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Arsenic contamination of groundwater: Review onarsenic contamination of Assam

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Abstract

Groundwater contamination is a global problem. Although groundwater is considered as safe, high concentrations of heavy metals in groundwater like arsenic (As) can pose potential human health concerns and hazards. Arsenic is a natural chemical element of the earth's crust and is commonly distributed all over the environment. High concentrations of arsenic (As) in drinking water have been found in several parts of the world. World Health Organization's provisional guideline value for arsenic in drinking water - 0.01 mg/l (10 µg/l). In Assam, many districts have been reported to be most affected by arsenic contamination of groundwater which is above the permissible level. People in Assam have directly or indirectly consumed the groundwater. This paper emphasizes the overview of the present scenario of intensity of arsenic contamination in groundwater in different districts of Assam. The paper also critically reviews the sources of arsenic contamination and arsenic led human effects.

Keywords: Groundwater contamination; Arsenic; Human health; Pollution Concentration; Natural Resources

1. Introduction

Groundwater is one of the most precious natural resources in our planet. More than 2.5 billion people on the globe rely on groundwater for drinking. Although groundwater is considered sound and safe, high concentrations of metals like arsenic can pose possible risks to human health. Arsenic is classified chemically as non-metal or metalloid belonging to Group-15 of the periodic table. It can exist both in organic and inorganic forms. However, inorganic forms are more toxic than organic. World Health Organization's provisional guideline value for arsenic in drinking water - 0.01 mg/l (10 µg/l). With several newly affected regions reported during the last decade, a significant increase has been observed in the global scenario of arsenic contamination. It has been observed that different Indian states namely Assam, West Bengal, Bihar, Haryana, Karnataka, Punjab have been highly affected by arsenic. This paper mainly focusses on arsenic contamination in Assam and its different human health effects led by arsenic. Figure 1 shows the arsenic concentration map of the Brahmaputra floodplain of Assam.

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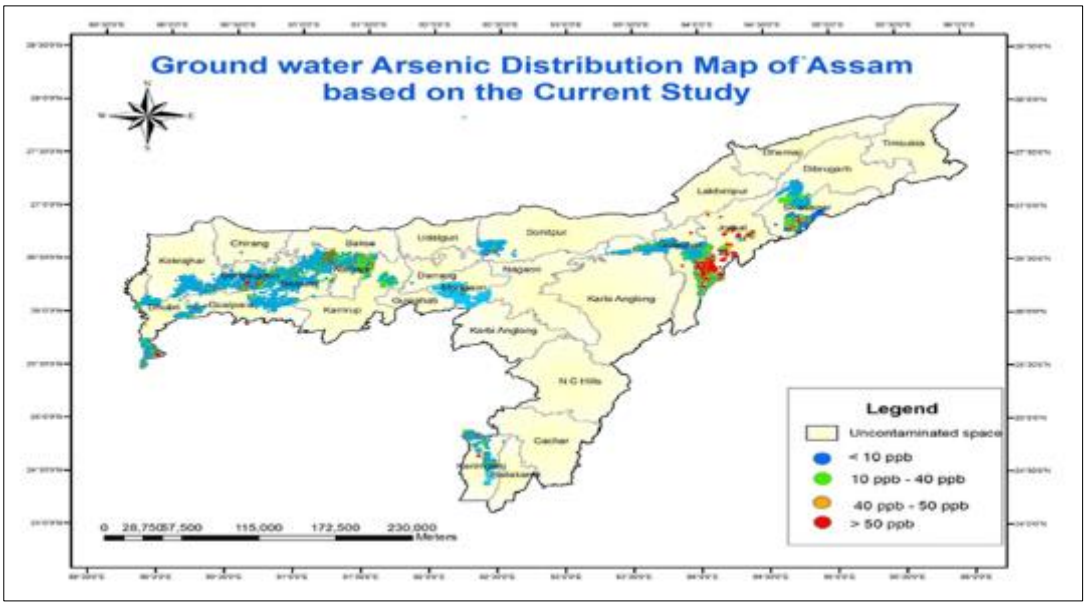

