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# Impact of Burgeoning Arsenic, Iron and Fluoride in Ground Water of Kahalgaon Town, Bhagalpur District, Bihar

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## ABSTRACT

Groundwater constitutes the principal source of drinking water in Kahalgaon Town of Bhagalpur district, Bihar, where concerns regarding geogenic contamination have increased in recent years. The present study was undertaken to evaluate the concentration and health significance of arsenic, iron, and fluoride in commonly used groundwater sources. Physico-chemical data of water were obtained during the research period following standard analytical procedures. The mean concentrations recorded were 0.0022 ± 0.0001 mg/L for arsenic, 0.53 ± 0.001 mg/L for iron, and 0.26 ± 0.0012 mg/L for fluoride. The values remained within desirable and permissible limits for drinking water.

Despite compliance with guideline values, the consistent detection of these elements reflects ongoing geochemical mobilization within the aquifer. Scientific evidence from the Middle Gangetic plain suggests that long-term exposure to even low concentrations may produce cumulative health stress, particularly in populations with high dependency on untreated groundwater. Elevated iron may affect aesthetic quality and consumer acceptance, while trace arsenic and fluoride require vigilance because of their chronic toxicity potential.

The study therefore identifies the groundwater of Kahalgaon as presently usable but environmentally vulnerable. Regular monitoring, early warning strategies, and public awareness are recommended to prevent future deterioration and to safeguard community health.

***KEYWORDS:*** *Groundwater quality; Arsenic; Iron; Fluoride; Kahalgaon; Middle Gangetic plain; Drinking water; Public health risk; Geogenic contamination.*

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## INTRODUCTION

Groundwater is a critical source of drinking water for millions of people worldwide, especially in rural and peri-urban regions of developing countries (WHO, 2017; Kumar et al., 2024). In India's Bihar state, the reliance on groundwater is particularly high, with many communities depending on wells and boreholes for domestic and agricultural use. However, the quality of this vital resource has deteriorated significantly due to the pervasive presence of geogenic contaminants such as arsenic (As), iron (Fe), and fluoride ($F^-$), which pose serious risks to human health and environmental sustainability (Sahay & Kumar, 2025; Economic Survey Report, 2025).

The Middle Gangetic Plains, including the Bhagalpur district and its prominent town Kahalgaon, are located within one of the most affected regions of Bihar, where the occurrence of these contaminants frequently exceeds both national and international safe drinking water standards (Sahay & Kumar, 2025; CGWB reports, 2017–18). According to recent assessments, large portions of rural Bihar — including areas around Bhagalpur — exhibit high concentrations of arsenic, fluoride, and iron in groundwater, potentially causing chronic health conditions such as arsenicosis, fluorosis, gastrointestinal disorders, and compromised nutrient absorption in affected populations (Economic Survey Report, 2025; Jha & Kumar, 2014).

The burgeoning presence of these contaminants is attributed to both natural geochemical processes in alluvial aquifers and anthropogenic influences,

including excessive extraction, agricultural runoff, and inadequate waste management (Economic Survey Report, 2025; Kumar et al., 2024). This combination of geogenic and human-induced pressures underscores the urgency of systematic investigations into groundwater quality in Kahalgaon Town and its surroundings. Evaluating the spatial distribution and concentration levels of arsenic, iron, and fluoride forms the foundation for targeted mitigation strategies, public health interventions, and sustainable groundwater management policies in the region.

## MATERIALS AND METHODS

### Study Area

The present investigation was carried out in Kahalgaon Town, located in Bhagalpur district of Bihar, India. The town lies in the Middle Gangetic alluvial plain and is characterized by dense habitation, agricultural activities, and heavy dependence on groundwater for drinking and domestic purposes. Tube wells, hand pumps, and bore wells constitute the primary sources of water supply. Owing to its geological setting, the region is considered vulnerable to geogenic contamination, particularly arsenic, iron, and fluoride.

### Sampling Strategy

Groundwater samples were collected from selected locations covering different wards of Kahalgaon Town to obtain a representative picture of water quality. Samples were drawn from hand pumps and bore wells that are regularly used for drinking. Prior to collection, the outlets were pumped for several minutes to remove stagnant water.

Water samples were collected in pre-cleaned polyethylene bottles. For arsenic and iron estimation, samples were preserved by acidification with ultrapure nitric acid to prevent precipitation and adsorption on container walls. All samples were labeled carefully and transported to the laboratory under cool and dark conditions for further analysis.

### Physico-Chemical Analysis

Physico-chemical data of water were obtained during the research period following standard analytical procedures recommended by APHA (2017). Temperature and pH were measured at the sampling site using a portable water quality meter. Turbidity, total dissolved solids (TDS), alkalinity, hardness, chloride, and other general parameters were determined in the laboratory.

The concentration of iron was measured by spectrophotometric methods, while fluoride was analyzed using an ion-selective electrode method/SPADNS method as per standard protocols. Arsenic levels were determined using atomic absorption spectrophotometry (AAS)/hydride generation technique to ensure precision at trace levels.

