain species differences. A stronger district study would combine fish-tissue analysis, sediment analysis, some water chemistry, species ecology, and local consumption patterns. That design would make it possible to connect laboratory results to both ecosystem pathways and dietary exposure.

Finally, the paper suggests that South Dinajpur matters analytically because it shifts attention away from only large industrial or metropolitan systems. Smaller agrarian districts may reveal the cumulative effects of diffuse pollution more clearly than iconic polluted rivers do. In such settings, the absence of a dramatic industrial source can create a false sense of safety, even though agricultural intensity, sediment transport, and aquaculture chemical use may produce meaningful long-term risk. A district-centered conference paper is therefore not a minor scale of analysis. It is one of the most useful scales for thinking about fish safety in inland India.

## VI. CONCLUSION AND FUTURE WORK



This paper has argued that a conceptual conference paper is the most defensible present format for the topic "Freshwater Fish Safety and Bioaccumulation of Heavy Metals and Pesticides in South Dinajpur District." The district's agrarian structure, hydrological connectivity, fish diversity, and flood-sensitive landscape all make mixed contamination plausible, while regional evidence from West Bengal and the lower Gangetic basin confirms that edible fish in comparable systems can accumulate both heavy metals and pesticide residues. The main conclusion is that fish safety in South Dinajpur should be approached as a district-level public health and environmental issue, not as a question that can be settled through assumptions of either contamination or safety.

The paper's central contribution is conceptual. It proposes that fish safety in the district should be understood through a linked sequence of source, pathway, habitat, species ecology, tissue accumulation, and human exposure. This framework is useful because it connects environmental toxicology to food safety and district governance. It also provides a clearer basis for future empirical work than a single-contaminant or single-site approach would.

Future work should move in four directions. First, South Dinajpur needs a district-level baseline survey that measures both heavy metals and pesticide residues in edible fish. Second, sampling should cover rivers, canals, beels, ponds, and market sources across seasons. Third, the study should include multiple fish species and more than one tissue type in order to distinguish ecological exposure from consumer exposure. Fourth, local fish-consumption data should be incorporated so that health-risk interpretation reflects district dietary practice rather than generic assumptions. These steps would allow the present conceptual paper to be converted into a full empirical research agenda for zoology, public health, and fisheries governance.

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