Figure 1 Arsenic concentration map of Assam

2. Literature review

In India, arsenic contamination in groundwater is becoming an emerging issue in the water supply and health sectors. Its abundance has been primarily reported from the Bengal Delta of West Bengal. According to Singh (2004), high concentration of arsenic in groundwater of North eastern states of India viz. Assam, Manipur, Mizoram etc. has become a major cause of concern in recent years. The problem of arsenic in groundwater in Assam is also a matter of great concerned. The presence of groundwater arsenic in the state of Assam was first reported by Singh (2004), NERIWALM. His study revealed that 20 of the 30 districts of Assam have arsenic concentration exceeding 0.050 mg/l. Another study by Chakraborty et al. (2004) revealed that several underground water sources in India's northeast are unfit for consumption due to highly toxic contamination of arsenic. In 2005, Public Health Engineering Department (PHED), Assam carried out a state wide blanket survey for arsenic contamination in drinking water. In total 5729 water samples collected from 22 of the 30 districts in Assam, where the water samples collected from 18 districts had arsenic concentration greater than 0.05 mg/l. Brammer and Ravenscroft (2009) have reviewed the nature of the threats, taking into account the natural sources of arsenic pollution, areas affected, factors influencing arsenic uptake by soils and plants, toxicity levels and the dietary risk to people consuming arsenic-contaminated rice. Chetia et al. (2010) have studied about Groundwater arsenic contamination in Brahmaputra River basin of Golaghat district (Assam). They observed a very significant correlation between arsenic and iron and suggested that the mobilisation of arsenic in the groundwater of that region may have been caused by the reductive breakdown of arsenic-iron featuring minerals. Bhuyan et al. (2010) studied about arsenic and iron contamination of ground water in three development blocks of Lakhimpur district, Assam. His study shows the naturally occurring arsenic in ground water is more widespread than generally recognised. Ali Shah (2012) have studied on the Role of Quaternary stratigraphy on arsenic-contaminated groundwater from parts of Barak Valley, Assam, North–East India'. He suggested deeper tubewells (>60 m) in Plio-Pleistocene Older Alluvium aquifers would be a better option for arsenic-safe groundwater. Chandrasekhar et al. (2013) have reviewed a geotechnical signature of arsenic contaminated ground water in Barak Valley (Assam) and surrounding areas of north eastern India. In their observations, Arsenic is detected at levels above the maximum permissible limit of WHO guidelines concentration which contributes to the observed adverse toxicological effects to humans. The contaminated aquifers of their study area are likely to be confined to the Holocene alluvial terrain and Tipam formation. Elevated levels of Arsenic in the bedrock and soil of study area suggest that the source of Arsenic contamination is geogenic. Das Saurav et al. (2015) emphasized on the occurrence and distribution process of arsenic in ground-water sources as well as associated health risks in North-eastern Region (NER) of India. Mahanta et al. (2016) have studied about health costs of arsenic contamination of drinking water in Assam. They estimated three structural equations to determine health costs due to arsenic contamination and showed that the annual household health cost of a 1µg increase in arsenic concentration per liter is about INR 4. This study draws a policy implication for providing safe drinking water in Assam. Khan Adnan et al. (2017) had made an attempt to assess the arsenic contamination and role of anthropogenic activities on its release in the groundwater of alluvial aquifers occurring on deltaic flood plain of Indus River. Groundwater collected from three semi-urban union councils of Tando Muhammad Khan district revealed that the

groundwater has bad quality for drinking. Jain et al. (2018) reported on Physico-chemical characteristics and hydrogeological mechanisms in groundwater with special reference to arsenic contamination in Barpeta District, Assam (India). From their study it is found that the groundwater samples are contaminated with high amount of arsenic, which refers that water is unfit for consumption as well as agricultural activities. Hydrogeological studies revealed that regional geological factors might be responsible for excess arsenic concentration in the region. Sathe et al. (2020) have suggested that Arsenic enrichment in the shallow aquifer, contaminating groundwater source, has been envisaged as a serious health concern in parts of the Brahmaputra floodplains (BFP),

