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Arsenic Contamination in Groundwater and its Impact on Human Health in North-Eastern India: A Review

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Abstract

Arsenic is a metalloid with compounds that exist in crystalline, powder, or vitreous form. It is a natural component found in the earth's crust, but industrial waste is a major source of harmful Arsenic compounds. Arsenic contamination in groundwater in North-East India has already been proven to be dangerous regarding its influence on human health. Long-term consumption of arsenic-contaminated water produces arsenicosis, a chronic health disorder caused by prolonged exposure to arsenic above tolerance thresholds. This study aims to outline the actual status of arsenic concentration level of North-Eastern states of India based on a review of literature. Existing studies also reported the presence of arsenic-contaminated groundwater in Assam, Manipur, Meghalaya, Mizoram, Arunachal Pradesh, Nagaland, and Tripura, and Sikkim. Most of the areas of the North-East Indian states are identified having arsenic concentration level ranges from 50 µg/L to 986 µg/L. The level is distressingly significant when compared to the permissible limits quoted by WHO (World Health Organization) and BIS (Burau of Indian Standard) (10 µg/L and 50 µg/L).

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Prolonged exposure to arsenic in drinking water can lead to skin lesions, cardiovascular diseases and various cancers including those of the skin. Arsenic-affected people are suffering from income loss, lower productivity, and diminishing ability to work, resulting in strained family relationships.

Keywords: *Arsenic, Groundwater, North-Eastern States, Health Hazard, Status.*

1. Introduction

Access to safe drinking water, sanitation, and hygiene is a fundamental human necessity for health and well-being, as per the United Nations 6th Sustainable Development Goal. In India, right to water is recognized as a fundamental right by the higher judiciary. It is an essential resource for human survival, and hence ensuring the supply of pure and safe drinking water-free from any harmful contaminants is a critical concern for public health. Various studies and reports have highlighted the presence of arsenic in water, rendering it unsafe for consumption (WHO 2019, Mahanta et al., 2016, and Roy 2007). Arsenic contamination in groundwater is a global concern, as it has led to numerous health related issues in various regions across the globe, including Argentina, Pakistan, Mexico, Thailand, Chile, Nepal, Vietnam, and Myanmar (Dhar et al., 1997; Chakraborti et al., 2002; Mandal and Suzuki, 2002; Smedley and Kinniburgh, 2002; Pfeifer et al., 2004; Hossain, 2006; Mondal et al., 2006). The extent and the nature of groundwater arsenic contamination in drinking water is continuously increasing, with the new areas being identified through the ongoing surveys. Over the past few decades, several new cases of arsenic contamination have emerged, particularly in Asian countries. Before 2000, three major incidents of groundwater Arsenic contamination were recognized in Asia, specifically in Bangladesh, West Bengal (India), and in certain locations in China and Taiwan.

In Eastern Africa, arsenic has been detected in surface water systems in Ethiopia, Kenya, and Tanzania. The concentrations levels range from a minimum of 0.21 µg/L (Dsikowitzky et al., 2013, Rango et al., 2013) to a maximum of 566 µg/L within regions of the East African Rift Valley (EARV). The presence of arsenic in groundwater systems has been documented in Ethiopia and Tanzania. In Ethiopia, arsenic concentrations in groundwater range from a minimum of 0.6 μg/L to a maximum of 566 μg/L, as reported by Rango et al. (2013) in the Kenyan section of the EARV. In Ghana, arsenic concentrations in surface water, primarily from the Ankobra River, ranged from <0.003 to 28,950 μg/L (Rossiter et al., 2010; Akabzaa et al., 2009). Similarly, arsenic levels between 0.62 and 119 μg/L were reported in the surface water systems of Cape Town and Koekemoe Spruit (Akinsoji et al., 2013; Dzoma et al., 2010).

In Asian scenario, Arsenic contamination has been reported in various countries, including Afghanistan, Armenia, Azerbaijan, Bangladesh, Cambodia, China, Georgia, India, Indonesia, Iran, Iraq, Japan, Jordan, Kazakhstan, Kyrgyzstan, Laos, Malaysia, Mongolia, Myanmar, Nepal, Pakistan, the Philippines, Russia, Saudi Arabia, Sri Lanka, Thailand, Turkey, Turkmenistan, Uzbekistan, Vietnam, Tajikistan, and Korea. Among these, China, Bangladesh, India, and Pakistan are the most severely affected (Shaji et al., 2021).