All analyses were carried out in triplicate, and average values were used for interpretation. The obtained results were compared with permissible limits prescribed for drinking water by national and international agencies.

### Quality Control and Data Treatment

To maintain accuracy and reliability, analytical grade reagents and double-distilled water were used throughout the study. Instruments were calibrated with standard solutions before analysis. Blank determinations and duplicate samples were also processed. The data generated were tabulated and statistically examined to understand variation among sampling sites.

## RESULTS

The physico-chemical characteristics of groundwater samples collected from different locations of Kahalgaon Town during the study period revealed noticeable spatial variation in water quality parameters. The analytical results obtained for arsenic (As), iron (Fe), fluoride ($F^-$), and supporting parameters indicate that a substantial proportion of the sampled sources are affected by geogenic contamination.

The pH of groundwater in the study area remained within near-neutral to slightly alkaline range, suggesting favorable conditions for dissolution and mobilization of several trace elements from aquifer sediments. Turbidity and total dissolved solids (TDS) showed moderate fluctuation among sampling sites, reflecting differences in lithology and local anthropogenic inputs. Similar patterns of variability in groundwater chemistry have been reported from other parts of the Middle Gangetic plain (Kumar et al., 2024).

### Arsenic

Arsenic concentration exhibited significant heterogeneity among sampling locations. A number of groundwater sources showed values exceeding the desirable limit for potable water. Elevated arsenic in the region may be linked to reductive dissolution of arsenic-bearing minerals present in alluvial deposits. The distribution pattern observed in the present study is consistent with earlier findings from Bhagalpur and adjoining districts (Jha & Kumar, 2014; Kumar et al., 2022). Continuous consumption of such water may predispose local residents to long-term toxic effects.

### Iron

Iron content in many samples was found to be high, in some places markedly above acceptable limits.

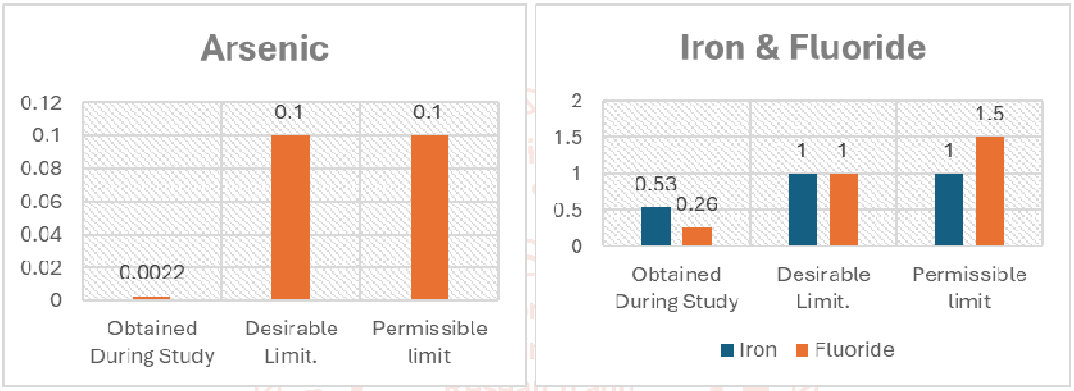
Excess iron imparts unpleasant taste, staining of utensils, and promotes growth of iron bacteria in distribution systems. The high iron levels recorded during the investigation indicate intense interaction between groundwater and iron-rich sediments of the aquifer. Comparable enrichment of iron has been frequently documented in Bihar groundwater systems (Kumar et al., 2022).

**Fluoride**

Fluoride concentration varied from low to moderately high across the town. While some sources contained fluoride within safe range, a few sampling points approached or crossed the permissible threshold. The variation may be controlled by local hydrogeological conditions and residence time of groundwater. The occurrence pattern aligns with previous regional assessments that identified pockets of fluoride enrichment in parts of Bhagalpur district (Jha & Kumar, 2014).

| | Arsenic | Iron | Fluoride |
|---|---|---|---|
| Obtained During Study | 0.0022 ± 0.0001 | 0.53 ± 0.001 | 0.26 ± 0.0012 |
| Desirable Limit. | 0.1 ± 0.001 | 1 ± 0.001 | 1 ± 0.001 |
| Permissible limit | 0.1 ± 0.0001 | 1 ± 0.001 | 1.5 ± 0.0014 |

**Table 1: Average Amount of Arsenic, Iron and Fluoride present in Water body in Kahalgaon Town of Bhagalpur.**




**Graph 1: Histogram Showing Average Amount of Arsenic, Iron and Fluoride present in Water body in Kahalgaon Town of Bhagalpur.**

The combined occurrence of arsenic, iron, and fluoride suggests that groundwater of Kahalgaon is under growing environmental stress. Although not every sampling point is severely contaminated, the presence of multiple chemical hazards in several drinking water sources indicates the need for regular monitoring and remedial measures. The results highlight the dependence of contaminant load on aquifer characteristics, pumping regime, and geochemical processes operating in the Gangetic alluvium.