Assam, India. It is observed that in some of the district such as Morangi, Golaghat South, Kaliapani, and Majuli, where the data are almost absent. Fatoki et al. (2022) revealed the significance of arsenic toxicity and its contribution to health-related challenges. S. Sathe et al. (2020) have suggested that Arsenic enrichment in the shallow aquifer, contaminating groundwater source, has been envisaged as a serious health concern in parts of the Brahmaputra floodplains (BFP), Assam, India. Shaji E et al. (2020) have studied about Arsenic contamination of groundwater in different parts of the world. They have suggested that prolonged consumption of arsenic-contaminated groundwater has caused severe health issues like arsenicosis. Researchers have raising concerns about the potential health effects of arsenic toxicity to the people of these region (Singh, 2004). Nath et al. (2022) presented the high- and low-risk areas in the two most affected districts of Assam, as well as the moderate-risk areas in the district of Majuli, whose inhabitants are relatively poor.

2.1. Sources of arsenic contamination

The groundwater aquifers may be contaminated by manmade and natural sources. Some of the common sources of pollution are: leakages from septic tanks and landfills, dumping of industrial waste and municipal waste, dumping of toxic chemical waste, radioactive disposal, mining and mine drainage, application of fertilizer and pesticides to agricultural field, etc. Further, groundwater may also be polluted by natural pollution sources like arsenic, lead, fluoride etc. The main sources of arsenic contamination are classified as natural sources and anthropogenic sources.

- Natural sources: Arsenic occurs naturally in soil and rock and can dissolve into the groundwater and can enter the drinking water wells. Arsenopyrite, which is found in abundance, is one of the most common mineral sources of Arsenic. It is generally found in anaerobic conditions and other minerals, such as phosphates and silicates that have the tendency to form rocky structures (Smedley and Kinniburgh ,2002)
- Anthropogenic sources: Arsenic can be released into the groundwater as a result of man-made activities like mining, coal and petroleum extraction, excessive use of pesticides and from industrial effluents.

2.2. Study area

The study area Assam is one of the seven North-Eastern states of India. Hydrogeologically the state can be divided into three units namely consolidated formation, semi consolidated formation and unconsolidated formation. More than 75% of the state is underlain by unconsolidated formation comprising of clay, silt, sand, gravel, pebble and boulders. Assam is one of the 28 states of India. It consists of different districts and blocks. Arsenic contamination is a serious problem in many districts of Assam. This research study mainly comprises of major arsenic contaminated districts in Assam. Golaghat, Jorhat, Sibsagar, Lakhimpur, Nagaon, Nalbari, Baksa,Barpeta, Cachar are the districts whose arsenic levels have crossed the permissible limits of WHO, that is 0.01 mg/l.

3. Methodology

The information and datas have been collected from secondary sources for example various Govt. report, different journals, articles, PHED (Public Health Engineering Dept.) website, SWID (State Water Investigation Directorate) website, Planning commission report etc.

3.1. Health effects of arsenic contamination

Arsenic is very fatal cancerous and harmful contaminant of drinking water. Arsenic exposure causes a pattern of non-carcinogenic dermal effects that begins with spotted hyperpigmentation. Long-term exposure to arsenic can cause cancer in the skin, lungs, bladder and kidney. According to a recent data in 2023, cancer cases spike in Assam due to arsenic and prolonged used of arsenic contaminated water for drinking causes several diseases, predominantly skin pigmentation, thickening, hard patches on the palms and soles of the feet(hyperkeratosis). According to an assessment published by Assam's Public Health Engineering Department in 2023, 6881 habitations in the state are affected by arsenic across 20 districts. Baksa district in lower Assam had highest 1506 such affected habitations. In upper Assam's

Jorhat district, 1454 habitations were affected followed by 1342 in Nalbari district. Fig. 2 shows an arsenic affected person in Assam.