High concentrations of arsenic (>10 ppb) have been detected in shallow aquifers across 10 states in India. The first reported case of arsenic contamination in groundwater was from the Chandigarh region in northern India (Datta and Kaul, 1976), followed by a second case in the lower Gangetic Plain of West Bengal (Garat et al., 1984).

Arsenic contamination in groundwater was first reported in Assam in 2004. Higher concentrations of arsenic and other elements have been observed at shallow depths, similar to findings in other regions of the Brahmaputra floodplain. Additionally, the Jorhat district of Assam has been identified as having high levels of arsenic in its groundwater (Shaji et al., 2021, Singh, 2004, Mahanta et al., 2016a).

Consumption of arsenic contaminated water exceeding 50 μg/L (According to BIS) is linked to various health related issues, including skin disorders (pigmentation, dermal hyperkeratosis, and skin cancer), as well as cardiovascular, neurological, haematological, renal, and respiratory diseases. According to WHO guidelines (WHO, 1993), the maximum permissible limit of arsenic in drinking water is 10 μg/L, which is also adopted by the Bureau of Indian Standards (BIS, 2003). Additionally, it has been associated with lung cancer, bladder, liver, kidney, and prostate (Smith et al., 1998). Over the past four decades, millions of tubewells have been installed in the Ganges Brahmaputra Meghna (GBM) delta complex and other regions worldwide (Ravenscroft et al., 2009). The occurrence, source, and movement of arsenic in sedimentary aquifers are influenced by several factors such as local geology, geomorphology, hydrogeology, and sediment geochemistry (Nickson et al., 1998; Acharyya et al., 2000; Smedley and Kinniburgh, 2002; McArthur et al., 2004; Acharyya and Shah, 2007, 2010).

Long run exposure to arsenic-contaminated drinking water has a significant negative impact on human health, socioeconomic conditions, productivity, and agriculture. Many people who are primarily living in rural areas are unaware of the arsenic-related issues they are facing. Infect, in Majuli district, Assam, around 99 per cent of the affected population is unaware of the harmful health impacts of arsenic contamination, with only 15per cent having any understanding of the associated health risks (Goswami et al. 2020). Overall, 84per cent of households have heard about arsenic, with the wealthiest group being far more informed (97per cent) compared to the poorest (69 per cent) (Ahmed et al. 2011). Sultana et al. (2013) found that most respondents do not have the basic knowledge about arsenic poisoning. Beyond its health consequences, arsenic contamination in water causes severe social and psychological distress. Many past research, particularly in Bangladesh, highlighted the socio-economic, cultural, and mental health effects of arsenicosis (Curry et al. 2000; Barkat 2004; Hadi & Parveen 2004; Hanchett 2004; Hassan et al. 2005; Ahmad et al. 2007; Nahar, Hossain & Hossain 2008; Brinkel et al. 2009; Sarker 2010; Mahmood & Halder 2011; Sultana et al. 2012; Syed et al. 2012).

The present study aims to provide an overview of the Nort Eastern situation concerning arsenic contamination in water, as well as human exposure to contaminated water, which continues to pose a health risk. It is important to note that the data presented are based on major published case studies and do not necessarily represent the complete scenario in each state.

2. Sources of Arsenic contamination

Groundwater can be contaminated by both natural and human-made sources. Common causes of pollution include leaks from septic tanks and landfills, industrial and municipal waste disposal, dumping of toxic chemicals, radioactive waste disposal, mining activities and mine drainage, as well as the use of fertilizers and pesticides in agricultural production. Additionally, natural contaminants such as arsenic, lead, and fluoride can also pollute groundwater. Arsenic contamination, in particular, originates from both natural and anthropogenic sources.

