Thesis Abstract

The Ganges River delta aquifer system, shared between India and Bangladesh, forms one of the largest transboundary freshwater reserves across the world. Groundwater from this aquifer system serves as the primary source of drinking and irrigation water for the ~110 million population of the delta. However, widespread occurrences of toxic levels of arsenic (As) within the delta groundwater have led to the largest mass poisoning in history. This study is the first comprehensive assessment of the delta aquifer system and involves characterization of the (a) hydrostratigraphic framework, (b) hydrogeochemical evolution, and (c) As contamination scenario.

High-resolution regional-scale modeling shows the presence of a single aquifer system across the delta. However, the hydrostratigraphy is spatially variable and can be architecturally divided into three distinct aquifer sub-systems from northwest to southeast: a single, thick continuous aquifer (Type I); a vertically segregated, semi-confined aquifer sub-system (Type II); and a multilayered, nearly confined aquifer sub-system (Type III). The major-ion chemistry and As concentrations within each sub-system have conspicuously different spatial distributions. The Type I aquifer is dominated by Ca-Mg-HCO_3-rich waters, while the aquifers to the south (Type II and Type III) exhibit increasing dominance of Na-Cl hydrofacies at shallow and intermediate depths and Na-HCO_3 hydrofacies in the deep aquifers. The spatial distribution of As is also characteristically different in each sub-system, wherein, the Type I aquifer exhibits comparable As concentrations at all depths, and the Type II and Type III aquifers show a sharp decrease in As concentrations with depth. These relatively homogenous hydrogeochemical signatures within the Type I aquifer possibly suggest deeper infiltration of recharge under higher vertical hydraulic gradients, while in Type II and Type III aquifers, the hydrogeochemical variability across depth is possibly a reflection of horizontally stratified groundwater flows, dictated by the spatial geometry of the intervening aquitard layers. Local-scale study reveals that the fate of As within the delta is a function of a complex interplay between the aquifer architecture, groundwater chemistry, and redox conditions. Machine learning-based modeling suggests surficial aquitard thickness and groundwater-fed irrigation to be the two most dominant controls on As occurrence across the delta. An estimated ~30.3 million people were found to be exposed to elevated groundwater As (>10 µg/L) within the delta. Findings from this study are expected to aid in systematic framing of sustainable management plans for the aquifers within the Ganges River delta system.

Keywords: *Hydrostratigraphy, Hydrogeochemistry, Arsenic, Machine Learning, Ganges River delta, West Bengal (India), Bangladesh*