

# Arsenic Contamination in Groundwater of Ghaghara Waterway and its Tributaries – A Review

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**Abstract:** Groundwater serves as an essential source of consumable water and it is employed for water system, domestic requirements and different other operations. The Ghaghara stream, critical influent of the Ganga River, navigates a significant parcel of Northern Uttar Pradesh and is encumbered by multitudinous little aqueducts. Research has demonstrated that the groundwater inside the Ghaghara receptacle and its tributaries is defiled with arsenic. To investigate the conc. of arsenic present in groundwater of Ghaghara river basin and its tributaries. Water samples were collected from different sources of Tubewell, River water. The water samples were then analysed through Atomic Absorption Spectrometry (AAS) that confirms the presence of arsenic. This method utilizes Flow injection hydride generation technique. The tubewells in the district Basti, Gonda, Ayodhya shows arsenic content above 10 microgram per litre while the conc. in the sediments of Ghaghara river was 7.11mg per kg, while the Seti and Sharda river basin shows trace amount of arsenic. Kuano river ranges from 8-9 mg/l in contrast Saryu river has conc. of arsenic 7-8mg/l. In Rapti river basin its groundwater shows elevated arsenic conc. which is 399mg/l. This review article compiles the information on arsenic situations in the groundwater of the Ghaghara waterway and its tributaries as reported till date.

**Keywords-** Arsenic, Ghaghara River, Tributaries.

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## I. INTRODUCTION

After passing through the Himalayas in Nepal, the Ghaghara canal joins the Sharda waterway at Brahma Ghat in India. It starts near Lake Mansarovar in Tibet. Its source is set up in the ice sheets of Mapchachungo, arranged at a rise of 4800 meters above ocean level. The swash's seepage coliseum envelops a region of 127,950 square kilometers, with around 55% of this range set up in Nepal and 45% in

India. The periodic water abnegate from rush inside the Ghaghara coliseum is assessed to be 94,400 million cubic meters. Groundwater situations in the locale of the Ghaghara coliseum change, extending from 0.91 to 8.58 meter underneath ground position amidst the summer showers, and from 0.4 to 7.46 meters underneath ground position amid the withdrawing rainfall. The essential tributaries of the Ghaghara stream incorporate the Bheri, Chauka, Rapti, Seti,

Sharda, Saryu, ChotiGandak, Jharahi, Kuwano (Rajiva Mohan 2018; Ravi *et al.*, 2021).

Arsenic conc. above the threshold level effects animals plants and environment. As it inhibits the seed germination ,retard the growth of roots , disrupts the photosynthesis and also causes oxidative stress which leads to leaf chlorosis , necrosis and ultimately retard the growth of plants. In humans acute exposure can cause nausea, vomiting, abdominal pain and so on. On chronic exposure it can cause hyper pigmentation, cancer hypertension and some neurological effects such as peripheral, neuropathy, cognitive decline. In this review article we have summerised the data of arsenic conc. in Ghaghara river basin and its tributaries by an extensive literature survey. The research gap, we have found after the literature survey is that , the proper or numerical data of arsenic conc. is not available of Ghaghara river basin and its tributaries . So it needs to be studied thoroughly to get the numerical data, so that the effects of its conc. on the ambient environment can be studied.

Arsenic contamination of groundwater, which can come from both natural and man-made sources, poses serious risks to the environment and human health worldwide. Millions of people over different nations depend on drinking water that contains elevated arsenic situations, which presents a genuine well-being peril. Immense exposure to inorganic arsenic through drinking water leads to arsenicosis, a decaying condition characterized by skin injuries and saturation changes, as well as spots on the palmand soles. Additionally, severe health issues like skin and other types of cancer are linked to arsenic exposure (Shiv Shankar *et al.*,2014).

