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Brahmaputra river basin groundwater: Solute distribution, chemical evolution and arsenic occurrences in different geomorphic settings

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ABSTRACT

Study region: Brahmaputra River basin, India.
Study focus: The present study deciphers the groundwater solute chemistry and arsenic (As) enrichment in the shallow aquifers of the study region. Four different geomorphologic units, e.g. piedmont (PD), older alluvium of river Brahmaputra and its tributaries (OA), active alluvium of river Brahmaputra and its tributaries (YA) and river channel deposits (RCD) were identified. More than 62% of all groundwater samples collected have dissolved As >0.01 mg/L, whereas about 87% of groundwater samples in OA terrain are enriched with As, which draws a distinct difference from the adjoining Gangetic aquifers.
New hydrological insights for the region: Most groundwater solutes of RCD and YA terrains were derived from both silicate weathering and carbonate dissolution, while silicate weathering process dominates the solute contribution in OA groundwater. Groundwater samples from all terrains are postoxic with mean pe values between Fe(III) and As(V)–As(III) reductive transition. While, reductive dissolution of (Fe–Mn)OOH is the dominant mechanism of As mobilization in RCD and YA aquifers, As in OA and PD aquifers could be mobilized by combined effect of pH dependent sorption and competitive ion exchange. The present study focuses on the major ion chemistry as well as the chemistry of the redox sensitive solutes of the groundwater in different geomorphic settings and their links to arsenic mobilization in groundwater.

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1. Introduction

Among the various organic and inorganic groundwater pollutants of recent times, geogenic groundwater arsenic (As) is observed as the most challenging contaminant in natural hydrological systems in a global scale (range from <1 μg/L to ~5000 μg/L in natural water) (Bhattacharya et al., 2002, 2006; Smedley and Kinniburgh, 2002; Mukherjee et al., 2008). The elevated concentrations of dissolved As in groundwater, higher than the World Health Organization (WHO) guideline value for drinking water of 10 μg/L, have been recognized in more than twenty geological provinces around the globe (Nriagu et al., 2007; Mukherjee et al., 2008). Most of the high As groundwater aquifers are located in parts of large sedimentary basins adjoining young mountain belts (Saunders et al., 2005; Naidu and Bhattacharya, 2009; Ravenscroft et al., 2009; Rahman et al., 2009; Mukherjee et al., 2014). Of these, the most extensive, As enriched aquifers are present in southeast Asia, which may be tectonically defined as foreland basins related to the Himalayan orogenic/Bhutan belt (Guillot and Charlet, 2007; Mukherjee et al., 2014). These include the Indus, Ganges and Brahmaputra river basins of Bangladesh, India, Nepal and Pakistan (Mukherjee et al., 2015). In most of these areas with As enriched groundwater, the aquifer sediments are of Quaternary age (Bhattacharya et al., 2001; Ahmed et al., 2004; Smedley, 2005; Nath et al., 2005; Charlet and Polya, 2006). The As enrichment in Ganges river basin (Bangladesh and Indian states of Bihar and West Bengal) have been very well studied for last three decades. In general, it was observed, that to a large extent, the distribution of the As-enriched aquifers are controlled by the geologic framework and geomorphic evolution of the river basins (Acharyya and Shah, 2007; Mukherjee et al., 2012, Diwakar et al., 2015). However, excluding very few publications available in the literature (e.g. Enmark and Nordborg, 2007; Bhattacharya et al., 2011; Chetia et al., 2011; Mahanta et al., 2015), the extent, distribution, origin, and mobilization process of As in the aquifers of river Brahmaputra basin, mostly located in the Indian state of Assam, has been largely undocumented, and unexplored.

Brahmaputra River (also known as Tsang Po in Tibet and China), the fourth largest fluvial system in the world, is the largest river that flow in the southeastern Tibet and northeastern parts of India, and is mostly responsible for landscape evolutions of associated region. Originated in the Trans-Himalayas, the river enters Indian state of the Assam through the deep Tsang Po gorge and flows as a wide and deep braided river system. The Brahmaputra river valley is mainly a Quaternary valley-fill with a few isolated pre-Cretaceous residual hills (Singh, 2005). In the Brahmaputra river basin, As enriched aquifers are located mostly in alluvial deposits by the Brahmaputra river channel and its tributaries (Chetia et al., 2011). In the present study, solute distribution and chemical evolution of groundwater and As enrichment of groundwater in part of the Brahmaputra basin, from near the eastern Himalayan foothills of Bhutan to the north bank of Brahmaputra river, is being studied in the perspective of the geomorphologic terrains.

2. Study area

The study area (Darrang and Udalguri districts), situated in the northwestern parts of Brahmaputra River basin of Assam (Fig. 1a), consists of braided alluvial flood plain deposits that are transported by the Brahmaputra river and its tributaries from the adjoining Himalayan provenance. The study area extends from north bank of Brahmaputra river to foothills or piedmont deposits of Eastern Himalayas near Bhutan–India Border. Tectonically, the study area is the eastern continuity of the Indo-Gangetic-Brahmaputra foreland basin of the Himalayas. In the study area, the northern tributaries of the river Brahmaputra drain through the southern slope of the Eastern Himalayas of Bhutan (Fig. 1a). The Brahmaputra river marks a boundary between the Pre-Cretaceous metamorphics and granites in the south and alluvial deposits in the north, up to the Himalayas. The geology of the Bhutan part of Eastern Himalayas comprises of Higher and Lesser Himalayas and the Siwaliks (Fig. 1a). All of the fluvial channels (Brahmaputra and its tributaries) in our study area flow through the strongly deformed Lesser Himalayan metasediments, composed of Precambrian limestone, dolostones, shale, quartzite and schists, along with gneisses and dolerite sills (Garzanti et al., 2004). The Siwalik is discontinuous in the eastern sections of the Himalayas, and includes a thick section of Neogene molasses. The Brahmaputra river basin sediments in the study area are mainly composed of alluvial deposits and it can be classified as older and younger alluvium. The older alluvium is exposed near or close to the