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Hydrogeological assessment along an east-west transect on the Jamuna floodplain in Jamalpur and Bogra districts, Bangladesh

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Abstract: *This research work has been carried out to observe the variations in aquifer properties and groundwater quality along an east-west transect on the Jamuna floodplain. Striplogs and lithologic cross-section demonstrate a continuous, semi-confined sand aquifer up to the depth of 80m. The upper part of the aquifer is predominantly composed of fine and medium sand but the dominancy of coarse sand and gravel has been observed with the increase of depth. A thin clay/silty clay layer covers the western and eastern part of the study area i.e. the floodplain of the Jamuna River. However, river bank and channel bar are characterized by sandy stratigraphy having no clay/silty clay layer. Available arsenic, iron and manganese concentrations data have been used in deciphering the vertical and spatial variations in groundwater quality. Arsenic concentration, irrespective of depth, is relatively high near the Jamuna River and decreases away from the channel. Though Iron concentration does not show any significant relationship with depth, remarkably high concentration is observed in samples adjacent to the Jamuna River. Manganese concentration is noticeable high in the study area and does not show any particular vertical and spatial relationship.*
Keywords: *Aquifer properties, Arsenic, Iron, Manganese, Jamuna floodplain*

I. Introduction

The Bengal Basin is part of the world's largest depositional system and accommodates almost half of the sediments shed from Himalayan collision (Metevier et al. 1999). The surface of the Bengal basin is vast floodplains formed by the Ganges, Brahmaputra and Meghna rivers but it is geomorphologically and structurally complex. The Brahmaputra-Jamuna flowing through Tibet, China, India and Bangladesh is the second largest river in Bangladesh and one of the largest rivers in the world. In fact, Jamuna is the downstream course of the Brahmaputra that took place following the earthquake and catastrophic flood during 1780s. The Jamuna discharges a large volume of water and simultaneously brings in huge amounts of sediments. During the rainy season it brings down about 1.2 million tons of sediment daily and the annual silt runoff is estimated to 735 million tons. The Brahmaputra-Jamuna River migrates laterally at rates of, at least, tens of meters per year (EGIS 1997). Holocene sediments deposited through the aggradations, avulsion, and lateral migration of the Brahmaputra river have buried the latest Pleistocene boundary and infilled the Brahmaputra-Jamuna valley incorporating several morphologic features. Due to the dynamism of the processes that shape, rework, and ultimately preserve the colossal sediment deposits, the stratigraphy of depositional systems can be very difficult to decipher. The sedimentation, stratigraphy and geomorphology led by the Jamuna River have largely influenced the hydrogeology, groundwater chemistry around the Jamuna flood plain (Ahmed et al. 2004; Mukherjee 2006; Hasan et al. 2007; Acharyya and Shah 2007).

The current understanding of subsurface condition in the study area has been based on relatively some widely spaced (50-200 km) boreholes, and observational data are still lacking (Goodbred and Kuehl 2000; Nicholls and Goodbred 2004). It is essential to drill systematically positioned, closely placed transects to depict the complex architecture of the underlying stratigraphy. In this perspective a closely spaced borehole transect drilled under BanglaPIRE project along with other relevant data is considered to understand the hydrogeology of the study area. This paper describes the variations in aquifer properties and groundwater quality along an E-W transect on the Jamuna floodplain.

Study Area

The study area is located at Bogra and Jamalpur districts, the north-north western part of Bangladesh (Fig. 1). Bogra district lies with a coordinate of 24° 30´ to 25°10´ N and 88°50´ to 8950´ E and Jamalpur district lies between 24˚40´ to 25˚20´ N latitudes and 89˚40´ to 90˚10´ E longitude. The study has been carried out along an east-west transect stretching from Bogra Sadar upazila in the west to Jamalpur Sadar upazila in the east.

II. Materials And Methods

The different data used in this work were collected from different organizations. Twenty three almost equally spaced (1 km) borelogs along with depth and location information were collected from BanglaPIRE project. One hundred and sixty groundwater quality data were taken from Department of Public Health and Engineering (DPHE) and British Geological Survey (BGS). Deskwork includes assemblage, scrutiny and processing of collected data. Excel Spreadsheets were used to organize borelogs and groundwater quality parameters. Borelog data were imported into RockWorks software to produce multi-log section and lithologic cross-section to assess the vertical and spatial variations in lithology and finally to decipher the hydrostratigraphy of the study area. ArcGIS 10 software was used to produce different maps based on groundwater quality data to see the variations in spatial distribution of each parameter.