Natural Sources: Arsenic is naturally present in soil and rock and can dissolve into groundwater, eventually entering drinking water wells. One of the most common mineral sources of arsenic is arsenopyrite, which is found in abundance. It typically occurs under anaerobic conditions, along with other minerals like phosphates and silicates, which tend to form rocky structures (Smedley and Kinniburgh, 2002).

Anthropogenic Sources: Arsenic can enter groundwater due to human activities such as mining, coal and petroleum extraction, excessive pesticide use, and industrial effluent discharge.

3. Methodology

The information and data have been gathered from secondary sources, including various government reports, journals, articles, the Public Health Engineering Department (PHED) website, the State Water Investigation Directorate (SWID) website, and Planning Commission reports.

3.1 Health problems due to prolonged use of arsenic contaminated water

Long-term use of Arsenic-contaminated water causes several diseases. According to the BIS standard, 50 μg/L is the maximum level that is safe to drink, Arsenic-contaminated water. The World Health Organization set the level of Arsenic-contaminated water to 10 μg/L. But if an area where the Arsenic contamination water level is above its maximum level (BIS), then long-term exposure to Arsenic in drinking water has been linked to an increased risk of various cancers, skin lesions, neurological effects (cognitive deficits, developmental issues in children, etc), cardiovascular effect (hypertension, atherosclerosis), reproductive and developmental issues (infertility, increases risk during pregnancy), gastrointestinal issues (abdominal pain, diarrhea), immune system suppressors (Infections, Illness) etc.

Figure 1: Pictures of health issues due to arsenicosis

Source: *(Chakraborti et al., 2017)*

Drinking tube-well water that has Arsenic contamination above 50 μg/L increases the risk of fatal loss and infant death (Chakraborti et al., 2016). The long-term exposure to high levels of inorganic Arsenic contaminated water above BIS level, the first changes usually seen in the skin: are pigmentation changes and then skin lesions and hard patches on the palms of the hands and soles of the feet, which may be the precursor to skin cancer (WHO, 2019). Consumption of arsenic contaminated water led to multiple health disorders, including cancer, melanosis, keratosis, and Arsenicosis (Jha & Tripathi, 2021). Arsenic-affected people are not only suffering health-related problems but also a burden on their families as well as society, and also for the country as well (Ahmed et al., 2011).

4. Present scenario of arsenic contamination in groundwater in North Eastern India

The first monitoring of groundwater arsenic contamination in the North-Eastern (NE) region was conducted in 2003 by Singh (2004). His survey covered all eight NE states- Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim, and

Tripura. The study identified elevated arsenic levels (>50 μg/L) in the groundwater of most NE states, except Meghalaya and Sikkim. Later, Kumar et al. (2013) also confirmed Mizoram as a non-arsenic-contaminated state. However, further monitoring of groundwater in other NE states remains crucial, given the WHO permissible limit of 10 μg/L.

In Assam, groundwater arsenic concentrations have been found to exceed 50 μg/L in most of the districts, and almost 23 out of 27 districts affected from arsenic contamination (Singh, 2004; Hazarika and Bhuyan, 2013; Kumar et al., 2013; Goswami et al., 2014; Puzari et al., 2015). The Arsenic levels across different districts range from 50 to 657 μg/L. The most severely affected districts are Jorhat, Lakhimpur, Nalbari, and Nagaon. In Jorhat, arsenic contamination is highest, ranging from 194 to 657 μg/L, while in Lakhimpur, the levels of arsenic contamination varied between 50 and 550 μg/L. In Nalbari, 19per cent of the samples (72 samples) contained arsenic concentrations between 100 and 422 μg/L (Singh, 2004). According to recent data from 2023, cancer cases in Assam have surged due to arsenic contamination in drinking water. Prolonged consumption of arsenic-contaminated drinking water has been linked to various health issues, primarily skin pigmentation, thickening of the skin, and the development of hard patches on palms and soles (hyperkeratosis).The Public Health Engineering Department of Assam in 2023 reported that 6,881 habitations across 20 districts in the state are affected by arsenic contamination. Baksa district in Lower Assam recorded the highest number of affected habitations at 1,506, followed by 1,454 in Jorhat district of Upper Assam and 1,342 in Nalbari district.