A joint study carried out by Dr Bhubaneswar Borooah Cancer Institute (BBCI), Guwahati, along with some leading institutions, has found chronic arsenic exposure in drinking water, even at low moderate levels, as a potential risk factor for the development of gallbladder cancer (GBC) in arsenic-endemic regions of India. BBCI, Guwahati had conducted the research between 2019-2021 along with Public Health Foundation of India (PHFI) and Centre for Chronic Disease Control, New Delhi; Mahavir Cancer Sansthan and Research Centre, Patna; and Indian Institute of Technology, Kharagpur in collaboration with the London School of Hygiene and Tropical Medicine. The two-year study was carried out in large tertiary-care hospitals that catered to patients across different parts of Assam and Bihar where both gallbladder cancer and arsenic contamination in drinking water are significant public health problems. It evaluated the association between arsenic levels in groundwater and gallbladder cancer (GBC) risk in a case-control study of long-term residents (≥10years) in the two states.

Further, it assessed arsenic exposure of the study participants (men and women aged between 30 and 69 years) based on their residential history since childhood and the corresponding average concentration of groundwater arsenic at the district level.

According to the findings, compared to residents living in regions with arsenic concentration in groundwater less than one microgram per litre, arsenic concentrations ranging from one to eight micrograms per litre in groundwater showed a two-times increased risk of gallbladder cancer, and higher arsenic levels (more than nine micrograms per litre) showed a higher risk of 2.4 times.

Figure 2 Arsenic affected persons (source: www.google.co.in)

4. Results and discussions

Identification of arsenic contamination in different sources in a groundwater aquifer is an important and challenging task for the researchers working on pollution of aquifer. The location and magnitude of arsenic contamination can be identified and prediction can be made using different technique. According to Tirtankar Sarma and Dr. Sailajananda Saikia in 2021, Hajo circle in Assam has arsenic contaminated groundwater. Table 1 shows the arsenic contamination in groundwater in Hajo circle, Kamrup, Assam. Table 2 shows the district wise list in which occurrence of Arsenic in Assam has been reported in the range 0.01 to 0.05 mg/ l and more than 0.05 mg/l respectively.

Almost 18 tube well samples have been collected and tested from the Hajo circle to analyse the groundwater arsenic contamination on that area. Out of the total geographical area, 210 sq km area has groundwater arsenic contamination less than 10.40 ppb. About 122 sq km has groundwater contamination between 10.41-20.80 ppb. Groundwater arsenic contamination between 20.81-31.20 ppb can be found in 20 sq km. In the study area ,41 sq km has arsenic contamination in groundwater between 31.21-41.60 ppb. Groundwater arsenic above 41.60 ppb can be found in 31 sq km area.

Table 1 Groundwater arsenic contamination in Hajo circle, Kamrup (source: primary survey)

Sl no.	Groundwater arsenic in ppb	Area in sq km	Percentage
1	0.00-10.40	210	50.73
2	10.41-20.80	112	27.05
3	20.81-31.20	20	4.83
4	31.21-41.60	41	9.90
5	41.61-51.99	31	7.49
Total		414	100

Table 2 Districts in Assam having arsenic concentration above permissible limit

Sl no.	District	Block	Location	Arsenic concentration(mg/l)
1	Golaghat	Golaghat	Golaghat	0.01
2	Jorhat	Jorhat	BijayNagar	0.01
3	Lakhimpur	Lakhimpur	Mori Dirgha	0.04
4	Nagaon	Nagaon	Bichamari	0.02
5	Nalbari	Nalbari	Tamulpur	0.02
6	Sibsagar	Sibsagar	Bandarmari	0.02
7	Nagaon	Nagaon	Gomotha	0.055
8	Cachar	Cachar	Moinarbond	0.065
9	Jorhat	Jorhat	Tipamia	0.1467
10	Barpeta	Barpeta	Kokkussia	0.02