III. Results And Discussion

Hydrostratigraphy

Hydrostratigraphy is mainly reliant on the aquifer materials and its geometry which is the lateral and vertical extent of the aquifer. Generally subsurface geological cross section, multi-log section are satisfactory way in determining the location of the aquifers, aquifer geometry and variability of aquifer materials (Mukherjee et al. 2007). To evaluate the hydrostratigraphy of the area multi-log section and lithologic cross-section were produced based on the borelogs along an E-W transect (AA′) stretching from Bogra Sadar upazila in the west to Jamalpur Sadar upazila in the east (Fig. 2). The lithology of borelogs consists of nine major types of unconsolidated sediments: clay, silty clay, very fine to fine sand, fine to medium sand, fine to medium sand with gravel, fine to coarse sand with gravel, medium to coarse sand, coarse sand, gravel. From the hydrostratigraphic point of view, sand and gravel are considered as aquifer and clay and silty clay as aquitard.

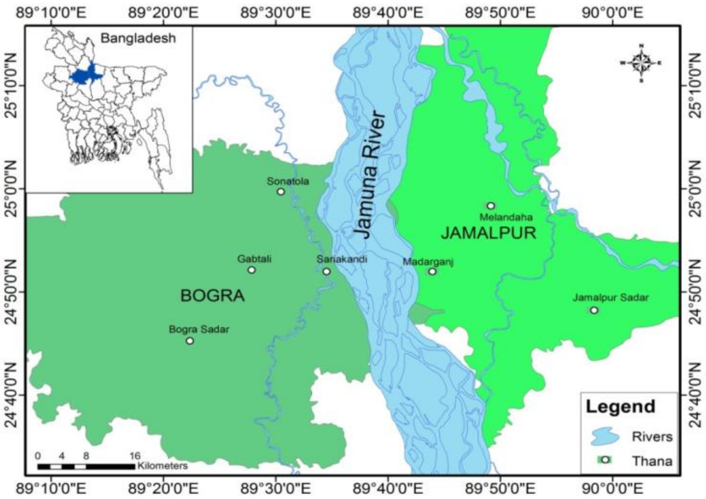

Fig. 1 Location map of the study area

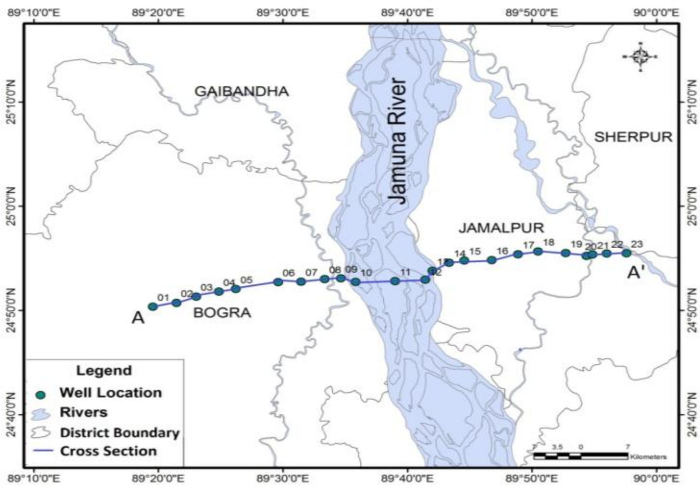

Fig. 2 Location map of the boreholes in the study area

Striplogs

Striplogs of all 23 borelogs were drawn for combined inspection of the logs in the study area (Fig. 3). Multi-log section along AA′ transect shows the dominancy of sand particles and all the logs show more or less fining upward sequence. The logs in the western and eastern part of the section i.e. in the floodplain (e.g. well 2, 4, 16, 20) demonstrate few clay and silty clay layers. The existence of finer sediment like clay and silt at the top of both sides of Jamuna River is due to vertical accretion during floods. The deeper part of the floodplain consists of channel fill deposits of medium to coarse sand with gravel and very little clay. However, logs drilled in the middle of the section i.e. in river bank (e.g. well 10, 12) and channel bar (well 11) are characterized by sandy stratigraphy having no clay/silty clay layer. Clay and silt deposits are washed away by river water for that clay/silt deposits cannot be found at the top of the river banks. Deeper part of the river bank is characterized by sand layers of different grain sizes. Channel bar does not contain any clay layer because bar development occurs at high flow region. The base of channel bar is distinguished by coarse grain deposits.