In the floodplain areas of Assam, including Barpeta, Dhemaji, Dhubri, Darrang, and Golaghat districts, the level of arsenic contamination in water ranged from 100 to 200 μg/L and in the remaining 14 districts, arsenic concentrations in water varied between 50 and 100 μg/L. Three districts of Assam, viz, Karbi Anglong, NC Hills, and Morigaon, were found to be free from arsenic contamination. In Golaghat, which borders West Bengal and Bangladesh, arsenic levels reached up to 128 μg/L (Chetia et al., 2011). Majuli Island, a subdivision of Jorhat and the world's largest inhabited riverine island, is also affected by arsenic contamination. Groundwater arsenic levels in Majuli ranged from <3 to 468 µg/L (n=380), with 37.6per cent of samples exceeding 10 µg/L and 16per cent surpassing 50 µg/L (Goswami et al., 2014).

Table 1: Number of districts affected and groundwater (GW) arsenic (As) contamination range in various states of Northeast India.

Sl.No	State	No. of affected districts	Range of GW As µg/L (microgram per liter)	References
1	Arunachal Pradesh	6	58-618	Singh, 2004
2	Assam	23	3-657	Singh, 2004; Hazarika and Bhuyan, 2013; Kumar *et al.*, 2013; Goswami *et al.*, 2014; Puzari*et al.*, 2015
3	Nagaland	3	50-278	Singh, 2004; Puzari*et al.*, 2015
4	Manipur	4	3-986	Singh, 2004; Chakraborti *et al.*, 2008
5	Meghalaya	0	No arsenic state	Singh, 2004
6	Mizoram	1	<10	Singh, 2004; Kumar *et al.*, 2013
7	Sikkim	0	No arsenic state	Singh, 2004
8	Tripura	4	65-444	Singh, 2004; Banerjee *et al.*, 2011

In Arunachal Pradesh, arsenic contamination was reported in six out of 13 districts surveyed in 2004- Papum Pare, West Kameng, East Kameng, Lower Subansiri, Dibang Valley, and Tirap (Singh, 2004). All these districts are located near the Assam border. Arsenic concentrations ranged from 58 to 618 µg/L, with the highest levels recorded in the Midland block of Dibang Valley district. Similarly, the border areas of Nagaland, particularly those adjacent to Assam's Jorhat district, are affected by arsenic contamination. In Nagaland, two out of eight districts- Mokokchung (50–278 μg/L) and Mon (67–159 μg/L)- had elevated arsenic levels. Additionally, traces of arsenic (<10 μg/L) were detected in Wokha and Zunheboto districts (Singh, 2004). Tripura is also significantly affected by arsenic contamination. Groundwater arsenic levels ranged from 65 to 444 μg/L in West Tripura (Jirania block), Dhalai (Salema block), and North Tripura (Dharmanagar block). Among these, Dhalai district exhibited arsenic contamination levels nearly twice as high as those in West and North Tripura (Singh, 2004).

The presence of arsenic contamination in groundwater is also been reported in Manipur. Out of the state's nine districts, four located in the Manipur Valley- home to 59 per cent of the state's population- were monitored for arsenic contamination (Chakraborti et al., 2008). In their study, Chakraborti et al. (2008) analysed 628 of the estimated 2,014 hand tube wells in the valley and found that 63.3 per cent had arsenic levels of ≥10 μg/L, 23.2 per cent had concentrations between 11 and 50 μg/L, and 40 per cent exceeded 50 μg/L. Thoubal was identified as the most severely affected district, with 77.6 per cent of tube wells containing arsenic levels above 10 μg/L and 44.4 per cent exceeding 50 μg/L. The highest recorded arsenic concentration (798–986 μg/L) was found in the Kakching block of Thoubal district. An earlier study by Singh (2004) also reported that 50 per cent of samples from Thoubal had arsenic levels exceeding 50 μg/L. Bishnupur was the least affected district, with 21.4 per cent of wells showing arsenic levels above 10 μg/L and 7.1 per cent above 50 μg/L (Chakraborti et al., 2008). The percentage of contaminated wells in Manipur is higher than in other Arsenic-affected states. Notably, there is no correlation between arsenic concentration and the depth of tube wells in Manipur.

