Abstract

Contamination of groundwater by Arsenic (*As*), a known carcinogen, is a major drinking water concern affecting millions globally including South and South East Asia. Often associated with iron (III) hydroxides within soils and sediments, arsenic gets released into groundwater through multiple hydrogeochemical processes. Nearly three decades of research has led to our understanding that reductive dissolution of Fe (III) oxyhydroxides is the primary mechanism of arsenic release into aquifers. Yet, mechanisms of release and accumulation both still remain elusive in terms of effects of local geological and hydrological conditions. The interest to unravel the unknowns has escalated particularly with recent revelation of more new areas discovered to host groundwater arsenic contaminated aquifers.

Large unguarded rural populations are vulnerable due to recent revelation of arsenic contamination of groundwater in the upper Brahmaputra Floodplains aquifers in Assam, India. This has led to scattered interventions to understand the processes, mechanism, spatial distribution and factors contributing to local arsenic release mechanism into groundwater. However, the enormity and natural complexity of the region calls for more intensive research to understand the groundwater arsenic contamination issue within the region and to find possible remediation measure to alleviate the problem.

The mechanism of arsenic release have been investigated along two selected transects in the unperturbed, pristine, upper Brahmaputra River Basin in Assam, India. The work is based on the recent revelation of groundwater arsenic contamination scenario in Assam. Two different tectono-sedimentary sites located on the northern and southern banks of the Brahmaputra River were selected for the study based on the results of a large scale field monitoring program by UNICEF-IITG-PHED. Sediment and groundwater samples collected along the two selected transects were analyzed to examine the spatial variation and the factors controlling arsenic distribution in the study sites. Samples from both public and private utilities were collected following standard protocols and analyzed for their major ions and from arsenic enrichment.

A total of 247 groundwater samples were analyzed for seventeen different parameters viz. pH, EC. Temperature, Dissolved Oxygen, Oxidation-reduction potential (E_h), Na^+, K^+, Mg^{2+}, Ca^{2+}, HCO_3^-, SO_4^{2-}, NO_3^-, Cl^-, PO_4^{3-}, As, Fe and Mn were analyzed to examine the role of hydrogeochemistry in controlling arsenic distribution in the pristine river floodplain. Results revealed the dominance of water rock interactions in controlling groundwater evolution in the study area. Hydrochemical data from shallow wells revealed a predominantly reducing characteristic in the aquifers, with low NO_3^- and SO_4^{2-} characteristics and high HCO_3^- concentrations. Groundwater occurrence with similar characteristics indicated reductive dissolution of Fe(III) oxyhydroxides as the mechanism of arsenic release into groundwater, however, the low to moderate interrelationship of arsenic with other redox parameters viz. Mn, Fe etc. indicate that As release into groundwater along both the transect is an interplay of more complex mechanisms. Competition by anions viz. PO_4^- was observed to have played some role in arsenic release.

One of the major causes of concerns regarding the growing arsenic crises around the world is the bewildering degree of spatial Arsenic variability. These contrasts have been evidently linked by different studies to the redox state of the underlying sediments, primarily, an association of low groundwater arsenic with relatively oxic, uplifted Pleistocene aquifers, and high groundwater arsenic concentrations in anoxic Holocene aquifers. To understand the factors controlling spatial distribution of arsenic in the study area, and the factors contributing to the variability were studied indepth. Results revealed an interesting pattern along the 35 km southern transect, where arsenic concentrations gradually increased with distance away from the river.

To evaluate the role of sediments in naturally attenuating arsenic, batch studies were conducted using selected sediment samples from the northern transect. Results revealed that oxidized brown sediments, with high solid phase iron concentrations, have higher arsenic adsorption capacity in contrasts to the grey sand and greyish brown sand. Isotherm study revealed that sediments followed Freundlich isotherm model, indicating the dominance of multilayer adsorption on the sediment samples.

Considering the complexity of the study transects, bounded by the Eastern Himalayas and the Brahmaputra River in the northern transect and the Naga Patkai Hill ranges and the Brahmaputra River in the southern transect; the role of geology, geomorphology and hydrology in controlling arsenic enrichment was another vital aspect investigated in the study. With spatial distribution patterns different from those observed in the Bengal Basin, where elevated groundwater arsenic concentrations along the banks of the lower Brahmaputra River in Bangladesh attributed to the effects of a regular supply of fresh, fine-grained sediments, along the southern transect, elevated arsenic concentrations increase with distance from the river. The role of aquifer flushing as an important hydrological control was attributed to be controlling the pattern of distribution along the transect. Hydrological factors including topographic gradients and slope were observed to be major controls on the distribution patterns along the northern transect.