Research demonstrated that around 108 nations have groundwater bemired with arsenic a situations surpassing the World Health Organization's specified topmost restrain of 10 parts per billion. Arsenic is a typically passing element set up in the earth's housing that interatom with chlorine, oxygen, and sulfur to make inorganic arsenic composites. These composites are world wide employed over different parts, counting creatures, medicinal, husbandry, critter bolster, electronics, chemical fighting, and metallurgy. Release of Arsenic especially due to its discharge into groundwater through the interaction of rock and water in aquifers, which leads to a decline in groundwater quality. The World Health Organization's 2001 priority list of hazardous substances identified arsenic as the most toxic element, earning it the title 'king of poison.' Since 1993, the permissible limit for arsenic in drinking water has been established at 10 µg/L, a reduction from the previous limit of 50 µg/L. Recent reports over the past decade have indicated that the middle Ganga plain region, particularly the Indian states of Bihar, Uttar Pradesh, and Jharkhand, is severely contaminated with arsenic. Uttar Pradesh, characterized by its fertile land and numerous rivers, is particularly affected, with many districts along the Ganga and its tributaries exhibiting elevated arsenic levels in groundwater. The major tributaries of the Ganga in Uttar Pradesh, such as the Ramganga, Gandak, Gomti, Yamuna, and Ghaghara, predominantly originate from the Himalayas and may transport arsenic in their sediments. Significant effects are felt in the districts of the Ghaghara basin,

particularly in the heavily populated northeastern area (E. Shaji *et al.*, 2021).

## II. METHODOLOGY

In this review article we have summarized the data of arsenic conc. in Ghaghara river basin and its tributaries by an extensive literature survey. Relevant articles were identified and collected by extensive search in published literature Research gate, Elsevier, Science Direct Google Scholar. Articles published between 1977-2023 were analysed. The current understanding gap for future research was critically analysed with the help of these literatures.

### ➤ *Source of Arsenic in the Ghaghara Basin*

The convergence of sediments from the Himalayan mountain range led to the formation of the Ghaghara basin. This region is characterized by various mineral deposits containing arsenic, including hydrothermal pyrite-chalcopyrite arsenopyrite-galena mineralization associated with quartz veins found in the Buniyal, Doda, AlmoraGarhwal, J, and K Hills (Tewari and Gaur 1977). Additionally, the Terai sediments, which are derived from the Himalayan hill range of Nepal, exhibit arsenic contamination (Gurung *et al.*, 2005). In the northern regions of the Gangetic plain, most rivers originate from the Himalayan hill range, including the Ghaghara River, which flows through the Terai belt of Nepal. During the monsoon season, the concentration of arsenic in the suspended sediments of the Ghaghara River is measured at 7.11 micrograms per gram (Shah 2014).

### ➤ *Arsenic in Groundwater of Ghaghara Basin*

Due to the absence of piped water systems in most villages, the risk of arsenic exposure is significantly greater in rural areas compared to urban settings. Those who rely on tube wells or hand pumps for drinking water from arsenic-polluted sources may face serious health risks. Groundwater arsenic contamination is evident in the upper reaches and floodplains of the Ghaghara River, particularly in the districts of Gonda, Ayodhya, and Basti in Uttar Pradesh. The presence of arsenic in tube well water samples was confirmed through an atomic absorption spectrometry method utilizing flow injection hydride generation. The percentage of tube wells in the districts of Gonda, Ayodhya, and Basti with arsenic contents above 10 µg/l is roughly 61%, 38%, and 42%, respectively. Furthermore, arsenic levels in these districts are alarmingly high, with Basti, Ayodhya, and Gonda showing 26%, 15%, and 45% of tube wells surpassing 50 µg/l, respectively. Notably, 47% of the tube wells in these districts that exhibit arsenic levels above 10 µg/l are located within Holocene Newer Alluvium aquifers at depths ranging from 10 to 35 meters. Additionally, approximately 35%, 69%, and 86% of the tube wells in these areas are situated at a convenient depth of 21–45 meters. The Ghaghara River's suspended sediments have been found to have a notable amount of arsenic (7.11 mg/kg). Most of the arsenic-affected communities in the Ghaghara Basin are located adjacent to the floodplains and meander channels of the river, whether they are currently active or have been abandoned. Conversely, the tube wells in the towns of Nawabganjand Ayodhya are not at risk of arsenic contamination due to their

positioning on the elevated surfaces of Pleistocene Older Alluvium. Groundwater arsenic pollution is largely caused by the quaternary geomorphology of the Ghaghara Basin, with the main mechanism for arsenic release into groundwater being the reductive dissolution of iron hydroxides (Babar Ali Shah 2017).

