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"Flood Disaster Impact on Water Quality: A Case Study of Buxar District, Bihar"

Shubhra kumari
NET-JRF, Research Scholar, Geography Department
Veer kunwar singh University, Ara

Abstract
Seasonal floods in the Gangetic plains of Bihar, particularly in districts such as Buxar, pose significant threats to rural water security. This study investigates the effects of seasonal floods on the quality of drinking water in Buxar, with a focus on variations in groundwater and surface water contamination across pre-flood, flood, and post-flood periods. Drawing upon official datasets including the Bhujal Suchna Pustika (2022), CGWB quality assessments (2018–2023), and Bihar Health Department surveillance reports, the study reveals significant spikes in turbidity, total coliform counts, and heavy metal concentrations—particularly arsenic and iron—during flood events. The findings underscore how recurrent inundation exacerbates exposure to both biological and chemical hazards. The paper further evaluates the limitations of ongoing mitigation programs like Nal Jal Yojana and recommends a multi-tiered resilience framework involving localized treatment, infrastructure redesign, and real-time water quality monitoring. These insights are critical for ensuring public health and sustainable water governance in flood-prone rural India.

Keywords: Flooding, Groundwater Contamination, Arsenic Exposure, Public Health, Drinking Water Safety, Disaster Risk Reduction, Monsoon Floods

1. Introduction

Floods are among the most frequent and destructive natural hazards in Bihar, impacting agriculture, infrastructure, and human health. One of the less visibly recognized, yet critically important, consequences of flooding is the degradation of drinking water quality. In the Buxar district, situated along the northern floodplains of the Ganges River, this concern becomes particularly acute due to the widespread dependence on shallow groundwater sources for domestic use.

Seasonal monsoon floods (typically from June to September) submerge large swaths of low-lying rural terrain. As floodwaters spread, they often carry contaminants from open defecation zones, overflowing septic tanks, and chemically treated agricultural lands, which mix with drinking water sources such as hand pumps, wells, and ponds. This not only causes immediate outbreaks of waterborne illnesses but also accelerates long-term exposure to toxic elements like arsenic, which is naturally present in the alluvial aquifers of the region (CGWB, 2023).

Despite policy efforts to provide piped water through programs like the Har Ghar Nal Jal Yojana, a significant proportion of the rural population in Buxar continues to rely on unprotected groundwater systems that are highly vulnerable to flood-induced pollution (PHED Bihar, 2022). This dual challenge of infrastructural fragility and hydrogeological sensitivity underpins the urgency of this study.

This paper addresses the following research questions:

- How do monsoonal floods affect key drinking water quality indicators in Buxar district?
- What are the major sources of contamination during flood events?

- ❖ How effective are existing mitigation strategies, and what improvements are necessary to safeguard water quality?

By answering these questions, this study aims to generate actionable insights for policymakers, public health planners, and local communities striving to ensure safe and sustainable drinking water access in flood-prone regions of rural India.

2. Study Area and Methodology

2.1 Study Area: Buxar District, Bihar

Buxar is a flood-prone district located in western Bihar, bounded by the Ganges River to the north and the Karmanasa River to the west. Spanning an area of approximately 1,703 square kilometres, it is home to a predominantly rural population exceeding 1.7 million (Census of India, 2011). The district lies within the Indo-Gangetic plain and is characterized by fertile alluvial soils, which support intensive agriculture but also render the region highly susceptible to waterlogging and seasonal inundation.

During the monsoon season, the Ganges and its tributaries frequently overflow their banks, leading to flooding in low-lying villages such as Tiwai (Chausa block), Umarpur (Buxar block), Jawahi (Chakki block), and Nainijor (Brahmapur block). In these areas, shallow groundwater sources—such as hand pumps and tube wells, which are vulnerable to flood-related contamination—are often compromised by floodwaters that carry both organic and inorganic contaminants. The dependence of rural households on these sources for daily water needs significantly heightens the risk of waterborne diseases and toxic exposures.

