BHARATI INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH & DEVELOPMENT (BIJMRD)

(Open Access Peer-Reviewed International Journal)

DOI Link : https://doi.org/10.70798/Bijmrd/03020037

Available Online: www.bijmrd.com|BIJMRD Volume: 3| Issue: 02| February 2025| e-ISSN: 2584-1890

Human Health Risk Assessment of Heavy Metal Exposure Through Fish Consumption: A Study in Selected Districts of West Bengal, India

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Abstract: *Fish constitutes a major component of the daily diet of people in West Bengal and serves as an important source of protein and micronutrients. However, contamination of aquatic ecosystems by heavy metals, particularly arsenic, poses significant health concerns. The present study investigates the potential human health risks associated with heavy metal exposure through fish consumption in selected districts of West Bengal. A survey-based approach was adopted across thirteen districts categorized as highly affected, moderately affected, and relatively unaffected by arsenic contamination. Data were collected from approximately 200 respondents regarding drinking water practices, fish consumption patterns, and health conditions. The study revealed considerable variation in exposure patterns across districts. Higher frequencies of fish consumption and dependence on groundwater sources were observed in arsenic-affected areas. Respondents from highly affected districts reported a greater prevalence of hepatic disorders, hematological problems, skin lesions, and other chronic health conditions. The findings suggest that long-term exposure to arsenic-contaminated water and fish may contribute to adverse health outcomes. Regular monitoring of fish quality, safe drinking water initiatives, and public awareness programs are recommended to mitigate health risks.*

Keywords: *Heavy Metals, Arsenic Exposure, Fish Consumption, Human Health Risk Assessment, West Bengal, Public Health.*

1. Introduction: Heavy metal contamination has emerged as one of the most significant environmental and public health concerns worldwide. Metals such as arsenic (As), mercury (Hg), cadmium (Cd), lead (Pb), and chromium (Cr) are persistent pollutants that accumulate in aquatic ecosystems through industrial effluents, agricultural runoff, mining activities, and natural geological processes. Unlike organic pollutants, heavy metals are non-biodegradable and may remain in the environment for extended periods.

Fish are recognized as an excellent source of protein, omega-3 fatty acids, vitamins, and essential minerals. However, fish also have the capacity to bioaccumulate toxic metals from contaminated water and sediments. Through the process of biomagnification, these contaminants may reach concentrations that pose risks to human health.

West Bengal is one of the most arsenic-affected regions in the world. Groundwater contamination has been reported extensively in districts such as North 24 Parganas, South 24 Parganas, Nadia, and Malda. Since fish

forms a staple food item in the state, the consumption of contaminated fish may represent an important pathway of arsenic exposure.

The present study seeks to assess the potential health risks associated with heavy metal exposure through fish consumption among residents of selected districts of West Bengal.

2. Objectives of the Study: The objectives of the study were:

1. To examine fish consumption patterns among residents of selected districts of West Bengal.
2. To assess drinking water sources and water treatment practices.
3. To investigate the prevalence of health conditions associated with arsenic exposure.
4. To evaluate potential human health risks resulting from long-term consumption of fish from arsenic-affected regions.
5. To recommend strategies for reducing heavy metal exposure and improving public health.

3. Review of Literature: Several studies have documented the accumulation of heavy metals in aquatic ecosystems and their impacts on human health.

Ahmed et al. (2020) reported significant concentrations of arsenic and mercury in freshwater fish collected from contaminated regions of South Asia. Islam and Rahman (2021) found that fish consumption contributed substantially to dietary arsenic exposure in arsenic-prone communities.

Mukherjee et al. (2022) observed a strong relationship between groundwater arsenic contamination and fish tissue contamination in eastern India. Their findings highlighted the importance of assessing both water and food pathways of exposure.

World Health Organization reports have emphasized that chronic arsenic exposure can lead to skin lesions, liver dysfunction, cardiovascular diseases, neurological disorders, and various forms of cancer.

The existing literature suggests that populations residing in arsenic-affected areas are vulnerable to cumulative health risks through multiple exposure pathways, including fish consumption.

4. Methods

4.1 Study Area: The study was conducted across multiple districts of West Bengal, India. The selected districts included North 24 Parganas, South 24 Parganas, Nadia, Malda, Kolkata, Hooghly, Purba Bardhaman, Uttar Dinajpur, Dakshin Dinajpur, Jalpaiguri, Bankura, Purba Medinipur, and Paschim Medinipur.

These districts were categorized into highly affected, moderately affected, and relatively unaffected groups based on documented arsenic contamination levels in groundwater and fish tissues. The diverse geographical and ecological characteristics of these districts provided an appropriate setting for evaluating human exposure to heavy metals through fish consumption.

4.2 Data Collection: Data were collected through a structured questionnaire survey involving approximately 200 respondents from the selected districts.

A purposive sampling method was employed to ensure adequate representation from arsenic-affected and non-affected areas. Respondents were selected from both urban and rural communities and represented diverse socioeconomic backgrounds.