Significant arsenic accumulation has been observed, with women displaying higher concentrations than men in their nails, hair, and urine among local populations. The detrimental effects of arsenic are evident through the increased incidence of various diseases. Reproductive outcomes, including spontaneous abortions, higher rates of preterm births, stillbirths, neonatal deaths, and low birth weights, have also been documented in the basin. The drinking water quality index (WQI) in the Ghaghara basin is noticeably low, according to the Bureau of Indian Standards, in addition to arsenic contamination. In several villages across the districts of Bahraich, Ballia, and Lakhimpur Kheri, arsenic levels in agricultural soil have surpassed the limits set by the Food and Agriculture Organization. Conversely, water from deep tube wells has been found to have relatively safe arsenic levels, making it suitable for drinking. To maintain soil health and mitigate arsenic contamination in the food chain, it is advisable to promote the use of surface water for irrigation, thereby lowering cancer risks (Sanjay Dwivedi *et al.*, 2023).

A study in the Bahraich district revealed concentrations of arsenic and its speciation, including arsenic (III) and arsenic (V), along with interactions with other major and trace solutes in the water from the Ghaghara basin. Furthermore, 57% of groundwater samples exhibited elevated arsenic concentrations ( $> 10 \mu\text{g/L}$ ), with 67.4% showing higher levels of arsenic (III) compared to arsenic (V), suggesting a potential risk of arsenic (III) poisoning. Elevated arsenic levels were correlated with increased concentrations of Fe, Mn, and  $\text{HCO}_3^-$ , particularly in samples from shallow wells. According to the Central Water Commission (2021), arsenic levels in the Ghaghara river range from 10 to 14 g/L, indicating a hazardous level of arsenic toxicity (Imran Khan *et al.*, 2023).

#### ➤ Arsenic Contamination in Tributaries of River Ghaghara

In the pre monsoon, monsoon and post monsoon period, total of 45 water samples (15 from each season) were collected from the Seti river basin to examine the seasonal variations and associated health risks of dissolved trace element (TEs) the assessment of 15 TEs indicated that Lithogenic sources predominantly influenced the levels of Nickel, Chromium and Arsenic were as Zinc, Manganese, Cadmium, Cobalt, Copper, Cesium and Lead were derived from both geogenic and anthropogenic sources (Ramesh Raj Pant *et al.*, 2021).

To conduct geochemical analysis and identify the primary geochemical processes affecting groundwater chemistry, thirty groundwater samples collected from the banks of the **River Sharda**. Reports indicate that arsenic contamination in shallow wells (3-10m) is confined to more recent Holocene - aged alluvium. Monitoring at ten sites

showed a moderate annual decline in groundwater levels of 0.067m. The extensive extraction of groundwater for irrigation, coupled with reduced recharge and diminished rainfall, may have accelerated groundwater flow, while increasing temperature and weathering processes have facilitated Arsenic mobilization. Long term observation reveals a decrease in rainfall by 1.97mm/year, alongside a rise in temperature of 0.0049°C annually. These fluctuations in temperature and rainfall may have also influenced the mobilization of Arsenic in groundwater. Nitrate ( $\text{NO}_3^-$ ) levels were found to be low in samples with minimal Arsenic under reducing conditions, whereas samples with elevated Arsenic concentration exhibited significant Iron content, suggesting a common source. Furthermore, the alkaline nature of the aquifer and high concentration of bicarbonate ( $\text{HCO}_3^-$ ) may have played a role in the accumulation of Arsenic (Sonal Bindal *et al.*, 2020).

The Central Water Commission (2021), under the Ministry of Jal Shakti, reports that the arsenic concentration in the **Kuwano River** ranges from 9 to 8 g/l, indicating a critical level of arsenic toxicity. In contrast, the **Saryu River** exhibits an arsenic concentration of 7 to 8 g/l, which is categorized as a moderate level of arsenic toxicity (Gopal Shankar 2023).

Arsenic concentrations in the **Rapti River** Basin, which is situated in the Terai region of Uttar Pradesh, India, have been reported to exceed 399  $\mu\text{g/L}$ . Villages situated on the left bank are found to be contaminated with arsenic, whereas those on the right bank do not exceed the World Health Organization's (WHO) standard of 10  $\mu\text{g/L}$  for arsenic concentration. Elevated iron (Fe), bicarbonate ( $\text{HCO}_3^-$ ), and arsenic levels indicate that  $\text{FeOOH}$  dissolves reductively, which raises the amount of arsenic in groundwater. Additionally, low sulfate to chloride ( $\text{SO}_4/\text{Cl}$ ) ratio values, ranging from 0 to 3.57, indicate a highly reducing environment. Throughout the Rapti River, high arsenic concentrations were detected in 8 out of 12 selected villages, with approximately 41% of samples exceeding the WHO permissible limits. The river's dynamics appear to distribute arsenic, as all samples with elevated arsenic levels were found on the left bank, which is at a lower elevation compared to the right bank (Chander Kumar Singh *et al.*, 2018).