2.2 Methodology

This study adopts a mixed-methods approach combining quantitative analysis of secondary data, spatial mapping of contamination zones, and temporal comparison of water quality indicators across three defined flood phases:

- ➢ Pre-Flood Phase: March–May
- ➢ Flood Phase: July–September
- ➢ Post-Flood Phase: October–December

Data Sources:

- ❖ Water Quality Data: Sourced from Bhujal Suchna Pustika (Buxar, 2022) and the Central Ground Water Board's regional reports (CGWB, 2018–2023), focusing on physicochemical and biological parameters.
- ❖ Public Health Data: Collected from the Bihar Health Department's disease surveillance cell, with emphasis on flood-season outbreaks of diarrhoea, cholera, and typhoid.
- ❖ Policy and Literature Review: Incorporates guidelines and findings from WHO (2017), BIS standards, and state-level disaster management publications (BSDMA, 2021).

Water Quality Parameters Assessed:

- ❖ **Physicochemical**: pH, turbidity, Total Dissolved Solids (TDS), Biochemical Oxygen Demand (BOD)
- ❖ **Biological**: Total coliform count
- ❖ **Heavy Metals**: Arsenic (As), Iron (Fe), and Fluoride (F)

Sampling Framework:

Data were compiled from 12 strategically selected test sites across the four most flood-affected blocks. For each site, seasonal averages were calculated for the above parameters to capture temporal variations. The selection ensured representation from both upstream and downstream flood zones.

Analytical Tools Used:

- **Microsoft Excel:** For trend analysis, statistical comparison, and visual charting.
- **ArcGIS**: To map high-risk contamination clusters and visualize spatial patterns.
- Standards Comparison: Values were evaluated against WHO (2017) and BIS (2012) drinking water guidelines to determine safety thresholds.

This methodological framework allows for a comprehensive assessment of how monsoonal flooding alters the physical, chemical, and microbial composition of drinking water in Buxar, offering a basis for localized water safety interventions.

3. Results and Discussion

3.1 Physicochemical Impacts of Flooding on Water Quality

Flood events in Buxar significantly alter the physical and chemical composition of drinking water sources. Data analysis across 12 monitoring sites revealed a sharp increase in turbidity, TDS (Total Dissolved Solids), and BOD (Biochemical Oxygen Demand) during the flood phase (July–September), compared to pre-flood (March–May) and post-flood (October–December) periods.(Table1)

Table 1: Seasonal Variation in Key Water Quality Parameters (Average of 12 Sites)

Parameter	Pre-Flood	During Flood	Post-Flood	WHO/BIS Standard
pH	7.3	6.8	7.0	6.8-8.5
Turbidity (NTU)|	4.5	42	15	< 5 NTU
TDS(mg/L)	370	640	420	< 500 mg/L
BOD (mg/L)	2.1	6.8	3.5	< 3 mg/L (desirable)

Figure 1 shows the seasonal variation in key drinking water quality indicators—turbidity, total dissolved solids (TDS), and biochemical oxygen demand (BOD)—across 12 monitoring sites in Buxar. All three parameters show a significant deterioration during the flood phase, crossing permissible safety limits defined by WHO/BIS (WHO, 2017).

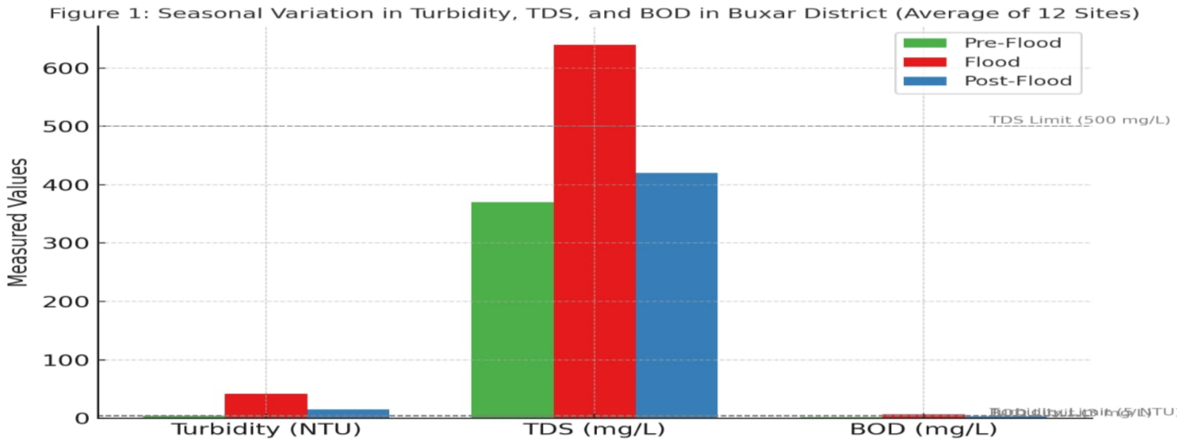

Figure 1: Seasonal Variation in Turbidity, TDS, and BOD in Buxar District (Average of 12 Sites)