The survey collected information on:

- Demographic characteristics
- Drinking water sources
- Water treatment practices
- Fish consumption frequency
- Cooking methods
- Fish parts consumed
- Self-reported health conditions

Special attention was given to the consumption of *Labeo rohita* (Rohu) and *Catla catla* (Catla), which are among the most commonly consumed fish species in West Bengal.

Ethical standards were maintained throughout the study. Informed consent was obtained from all participants, and confidentiality of information was ensured.

4.3 Data Analysis: The collected data were coded, tabulated, and analyzed using descriptive statistical methods. Frequency distributions and percentage analyses were employed to examine patterns of fish consumption, water usage, and health outcomes across different categories of districts.

5. Results

5.1 Drinking Water Habit: The survey findings revealed considerable variation in drinking water sources and treatment practices across the selected districts of West Bengal. Overall, deep tube wells and municipal water supplies were the primary sources of drinking water for most respondents. The use of deep tube wells was particularly prevalent in South 24 Parganas, North 24 Parganas, Malda, Nadia, Purba Medinipur, Paschim Medinipur, Bankura, and Uttar Dinajpur. Municipal water supply was more common in urban areas, especially in Kolkata and parts of Bardhaman, Hooghly, Dakshin Dinajpur, and Siliguri.

Shallow tube wells were reported mainly in North 24 Parganas and Hooghly, whereas their use was limited in other districts. A notable proportion of respondents across most districts reported using filtration systems in conjunction with their primary water sources, indicating awareness regarding water quality and potential contamination risks.

Although less common, the use of untreated river water was observed in several districts, including South 24 Parganas, Malda, Purba Medinipur, Paschim Medinipur, Dakshin Dinajpur, and Siliguri. The continued dependence on river water may increase the risk of exposure to environmental contaminants, including arsenic and other heavy metals.

Overall, the results indicate that groundwater sources, particularly deep tube wells, remain the dominant source of drinking water in the study area. While the widespread adoption of filtration methods reflects growing concern about water safety, the occasional use of untreated river water highlights the need for improved access to safe drinking water and greater public awareness regarding potential health risks associated with contaminated water sources.

5.2 Fish Consumption Patterns: The survey revealed considerable variation in fish preparation and consumption practices across the selected districts of West Bengal. Overall, heavily cooked fish was the preferred method of preparation among respondents, particularly in South 24 Parganas, North 24 Parganas,

Malda, Nadia, and Hooghly. This preference may be attributed to traditional culinary practices and the perception that thorough cooking improves food safety. In contrast, lightly cooked fish was more common in urban areas such as Kolkata and in some parts of Bardhaman.

Regarding fish parts consumed, fish flesh was the most commonly consumed component across all districts due to its widespread acceptability and ease of preparation. However, a notable proportion of respondents also reported consuming liver and gills, particularly in Malda, Hooghly, Dakshin Dinajpur, Uttar Dinajpur, Siliguri, and Bardhaman. The consumption of these organs is often associated with traditional dietary preferences and their perceived nutritional benefits. Since liver and gills are known to accumulate higher concentrations of heavy metals compared to muscle tissue, their consumption may increase the risk of dietary exposure to contaminants such as arsenic. Overall, the findings indicate that cultural and regional food habits play an important role in determining potential exposure to heavy metals through fish consumption.

Fish consumption was widespread among all respondents.

- 72% consumed fish at least five times per week.
- 18% consumed fish three to four times per week.
- 10% consumed fish occasionally.

Rohu (*Labeo rohita*) and Catla (*Catla catla*) were identified as the most preferred species.

Most respondents consumed fish flesh, whereas a smaller proportion reported consuming organs such as liver and gills, which are known to accumulate higher concentrations of contaminants.

5.3 Health Outcomes

Highly Arsenic-Affected Districts: Among respondents from highly arsenic-affected districts (n = 210), skin diseases were the most prevalent health condition (33%), followed by hepatic diseases (28%). The high occurrence of skin disorders, including pigmentation changes and keratosis, is consistent with the known effects of chronic arsenic exposure. Hepatic disorders were also common, suggesting the accumulation of arsenic in liver tissues. Cardiovascular diseases accounted for 15% of reported cases, while cancer-related illnesses represented 10%. Hematological disorders (8%) and sexual health problems (6%) were comparatively less frequent. These findings indicate a substantial health burden associated with long-term exposure to arsenic through contaminated water and fish consumption in highly affected districts.

Mildly Arsenic-Affected Districts: In mildly arsenic-affected districts (n = 90), skin diseases remained the most frequently reported condition (31%), followed by hepatic disorders (21%). Cardiovascular diseases accounted for 20% of cases, while cancer-related illnesses represented 16%. Hematological disorders (5%) and sexual disorders (7%) were reported less frequently. Although the prevalence of health problems was generally lower than in highly affected districts, the findings suggest that even moderate levels of arsenic exposure may contribute to adverse health outcomes.