Lithologic cross-section

The cross section along AA′ shows dominancy in sandy deposits (Fig. 4). The study area is characterized a single, continuous, semi-confined aquifer up to the depth of 80m. Upper part of the aquifer mostly shows finer sands, but grain size increases with depth. A thin clay/silty clay layer (ranging from 5 to 12m) is observed at places (mostly at the western and eastern part) at the top of the aquifer and rest of the places are devoid of any clay/silty clay layers.

Groundwater Quality

Bangladesh is considered to be the most acutely arsenic-affected region in the world (e.g. Smith et al. 2000; Ravenscroft 2003; Mukherjee et al. 2008). In addition to arsenic, The DPHE (1999) has identified manganese as a common naturally occurring constituent in Holocene floodplains of Bangladesh affecting groundwater quality. Iron is known as a widespread nuisance (Ravenscroft et al. 2005). The status of the groundwater quality parameters in the study area is discussed based on health sensitive parameters viz. arsenic, manganese and iron concentrations focusing their vertical and spatial distribution patterns considering WHO (2011) and Bangladesh Drinking Water Standards (BDWS) (DoE 1997). Over 98 % of the wells considered for groundwater quality analysis have depths less than 50m (Fig. 5).

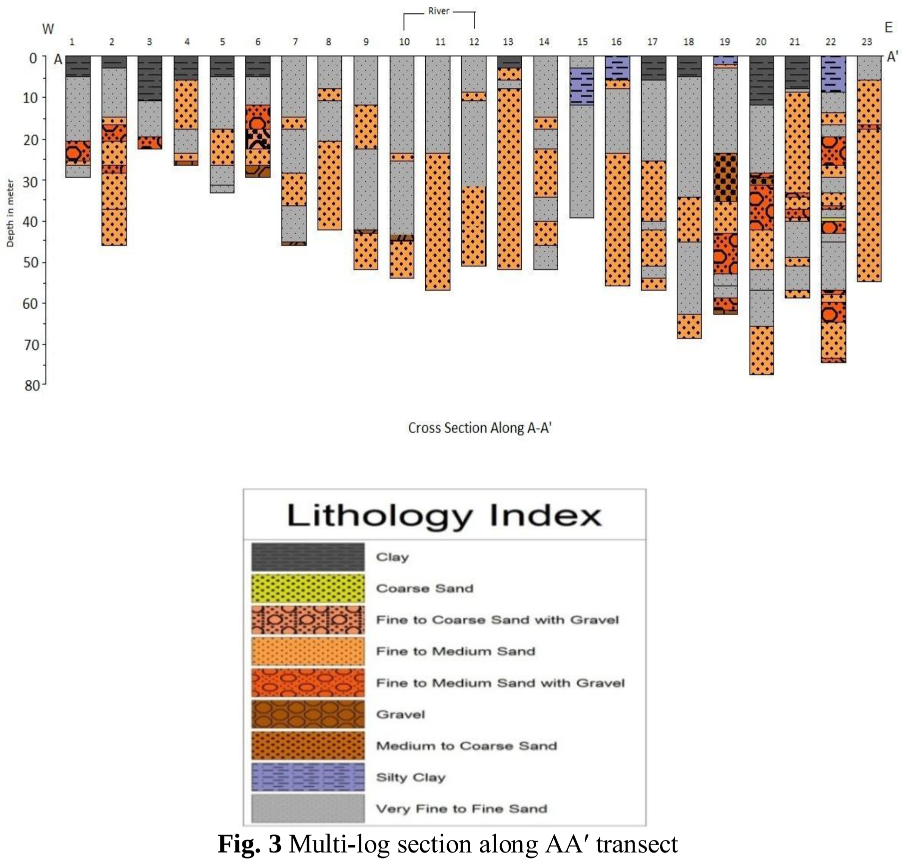

Fig. 3 Multi-log section along AA′ transect

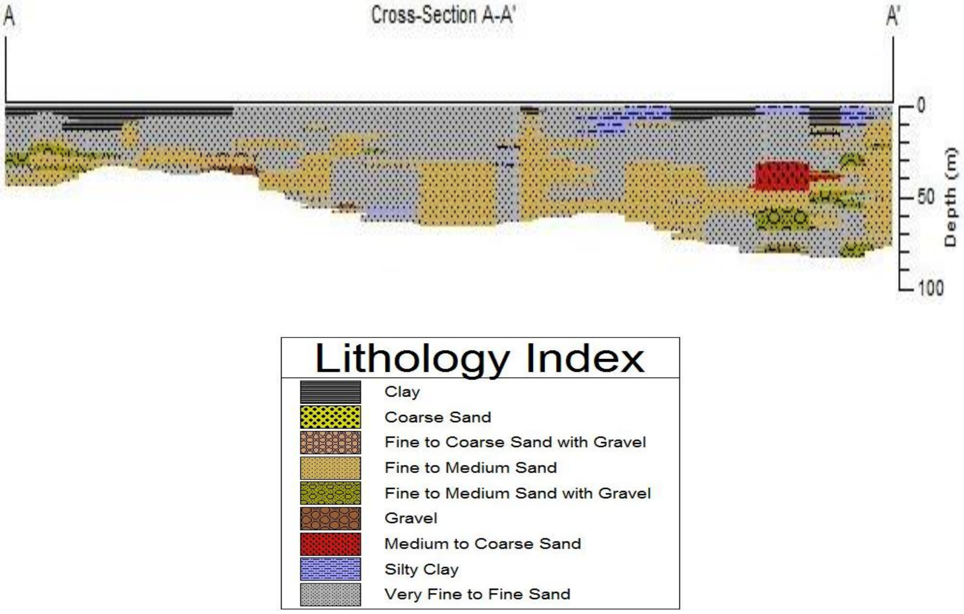

Fig. 4 Lithologic cross-section along transect AA′

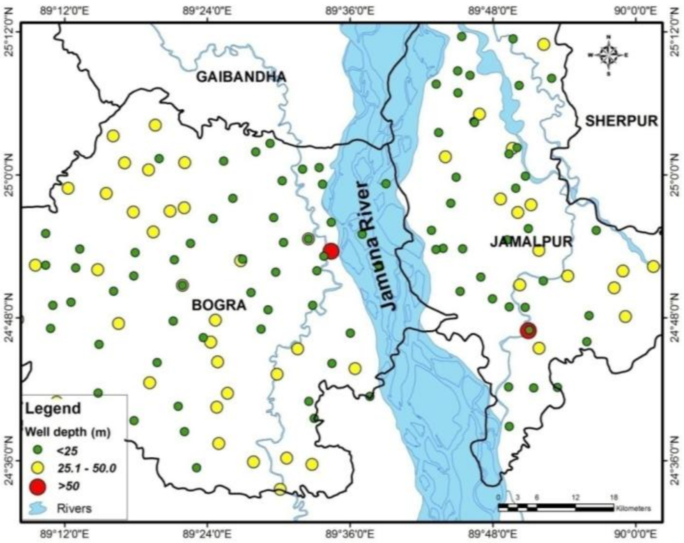

Fig. 5 Location map of groundwater quality samples with depths

Iron

Groundwater in the shallow tubewells of the study area is characterized by overall high iron concentration and it ranges from 0.02 mg/l at Islampur in Jamalpur to 25.40 mg/l at Kahaloo in Bogra. Around 40% of the samples exceed BDWS for iron concentration (1 mg/l). According to spatial distribution map iron concentration is remarkably high near the Jamuna River and decreases away from the river (Fig. 6).

Depth distribution graph of iron concentration does not show any distinct relationship but concentration is relatively high at depth around 20m (Fig. 7).

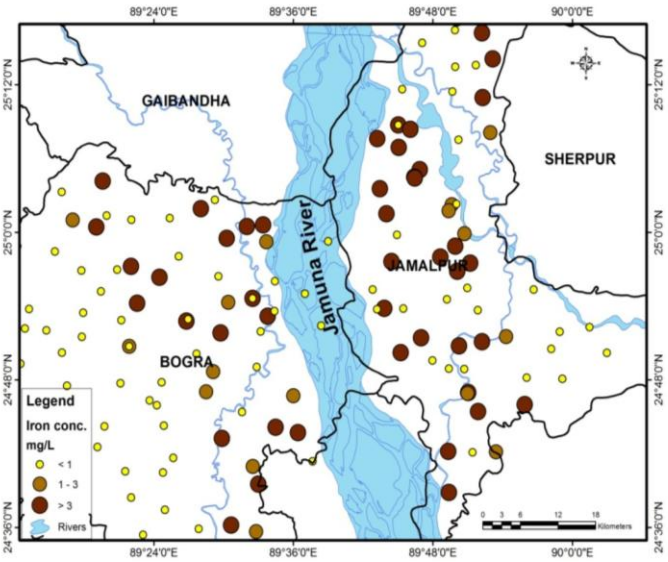

Fig. 6 Spatial distribution of iron concentration in groundwater of the study area