Groundwater testing for arsenic and other critical water quality parameters was conducted between April and August 2011, resulting in the collection of 248 samples from various locations in the Gorakhpur district. Of these, 29.84% of groundwater samples exhibited arsenic levels between 10 and 50 parts per billion (ppb), while 6.45% surpassed 50 ppb. Consequently, 36.29% of the samples had arsenic concentrations exceeding the WHO threshold of 0.01 mg/l or 10 ppb. This situation is particularly alarming in four blocks of the district—Barhalganj, Jungle Kauria, Piprauli, and Khorabar—where over 50% of the samples were found to be non-compliant. The highest arsenic concentration, recorded at 91 ppb, was identified in the Khorabar block, indicating a significant risk to the health of Gorakhpur residents consuming groundwater (Sanjay Kumar *et al.*, 2014).

Using field test kits and a thorough screening and blanket testing approach, UP Jal Nigam tested for arsenic in 150,000 sources in Uttar Pradesh between 2005 and 2008. Geographical information system (GIS) mapping was done in the Bahraich district. The district is characterized by two distinct physiographic units, Tarhar and Uprahar, which illustrate the highland and lowland Quaternary alluvial plains. UP Jal Nigam identified 7,190 (52.06%) of the tested sources had arsenic levels above 0 µg/L after testing 13,812 of the district's 30,216 India Mark II hand pumps for arsenic pollution. Further analysis indicates that 10.86% of the affected sources recorded arsenic concentrations greater than 50 µg/L, while 56.66% fell within the 10–40 µg/L range. The village-level mapping facilitated by the GIS platform indicates that the lowland physiographic units, specifically the Huzoorpur and Tajwapur blocks, exhibit elevated arsenic levels (Amit *et al.*,2014).

The **Choti Gandak river** basin, recognized as India's most significant cane-sugar industrial region situated on the

Ganga plain, was the focus of an investigation into the environmental impacts of these industrial activities. To evaluate the ecological impacts in the Choti Gandak River Basin, soil and water samples were methodically gathered. The findings indicate that industrial operations and adjacent agricultural practices have significantly influenced the concentration of various metals, as evidenced by heightened levels of heavy metals in both soil and aquifers. Notably, concentrations of iron and manganese in groundwater exceed the permissible limits established by the World Health Organization, with elevated iron levels contributing to increased arsenic concentrations in groundwater (Vikram Bhardwaj *et al.*,2010).

### III. RESULT AND DISCUSSION

Ghaghara River, particularly in the districts of Gonda, Ayodhya, and Basti in Uttar Pradesh.

Table 1: Showing Comparison of Different Arsenic Conc. in Groundwater of Tubewell in Above Districts.

| District | As Conc. above 10ug/L | As Conc. above 50ug/L |
|----------|-----------------------|-----------------------|
| Gonda    | 61%                   | 26%                   |
| Ayodhya  | 38%                   | 15%                   |
| Basti    | 42%                   | 45%                   |

Table 2: Showing Arsenic Concentration of Major Tributaries of Ghaghara River.

| S. No. | Tributary Rivers | Arsenic Concentration |
|--------|------------------|-----------------------|
| 1.     | Seti             | Trace Amount          |
| 2.     | Sharda           | Trace Amount          |
| 3.     | Kuwano           | 8-9gm/L               |
| 4.     | Saryu            | 7-8 gm/L              |
| 5.     | Rapti            | 399 ug/L              |
| 6.     | Choti Gandak     | Trace Amount          |

### IV. CONCLUSION

The above mentioned Review article indicated that the groundwater within the Ghaghara river basin and its tributaries is tainted with arsenic. As reported by the Central Water Commission(CWC) (2021), the concentration of Arsenic in the groundwater of the Ghaghara river basin ranges from 10 to 14 g/l, exceeding the World Health Organization's guidelines and classified as hazardous. The Rapti river basin exhibits an arsenic concentration of 399 µg/l. Additionally, the Saryu, Seti, and Choti Gandak rivers which are tributaries of the Ghaghara river, show significant levels of iron and other elements, with iron facilitating the dissolution of arsenic in groundwater. However, there is a lack of data regarding arsenic contamination in some tributary rivers, necessitating further investigation to assess the groundwater conditions and identify the sources of arsenic contamination.

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