Average values of turbidity, total dissolved solids (TDS), and biochemical oxygen demand (BOD) recorded across 12 monitoring sites show significant deterioration in water quality during the flood phase, exceeding WHO/BIS safety limits (WHO, 2017).

Observations:

- ❖ Turbidity levels during floods were over eight times the permissible limit, suggesting high sediment load and organic matter.
- ❖ BOD levels indicated an increased biological load, possibly due to faecal contamination and decomposing vegetation.
- ❖ TDS spiked during floods, reflecting the influx of dissolved agricultural runoff and sewage.

These trends align with patterns previously observed in flood-prone Indo-Gangetic regions (Kumar & Singh, 2021), where floodwaters increase both suspended and dissolved contaminants (Kumar & Singh, 2021).

3.2 Heavy Metal Mobilization: Arsenic and Iron

The geology of Buxar's alluvial plains is naturally rich in arsenic-bearing minerals. During floods, anaerobic conditions and prolonged water stagnation promote the leaching of arsenic (As) and iron (Fe) from soil into shallow aquifers.(Table 2)

Table 2: Average Arsenic Levels (ppb) in Selected Blocks

Block	Arsenic (ppb)	WHO Limit(10 ppb)	Status
Chausa	95	10	Unsafe
Buxar Sadar	80	10	Unsafe
Chakki	60	10	Unsafe
Brahmapur	70	10	Unsafe

As shown in Figure 2, arsenic concentrations in all four flood-affected blocks of Buxar significantly exceeded WHO's safe limit of 10 ppb. Among them, Chausa block recorded the highest average level (95 ppb), followed by Buxar Sadar (80 ppb). This pattern suggests strong geogenic mobilization of arsenic during flood conditions.

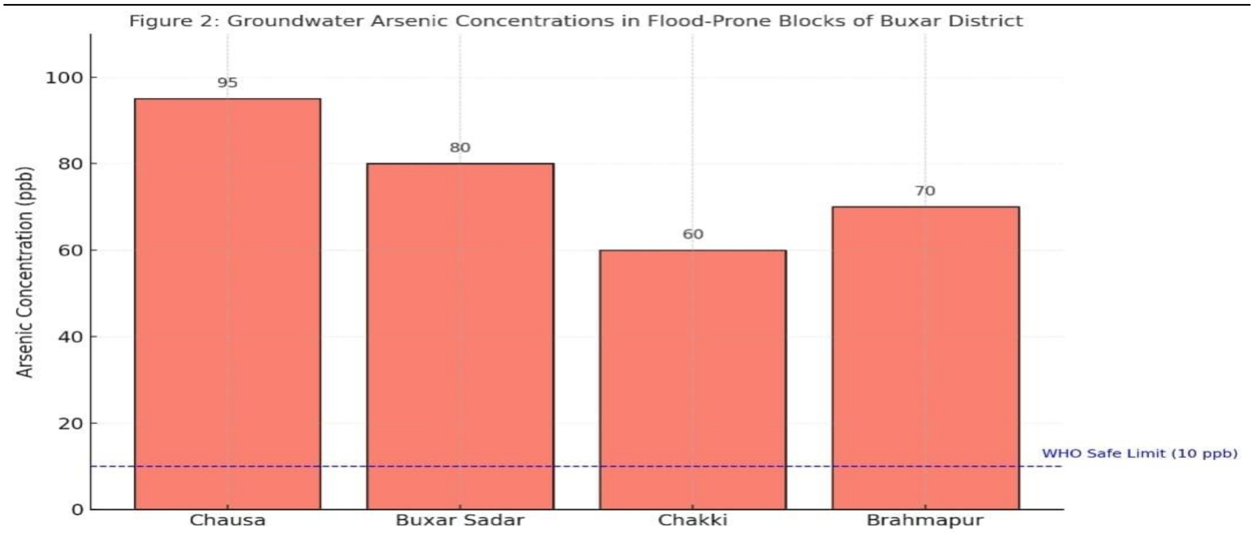

Figure 2: Groundwater Arsenic Concentrations in Flood-Prone Blocks of Buxar District

Arsenic concentrations in all observed blocks exceeded WHO's safe limit by 6–9 times, raising chronic health concerns including carcinogenic risks, skin lesions, and neurological damage (WHO, 2017).