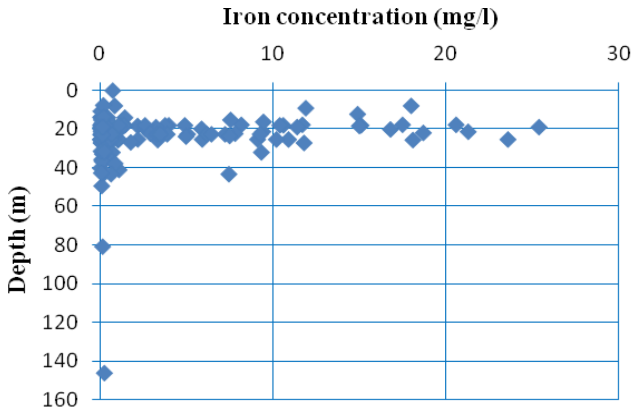

Fig.7 Depth distribution of iron concentration in groundwater of the study area

Manganese

Like iron, manganese concentration is high in the study area. Manganese concentration in shallow groundwater of the study area ranges from 0.006 mg/l to 4.6 mg/l. The highest manganese concentration (4.60 mg/l) is observed at Gabtoli and the lowest one (0.006 mg/l) is at Sherpur in Bogra. 93 out of 160 samples exceed the WHO standard for manganese (0.4 mg/l) and the number is 149 considering BDWS limit (0.1 mg/l). The spatial distribution map of manganese concentration does not show any particular trend (Fig. 8).

Depth distribution profile of manganese concentration does not show any distinct relationship (Fig. 9).

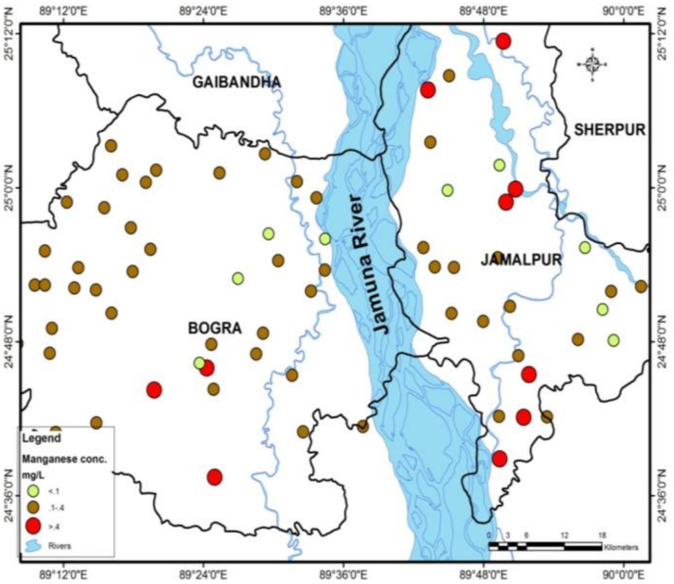

Fig. 8 Spatial distribution map of manganese concentration in groundwater of the study area

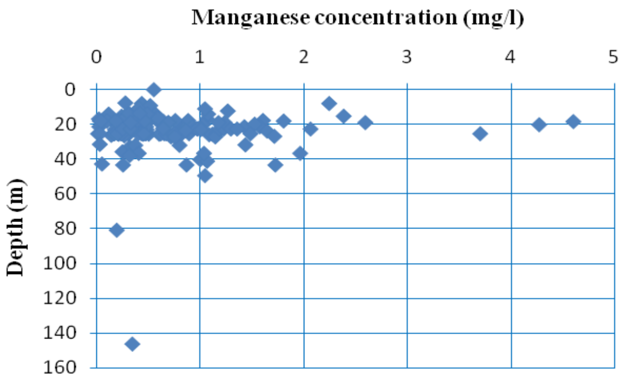

Fig. 9 Depth distribution of manganese concentration in groundwater of the study area

Arsenic

Arsenic concentration in the shallow tubewells of this area is comparatively low and it ranges from 0.05 µg/l to 19.40 µg/l. Spatial distribution map of As concentration reveals that concentration is relatively high near the Jamuna river but low at eastern and western part of the study area i.e. concentration declines away from the channel (Fig. 10). It is also observed that As concentration is somewhat high along the E-W transect.

