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Geochemical signature of arsenic-contaminated groundwater in Barak Valley (Assam) and surrounding areas, northeastern India

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Abstract

High arsenic (As) concentrations (12-97 µg/l) have been detected in the groundwater of the Barak Valley region (Assam), northeastern India. The main source of As is traced to the litho-facies of the Tipam formation.

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Keywords: Tipam formation; arsenic contamination; Barak Valley.

1. Introduction

Arsenic (As) in groundwater is one of the most toxic elements. Ingestion of As-rich groundwater leads to deleterious effects on human health including various types of cancers and diseases. The presence of As in groundwater has been reported extensively in recent years from different parts of the world including several from Asia [12]. In India, its abundance has been primarily reported from the Bengal Delta of West Bengal [1, 4]. More recently, studies show that the problem of As contamination is emerging in many northeastern (NE) states of India including Assam, Manipur, Mizoram, etc. [11]. In Barak Valley (South Assam) the incidence of dissolved As in the shallower aquifer has been reported [14]. Hence, the main aim of the present study is to (a) geochemically characterize the hydrogeological system and (b) investigate the sources of As in the groundwater in the Surma basin.

2. Study area

The investigated region of Surma Basin covers southern Assam and Mizoram. i) The southern part of Assam (Barak Valley) consists of three districts viz. Cachar, Karimganj and Hailakandi (24°8' and 25°8' N latitudes and 92°15' and 93°15' E longitudes).

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Age	Lithology	Formation/Group (symbol and thickness)
Recent-Subsistent		Alluvium
Holocene		Dihing Fm.
Pleistocene		Dupitila Fm.
Pliocene		Tipam Fm.
Miocene		Bokabil Fm.
		Upper Bhuban Fm. (Ubb) 1200 - 1800 m
		Middle Bhuban Fm.
		Lower Bhuban Fm.
Oligocene		Barail Group
Precambrian/Cambrian	X X X X X X X X X X	Basement

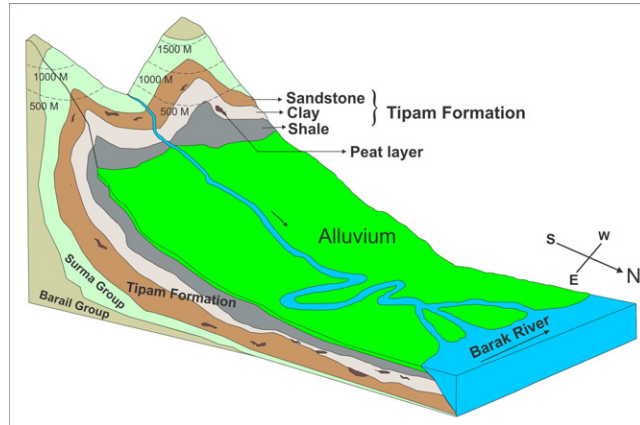


Fig. 1 Generalized stratigraphy of the study area (after [7]).

Fig. 2. Schematic cross section of Barak Valley.

The valley is bounded by the North Cachar Hills District of Assam and the state of Meghalaya to the north; Manipur to the east; Mizoram to the south; and Tripura and Bangladesh to the west. ii) Mizoram is situated in the centre of “salient of the Chittagong-Tripura fold thrust belt of India, sandwiched between Burma and Bangladesh (latitude 21°58’N – 24°35’N and longitude 91°15’E – 93°29’E), bounded by Chachar district of Assam and Manipur in the north, Chin Hills of Myanmar in the east, Chittagong hills of Tripura state and Bangladesh in the west and Arakan Hill ranges of Myanmar on the south.

3. Geology

The Surma basin of south Assam (Barak Valley) and Mizoram consist of N-S ridges of hilly terrain surrounded and bowl shaped synclinal valley elongated in the E-W direction respectively. The basin forms part of the greater Bengal basin [10]. Geologically, sediments of Barak valley can be divided into, i) unconsolidated alluvial deposits of Holocene age and ii) semi-consolidated deposits of the Surma Group – consisting of Bhuban formation which forms oldest rocks in the study area overlain by Bokabil subgroup, and Tipam Groups of Mio - Pliocene age and Holocene Dihing formation (Fig. 1). The alluvial deposits in Barak Valley consist of sand, silt and clay with gravel and occasional lignite beds. The semi-consolidated older rocks exposed in the area include shale, ferruginous sandstone, mottled clay, pebble bed and boulder bed etc., [8] belonging to Bhuban and Barail groups of rocks formed under marine condition, while subduction plate of Indian plate under the Burmese plate has resulted in the migrating accretionary prism complex [2] representing the remnant ocean basin sediments [6]. Further, the younger Tipam formation with thin layer of coal is deposited in the freshwater condition, overlying the shallow marine condition deposits of Bhuban formation of rocks [9]. Fig. 2 shows the schematic cross section of the study area as well as the litho-facies of Tipam formation and the alluvial blanket.

4. Methodology

Ninety water samples were collected for analyzing the cations, anions and trace elements in the laboratory. The As concentrations in water samples were measured immediately in the field by using an As Test Kit (Merkoquent®) to locate wells with high As concentration (Fig. 3). Various physical parameters such as pH, EC, etc., were also measured in the field. Arsenic and other elements in the collected water samples were analyzed by high resolution ICP-AES (Inductively coupled plasma atomic emission spectroscopy). As a part of our research work, representative rock samples were collected from different formations to determine As and other trace elements. Bedrock samples were chosen from

prominent geological formations of the study area. The microwave digestion technique was used to determined As and other trace elements by ICP –AES. The As concentration in the selected rock species is presented in Table 1. The essential chemical data relating to water samples are presented in Table 2.