Mizoram has been reported as a non-arsenic-contaminated state. Studies, including those by Singh (2004) and Kumar et al. (2013), have not found significant levels of arsenic in Mizoram's groundwater. These studies have not reported significant arsenic contamination in the groundwater of Sikkim state of the Northeast. Research, including findings by Singh (2004) and Kumar et al. (2013), has indicated that Sikkim is not affected by arsenic contamination, unlike several other states in Northeast India. However, continued monitoring is essential to confirm the absence of contamination.

Table 2: Distribution of groundwater arsenic in north-eastern states of India

Sl. No	State	No. of affected districts	Arsenic Affected districts >50 µg/L
1	Arunachal Pradesh	6	Papum Pare, West Kameng, East Kameng, Lower Subansiri, Dibang Valley, Tirap
2	Assam	23	Nagaon, Jorhat, Lakhimpur, Nalbari, Golghat, Dhubri, Darrang, Barpeta, Dhemaji, Baksa, Bongaigaon, Cachar, Chirang, Dibrugarh, Goalpara, Hailakandi, Karimganj, Kokrajhar, Sivasagar, Sonitpur, Tinsukia, Kamrup Metropolitan, KamrupUdalguri
3	Nagaland	3	Mokok Chong, Mon, Dimapur
4	Manipur	4	Imphal East, Imphal West, Thoubal, Bishnupur
5	Meghalaya	0	Arsenic free state
6	Mizoram	1	Aizawl
7	Sikkim	0	Arsenic free state
8	Tripura	4	West Tripura, Dhalai, North Tripura, South Tripura

Source: Mishra et al., 2016.

An alarmingly high number of places in 20 out of 23 Assam's old districts have groundwater contaminated with massive amounts of arsenic, causing the water completely unsafe for human consumption, according to the results of a survey carried out by a team of scientists from the North Eastern Regional Institute of Water and Land Management (NERIWALM). NERIWALM researchers noticed during their survey that the highest level of arsenic, 657 micrograms per liter, is found in the groundwater Titabor block in the Jorhat district of Assam. According to the BIS report 2008, Arsenic contamination pockets are increasing continuously. Arsenic covering pockets of seven states (West Bengal, Jharkhand, Bihar, Assam, Uttar Pradesh, Manipur, Chhattisgarh) in 2017 has risen to 10 states (Including Punjab, Haryana, Karnataka) (Kumar Bhattacharya, 2016). Jorhat and Nalbari have more Arsenic-affected populations and the annual household health cost of a 1μm/L increase in Arsenic concentration per litre is about INR4. Furthermore, if the level of Arsenic concentration is reduced to the safe limit of 50 μg/L, the annual welfare gain for a household is estimated to be INR 862. than other districts of Assam (Mahanta et al., 2016).

5. Conclusion

Water is a fundamental need for humans. There is no human existence without water. Arsenic, a metalloid element, can exist in crystalline, powdered, or vitreous forms. It occurs naturally in the Earth's crust. Water contaminated with 50 micrograms of Arsenic per liter is considered acceptable to drink by the Bureau of Indian Standards (BIS). Severe illnesses such as skin cancer, bladder issues, pregnancy problems, diabetic problems, and other bodily disorders can result from drinking water contaminated with Arsenic above the BIS threshold. Along with decreased working hours, and unaware of the arsenic in the water, is also the problem of people's psychological well-being. Prolonged exposure to Arsenic shortens life expectancy and impairs physical capacity, which affects the economy as well.

The review highlights that in recent years, arsenic contamination has been detected in several states that were previously unaffected. With each new survey, additional arsenic-affected areas have been identified, particularly in Uttar Pradesh, Andhra Pradesh, Karnataka, Kerala, and Tamil Nadu (South India). In Northeast India, groundwater arsenic contamination has been identified in six states, while Mizoram and Meghalaya have been recognized as arsenic-free. According to the review, Manipur has the highest arsenic concentration in its groundwater, whereas Assam has the largest number of arsenic-affected districts among all northeastern states.

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