3.3 Microbial Contamination and Public Health Risks

Floodwaters frequently mix with sewage, animal waste, and stagnant runoff—leading to severe microbial contamination. Coliform bacteria, an indicator of faecal contamination, were found in alarming quantities during the flood phase.(Table 3)

Table 3 : Seasonal Incidence of Waterborne Diseases (2018–2024, Buxar District)

Season	Diarrhoea Cases	Typhoid Cases	Cholera Cases
Pre-Flood	160	50	10
During Flood	780	230	58
Post-Flood	310	85	22

As illustrated in Figure 3, the incidence of diarrhoea, typhoid, and cholera spikes significantly during the flood months. The surge in cases corresponds with the contamination of drinking water sources by floodwaters carrying faecal matter and sewage.

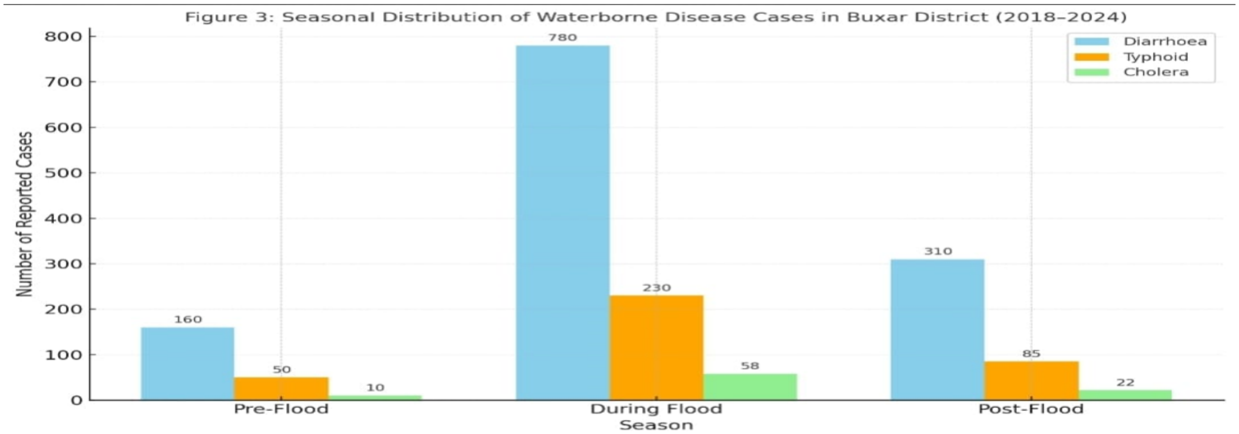

Figure 3: Seasonal Distribution of Waterborne Disease Cases in Buxar District (2018–2024)

The spike in diarrheal and typhoid cases correlates with the increased coliform count in contaminated hand pump and well water, especially in rural habitations lacking piped supply (PHED Bihar, 2023).

3.4 Spatial Risk Mapping of Contamination Zones

Using ArcGIS spatial analysis, contamination data were overlaid on geocoded sampling locations to identify high-risk clusters. The spatial heat maps revealed consistent contamination in the following villages:

- ❖ Tiwai (Chausa Block)
- ❖ Umarpur (Buxar Sadar Block)
- ❖ Jawahi (Chakki Block)
- ❖ Nainijor (Brahmapur Block)

These areas exhibited persistently high levels of arsenic, turbidity, and microbial load during flood months. The maps generated using Inverse Distance Weighting (IDW) interpolation method helped visualize risk gradients across the district.

Insight: These spatially identified zones should be prioritized for infrastructure interventions, water purification systems, and targeted community outreach.