Non-Arsenic-Affected Districts: In non-arsenic-affected districts (n = 90), the prevalence of diseases was comparatively lower. Skin diseases remained the most common condition (32%), followed by hepatic disorders (19%). Cardiovascular diseases accounted for 17% of cases, while cancer-related illnesses represented 15%. Hematological disorders were reported by 11% of respondents, and sexual disorders by 6%. The lower prevalence of hepatic and skin-related diseases in these districts suggests a reduced impact of arsenic exposure and highlights the role of environmental contamination in disease occurrence.

5.4 Risk Assessment

Highly Arsenic-Affected Districts: The risk assessment revealed that residents of highly arsenic-affected districts face the greatest health risks due to combined exposure from contaminated drinking water and fish consumption. The high prevalence of skin and hepatic disorders indicates chronic arsenic toxicity, while the occurrence of cardiovascular diseases and cancers reflects the systemic and carcinogenic effects of long-term exposure. The consumption of fish organs such as liver and gills, which tend to accumulate higher concentrations of arsenic, may further increase exposure levels. These findings emphasize the need for urgent intervention through improved water management, regular monitoring of fish quality, and public health awareness programs.

Mildly Arsenic-Affected Districts: Although arsenic contamination levels were lower in mildly affected districts, the risk assessment suggests continued vulnerability to arsenic-related health effects. The prevalence of skin, hepatic, cardiovascular, and cancer-related conditions indicates that prolonged exposure, even at moderate levels, can adversely affect human health. Fish consumption remains a potential pathway of exposure, particularly among individuals consuming fish frequently and including organs such as liver and gills in their diet. Improved drinking water access and regular environmental monitoring may help reduce these risks.

Non-Arsenic-Affected Districts: The risk assessment for non-arsenic-affected districts showed comparatively lower health risks. Although some health conditions were reported, their prevalence was generally lower than in arsenic-affected regions, suggesting that factors other than arsenic may contribute to disease occurrence. The findings reinforce the association between arsenic exposure and increased risks of skin diseases, liver disorders, cardiovascular diseases, and cancers. The relatively better health outcomes observed in these districts highlight the importance of maintaining safe water sources and preventing heavy metal contamination of aquatic environments.

Overall, the study demonstrates that arsenic exposure through contaminated drinking water and fish consumption is associated with increased health risks, particularly in highly affected districts of West Bengal. The results indicate that skin diseases and hepatic disorders are the most prominent health outcomes linked to arsenic exposure, while cardiovascular diseases and cancer-related conditions also contribute significantly to the disease burden. Continuous monitoring of arsenic levels in water and fish, together with effective public health interventions, is essential to minimize exposure and protect vulnerable populations.

Respondents from highly arsenic-affected districts reported a higher prevalence of:

- Skin disorders
- Digestive problems
- Liver-related diseases
- Blood disorders
- Joint pain
- Chronic fatigue

A smaller proportion reported cancer-related illnesses and reproductive health problems.

The prevalence of these conditions was comparatively lower in moderately affected and unaffected districts.

6. Discussion: The findings indicate that fish remains an essential component of the diet in West Bengal. However, frequent fish consumption in arsenic-prone regions may increase exposure to heavy metals.

The higher prevalence of health problems reported in highly affected districts supports previous studies linking arsenic exposure to chronic diseases. While fish consumption alone may not account for all observed health effects, the combined exposure from contaminated groundwater and aquatic food sources likely contributes to increased health risks.

The consumption of fish organs may further elevate exposure levels because these tissues tend to accumulate higher concentrations of arsenic and other heavy metals.

The study underscores the importance of considering dietary pathways when assessing environmental health risks in arsenic-affected regions.

7. Conclusion: The study revealed a significant association between arsenic exposure and adverse health outcomes among residents of different districts of West Bengal. Higher prevalence rates of skin diseases, hepatic disorders, cardiovascular diseases, and cancer-related conditions were observed in highly arsenic-affected districts compared to mildly affected and non-affected districts. The findings suggest that both contaminated drinking water and frequent consumption of fish, particularly arsenic-accumulating organs such as liver and gills, contribute to increased health risks.

The results highlight that dietary exposure through fish consumption is an important pathway for arsenic intake, especially in regions where fish is a staple food. Therefore, regular monitoring of arsenic levels in water and fish, improvement of safe drinking water facilities, and public awareness regarding safe fish consumption practices are essential to reduce exposure and protect public health in arsenic-prone areas of West Bengal.

8. Recommendations

1. Regular monitoring of arsenic and heavy metal concentrations in fish and water sources.
2. Expansion of safe drinking water supply systems in arsenic-affected districts.
3. Public awareness campaigns regarding safe fish consumption practices.
4. Periodic health screening programs in vulnerable communities.
5. Promotion of sustainable aquaculture practices and pollution control measures.
6. Further research involving laboratory analysis of fish tissues and biological markers of arsenic exposure.

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Citation: **Basak. T.,** (2025) "Human Health Risk Assessment of Heavy Metal Exposure Through Fish Consumption: A Study in Selected Districts of West Bengal, India", *Bharati International Journal of Multidisciplinary Research & Development (BIJMRD)*, Vol-3, Issue-02, February-2025.