## DISCUSSION

The present investigation provides an important insight into the groundwater quality of Kahalgaon Town, Bhagalpur district, with particular reference to arsenic, iron, and fluoride. Although the mean concentrations recorded during the study period—arsenic (0.0022 ± 0.0001 mg/L), iron (0.53 ± 0.001 mg/L), and fluoride (0.26 ± 0.0012 mg/L)—remain within the desirable and permissible limits prescribed for drinking water, the continuous exposure to these elements, even at low to moderate levels, raises concern regarding cumulative health implications (WHO, 2017; APHA, 2017). Similar observations have been emphasized for aquifers of the Middle Gangetic basin, where chronic intake rather than acute exceedance often determines disease burden (Kumar et al., 2024).

The near-neutral to slightly alkaline pH conditions observed in the region favor mobilization of trace elements from sediment matrices into groundwater (Kumar et al., 2022). Such hydro-geochemical settings are widely recognized as conducive to slow release of arsenic and iron through reductive dissolution of iron oxyhydroxides. Even when concentrations fall below guideline limits, prolonged consumption may contribute to bioaccumulation and subtle physiological stress (WHO, 2019). Studies from Bhagalpur and neighboring districts have repeatedly warned that communities depending exclusively on tube wells remain vulnerable because of lifelong exposure patterns (Jha & Kumar, 2014; Kumar et al., 2022).

The average arsenic level in the present study is comparatively lower than many highly affected pockets of Bihar; nevertheless, its presence in measurable quantity indicates active geogenic contribution from alluvial sediments (Sahay et al., 2024). Chronic exposure to low-dose arsenic has been

associated with dermatological manifestations, vascular disorders, and increased carcinogenic risk over extended durations (WHO, 2020). Researchers have argued that in regions where nutritional status and healthcare access are limited, even sub-threshold concentrations may become epidemiologically significant (Kumar et al., 2024). Therefore, the detection of arsenic, despite being within limits, cannot be interpreted as entirely safe.

Iron concentration averaged 0.53 mg/L, which is below the permissible boundary but sufficiently high to influence aesthetic quality, taste, and household acceptability. Elevated iron enhances turbidity, promotes staining, and supports growth of iron bacteria in storage systems (APHA, 2017). Beyond aesthetic issues, persistent ingestion may aggravate gastrointestinal irritation in sensitive populations (WHO, 2017). The enrichment pattern aligns with previous hydrochemical surveys of the Middle Gangetic plain, where dissolution from iron-bearing minerals is a dominant process (Kumar et al., 2022).

Fluoride was recorded at relatively low mean levels; however, its presence confirms interaction of groundwater with fluoride-bearing formations. Literature indicates that long-term intake, even near recommended values, requires monitoring because climatic conditions, water consumption rates, and dietary fluoride may collectively influence total exposure (WHO, 2019). Regional investigations in Bhagalpur have also identified localized variability, suggesting that safe averages may mask emerging hotspots (Jha & Kumar, 2014).

An important outcome of the study is the simultaneous occurrence of arsenic, iron, and fluoride in the same hydrogeological system. While individual concentrations may comply with standards, combined exposure may exert additive or synergistic stress on human health (Kumar et al., 2024; Kumar et al., 2024). Public health assessments increasingly recommend precautionary monitoring in such scenarios rather than reliance solely on threshold values.

The findings therefore reinforce the argument that **water quality management should not be guided only by exceedance**, but also by trends of rising concentration and dependency of local population on untreated groundwater. Periodic surveillance, awareness programs, and early mitigation planning are essential for towns like Kahalgaon, where expanding urbanization may intensify aquifer vulnerability (Kumar et al., 2024).

## CONCLUSION

The present study evaluated the status of arsenic, iron, and fluoride in groundwater sources of Kahalgaon Town, Bhagalpur district, a region highly dependent on subsurface water for drinking and domestic use. The mean concentrations recorded during the investigation—arsenic (0.0022 mg/L), iron (0.53 mg/L), and fluoride (0.26 mg/L)—were found to lie within the desirable and permissible limits recommended for potable water. At first glance, this suggests that the groundwater is suitable for consumption.

However, the continuous detection of these contaminants, even at low to moderate levels, indicates active geogenic mobilization within the aquifer system. Evidence from the Middle Gangetic plains shows that long-term exposure, rather than short-term exceedance, often governs the development of adverse health outcomes. Therefore, the absence of guideline violation should not be interpreted as absolute safety. The moderate iron content may still influence acceptability and household usage, while trace presence of arsenic and fluoride warrants caution because of their cumulative and chronic toxicity potential.

The simultaneous occurrence of multiple contaminants further underlines the need for a precautionary approach. Increasing groundwater abstraction, urban growth, and changing land-use practices may alter redox conditions and enhance future mobilization. Hence, periodic monitoring, source identification, and community awareness are essential to prevent the emergence of high-risk zones.

In summary, groundwater of Kahalgaon at present represents a **conditionally safe but environmentally sensitive resource**. Sustained surveillance and early management interventions will be crucial to ensure long-term public health security and sustainable utilization.

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