4. Government Response and Recommendations

4.1 Current Government Measures

Recognizing the recurrent flood-induced water contamination in districts like Buxar, both the Government of Bihar and national agencies have initiated several interventions aimed at improving rural water safety. Key measures include:

- ❖ **Nal Jal Yojana:** This rural piped water supply scheme, launched under Bihar's Har Ghar Nal Ka Jal mission, seeks to provide treated drinking water through household connections. However, flood-affected regions often face interruptions due to infrastructural vulnerability and water source contamination during monsoon seasons (PHED Bihar, 2022).
- ❖ **Arsenic Mitigation Units:** In high-risk villages, community-based arsenic removal plants have been installed. While technically sound, many of these systems suffer from poor maintenance and irregular filter replacement cycles (CGWB, 2023).

- **Mobile Water Testing Vans:** Deployed by the Public Health Engineering Department (PHED) during monsoon months, these mobile units test water from hand pumps and wells, issuing advisories when contamination exceeds permissible limits.
- **Chlorination Campaigns**: Periodic disinfection of groundwater sources, particularly hand pumps and open wells, is conducted before and during the flood season using chlorine tablets and bleaching powder.
- **Community Awareness Programs**: Public information campaigns, conducted through ASHA workers and panchayat-level outreach, aim to educate residents on safe water practices and emergency purification techniques.

Limitations:

- Piped supply schemes often fail or remain non-functional in flood-prone habitations.
- Arsenic removal units are inadequately monitored, leading to frequent breakdowns.
- Community engagement remains inconsistent, and behaviour change communication (BCC) is not yet robust enough to ensure sustainable adoption of safe practices.

4.2 Strategic Recommendations

In light of the findings of this study and identified policy gaps, a comprehensive, multi-layered approach is proposed to enhance drinking water resilience in flood-affected regions like Buxar:

1. Infrastructure Resilience

- Elevate hand pumps and water access points above known flood levels to prevent submergence and contamination.
- Install decentralized water treatment systems at the panchayat level, capable of removing both biological and chemical pollutants, including arsenic and iron.

2. Enhanced Monitoring and Surveillance

- Establish permanent water testing laboratories at the block level, equipped for microbiological and heavy metal analysis.
- Integrate IoT-enabled real-time sensors for key water quality parameters (e.g., turbidity, coliform count, arsenic) at high-risk sites.

3. Source Protection and Diversification

- Identify and deactivate vulnerable hand pumps located near sewage drains or agricultural runoff zones.
- Promote rainwater harvesting as a supplementary safe water source, particularly in elevated or arsenic-affected areas.

4. Community Participation

- Train local youth as Water Safety Volunteers, responsible for testing and reporting on water quality during flood seasons.
- Distribute low-cost water purification kits (chlorine tablets, ceramic or biosand filters) before the onset of monsoon.

5. Policy Integration and Financing

- Include water contamination due to floods as a core parameter in the District Disaster Management Plans (DDMP).
- Allocate dedicated budget lines for maintenance of water infrastructure and purification units in vulnerable gram panchayats.

6. Data Transparency and Public Access

- Create an open-access water quality dashboard for the district, where residents can view contamination alerts and test results during flood months.

These recommendations aim not only to respond to current contamination risks but to build long-term resilience through structural, behavioral, and policy-based reforms.

5. Conclusion

This study highlights the complex and multidimensional impact of seasonal flooding on drinking water quality in Buxar district, Bihar. The findings underscore how recurrent monsoonal floods not only deteriorate physical parameters such as turbidity and TDS but also trigger the mobilization of heavy metals like arsenic and iron from alluvial sediments. Simultaneously, microbial contamination due to inadequate sanitation and floodwater mixing leads to a dramatic surge in waterborne diseases such as diarrhoea, typhoid, and cholera.

The study also reveals that while government programs like Nal Jal Yojana and arsenic mitigation units have made inroads in addressing rural water insecurity, systemic issues related to infrastructure maintenance, community engagement, and real-time monitoring continue to limit their effectiveness. The spatial risk mapping conducted using GIS tools further indicates that certain villages consistently remain at high risk and require targeted interventions.

In the context of growing climate variability, where the frequency and intensity of floods are expected to rise, these findings call for a paradigm shift in water management strategies. The integration of decentralized treatment technologies, participatory monitoring systems, and location-specific policy planning is critical for building long-term resilience in rural floodplains. Buxar district, with its representative socio-environmental vulnerabilities, offers a valuable case for designing scalable, community-led water safety frameworks in flood-prone regions across India.

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