Table: 1 Selected Bulk As analysis data from different rock units (in mg/kg)

Rock Type	Clay	Sandstone	Shale	Mudstone	Iron banded Shale
As	18	9	8.5	8.5	8

5. Results and discussion

5.1. Groundwater geochemistry

Groundwater geochemistry in the Barak Valley region of Holocene aquifers reveals dominance of Ca-Mg-HCO₃ and Ca-Mg-SO₄-Cl water and less dominance of Na+K-SO₄-Cl and Na+K-HCO₃ water types. However, some well waters have mixed type of Ca-Mg-SO₄-Cl and Na+K-SO₄-Cl, pointing out mixing of fresh water (Ca-Mg-HCO₃) with saline water (NaCl). On the other hand, samples from Mizoram part of the area from Pliocene aquifers are dominantly of Ca-Mg-HCO₃ type with a few wells of Na+K-HCO₃ type, as normally expected for waters interacting with carbonate rich rocks. Moreover, the mixing type of hydrogeochemical evolution suggests that the occurrence of saline groundwater aquifers of the area is perhaps related to relict seawater trapped in the sediment during deposition. The formation has highly influenced marine transgression with fossil assemblages that broadly indicate changes in depositional environments throughout the stratigraphy with shallow marine, near shore, lagoonal through coastal to fluvial [5].

5.2. Soil and bedrock geochemistry

Our overall study of whole rock geochemistry results show consistently high concentrations of As ranges from 2 – 18 mg/kg; the concentrations are elevated with respect to world background sedimentary rock and soil concentrations [12]. The pattern of As distribution shows enrichment in Tipam group of rocks, while in the rest such as, Barail and Surma group of rocks, etc., As content is in the below average level (2 –5 mg/kg). We are thus inclined to conceive that the high As concentration in the alluvial areas perhaps owes its source to the Tipam rock suite. Hence, it is probable that As could have been released in to the sediments under favorable chemical environment.

Table 2. Essential chemical data of selected water samples with high dissolved As (µg/l). PO₄ and Fe are in mg/l.

Sample N°	1	2	3	4	5	6	7	8	9
As	20	56	22	27	97	42	24	71	25
PO ₄	0.11	0.87	0.11	0.56	2.5	0.9	1.3	1.87	0.32
Fe	33.33	27.15	0.93	16.91	0.15	81.57	0.18	0.62	0.12
Sample N°	10	11	12	13	14	15	16	17	
As	16	74	13	12	22	21	13	12	
PO ₄	0.53	0.76	0.11	0.97	0.82	0.12	0.9	0.9	
Fe	0.14	0.13	22.51	3.9	17.66	4.34	0.37	0.13	

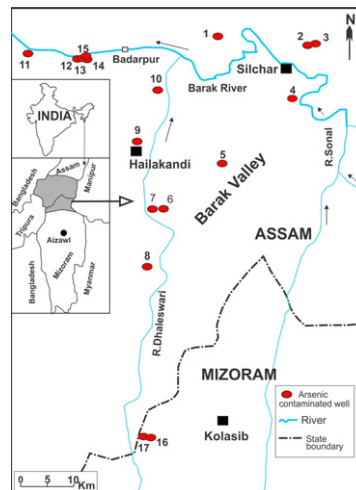


Fig. 3 Arsenic contaminated groundwater well location map.

5.3. Arsenic geochemistry

Arsenic is present in seventeen of the fifty ground water sources of Barak Valley area. All 17 wells used for drinking water, contain As concentrations exceeding the WHO drinking water guideline, 10 μ g/l [15], and the maximum concentration is 97 μ g/l. Arsenic concentrations are not showing any correlation with dissolved Fe, SO₄, Cl., but interestingly, a weak correlation with PO₄ has been observed in the As contaminated samples. The relative affinity for sorption to Fe oxide surfaces is PO₄ > SO₄ > Cl. Phosphate is the best known competitor to As, and displays similar geochemical behavior to As oxyanions. Arsenic mobilization by competitive sorption due to phosphate fertilizer application has been observed in agricultural soils [13], although there is no extensive use of fertilizer in the study areas. Phosphate is also known to strongly sorb onto carbonate minerals [3].

6. Conclusion

Arsenic-contaminated groundwater is most prevalent in the northeastern states of Assam, Manipur and Mizoram etc. In our study, As is detected in the groundwater of Barak Valley (Assam) at levels above the maximum permissible limit of WHO guidelines concentration 10 μ g/l. The As concentration in the well waters ranging from 12 to 97 μ g/l is significant enough to contribute to the observed adverse toxicological effects to humans. The contaminated aquifers are likely to be confined to the Holocene alluvial terrain and Tipam formation. Elevated levels of As in the bedrock and soil of study area suggest that the source of As contamination is geogenic. Interestingly, the As levels in several groundwater samples collected from the aquifers that are situated in Barail and Surma group shows less than permissible limit of the WHO guidelines. The possible physicochemical and tectonic conditions related to this observation are not well understood as of now. Further studies are in progress to understand the pattern and process of As contamination in the aquifers of the study area.

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