It is widely known that shallow aquifers of Bangladesh are contaminated by excessive arsenic concentration (e.g. Bhattacharya et al. 1997; van Geen et al. 2003); however, only around 13% of the samples in this area having depths less than 100 m surpass the WHO guide line value (0.01mg/l) and none of the samples exceeds BDWS for As (0.05 mg/l) (Fig. 11). The area is characterized by quite coarse grained sediments and it appears to have a low concentration of iron oxides with a corresponding low arsenic load.

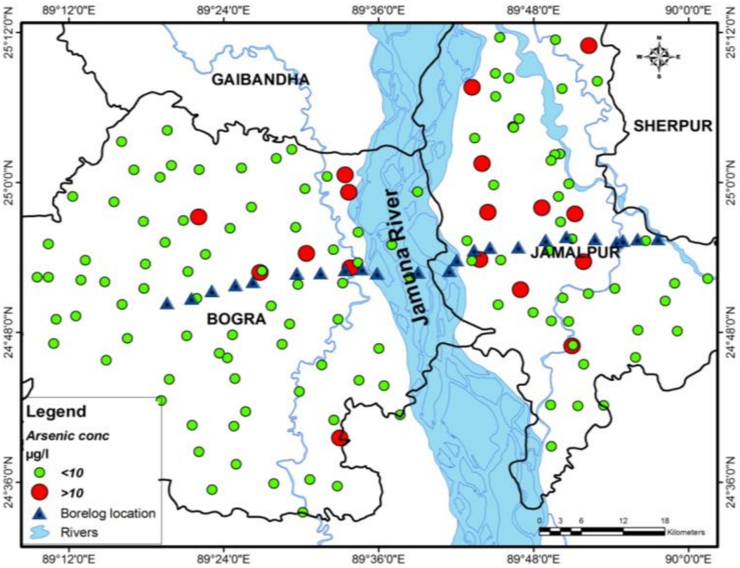

Fig. 10 Spatial distribution of arsenic concentration in groundwater of the study area

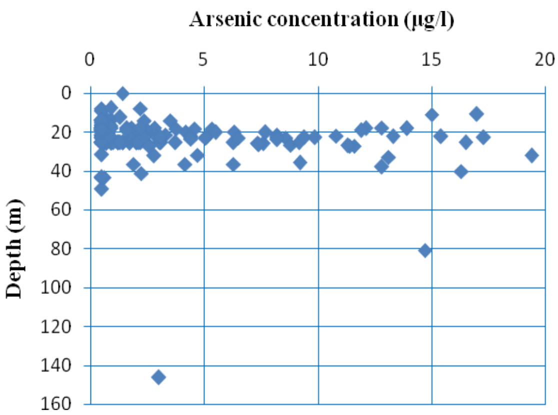

Fig. 11 Depth distribution of arsenic concentration in groundwater of the study area

IV. Conclusion

The floodplain of the Jamuna River is predominantly composed of sand-sized sediments that represent channel and bar, or fluvial braid belt deposits. Although floodplain clay and silt are sometimes preserved at the surface of the boreholes, very few clay and silt deposits are preserved in the deeper stratigraphy. Up to the depth of 80 m the study area shows a single aquifer system. As the aquifer system is unconfined in nature in the most of the places, there is potential risk of groundwater contamination from surface sources such as pesticides, fertilizers from agricultural fields, wastes from pit latrines, oil leaching from tanks etc. The majority of the shallow tubewells in the study area are arsenic free, a reverse scenario for most of the places of Bangladesh. However, some samples near the Jamuna River demonstrate relatively high arsenic concentration. Manganese concentration is high in the study area, but does not show any particular spatial and vertical relationship. The study area is also distinguished by noticeable elevated iron concentration. Iron concentration is high adjacent to the Jamuna River but decreases away from the channel. Iron concentration does not demonstrate any significant vertical relationship.

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