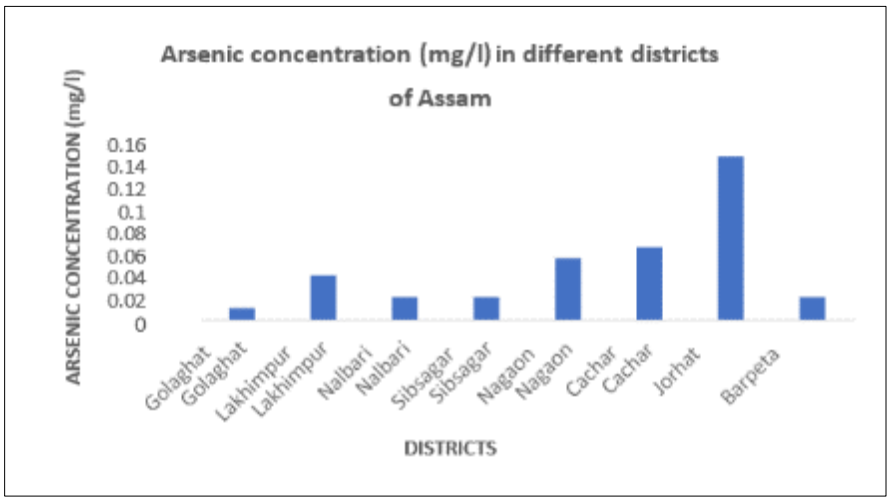

Figure 3 Graphical representation of arsenic concentrations of districts of Assam

The above figure shows the arsenic concentrations in the most arsenic affected districtsof Assam. The x-axis represents the districts of Assam and y-axis represents the arsenicconcentrations (mg/l). From the figure it can be observed that Jorhat district has the highest level of arsenic concentration of 0.1467 mg/l and Golaghat district has the leastlevel of arsenic concentration of 0.01 mg/l.

Talking about the impact of arsenic contamination water on human health, according to Sarma and Saikia (2021), epidemiological household survey has been conducted by them for study of arsenic related disease in Hajo Tehsil area. The following table 3 shows incidences of arsenic disease in Hajo.

Table 3 Incidence of arsenic related disease in Hajo Tehsil

Sl no.	Village	Respiratory disease	Skin disease	Cancer	Heart disease
1	Bargaon	5	4	6	1
2	No.1 Dolibari	2	3	5	1
3	No.2 Dolibari	4	3	9	5
4	Rakshashini Char	2	0	0	1

According to a recent article published in Times of India newspaper by Piyush Tripathi (2023), research conducted by researchers from Bihar and Assam has found that people exposed to arsenic through drinking water are at higher risk of gallbladder cancer. The study found that participants in the research exposed to arsenic concentrations averaging 1.38-8.97 microgram per litre in groundwater had a two times greater risk of gallbladder cancer, while those exposed to even higher arsenic levels (9.14-448.39 microgram per litre) experienced a 2.4 times increased risk of gallbladder cancer.

The study was conducted by scientists at the Centre for Environmental Health (CEH), Public Health Foundation of India (PHFI), Centre for Chronic Disease Control (CCDC), Dr. Bhubaneshwar Barooah Cancer Institute (BBCI), IIT Kharagpur in collaboration with the London School of Hygiene and Tropical Medicine (LSHTM). The study was carried out in large tertiary care hospitals, which cater to patients across different parts of Assam and Bihar.

Dr. Poornima Prabhakaran, Director, Centre for Environmental Health, Public Health Foundation of India, highlighted how this study is aligned with the Jal Jeevan Mission 2024 and Sustainable Development Goals of equitable clean and safe drinking water

5. Conclusion

Groundwater is important for domestic and irrigation purposes basically in rural areas where surface water is not available. On the basis of quantity and quality, groundwater is extracted from shallow and deep aquifer. Groundwater is generally considered as good quality, but if once contaminated, it is very difficult to restore its quality again. Researchers have raising concerns about the potential health effects of arsenic toxicity to residents of different district of Assam. Jorhat, Lakhimpur, Nalbari, and Nagaon in Assam have reported the highest concentration of arsenic (Singh, 2004). The literature review done in the in this study reveals that, lot of works have been carried out in these districts and performed laboratory approaches to identify arsenic contamination in groundwater and have predicted the distribution of arsenic contamination in different districts of Assam. Due to spatial heterogeneity of arsenic distribution in groundwater, it makes difficult to predict and select the sources of water for domestic, agricultural and industrial uses. Lots of Researchers have used machine learning techniques to predict the location of safe and unsafe areas of groundwater. It is observed from literature that arsenic concentration does not remain constant and found to vary with sediment age and depth of the tube wells. At the same time, it also varies with the seasons.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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