SUSTAINABLE ARSENIC MITIGATION

A STRATEGY DEVELOPED FOR SCALING-UP SAFE WATER ACCESS

Mohammed Hossain

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Faculty Opponent is Dr. Marinus Eric Donselaar, Associate Professor, Dept. of Geoscience and Engineering, Delft University of Technology, Delft, The Netherlands.

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ABSTRACT

In rural Bangladesh, the drinking water supply is mostly dependent upon manually operated hand pumped tubewells, installed by the local community. The presence of natural arsenic (As) in groundwater and its wide scale occurrence has drastically reduced the safe water access across the country and put tens of millions of people under health risk. Despite significant progress in understanding the source and distribution of As and its mobilization through sediment-water interactions, there has been limited success in mitigation since the problem was discovered in the country's water supply in 1993. This study evaluated the viability of other kinds of alternative safe drinking water options and found tubewells are the most suitable due to simplicity and technical suitability, a wide acceptance by society and above all low cost for installation, operation and maintenance. During planning and decision making in the process of tubewell installation, depth of the tubewell is a key parameter as it is related to groundwater quality and cost of installation. The shallow wells (usually < 80m) are mostly at risk of As contamination. One mitigation option are deep wells drilled countrywide to depths of around 250 m. Compared to safe water demand, the number of deep wells is still very low, as the installation cost is beyond affordability of the local community, especially for the poor and disadvantaged section of the society. Using depth-specific piezometers (n=82) installed in 15 locations spread over the 410 km^2 area of Matlab (an As-hot spot) in southeastern Bangladesh, groundwater monitoring was done over a 3 year period (pre- and post-monsoon for 2009-2011 period). Measurements were performed for hydrogeochemical characterization of shallow, intermediate and deep aquifer systems to determine the possibility of targeting safe aquifers at different depths as the source of a sustainable drinking water supply. In all monitoring piezometers, As was found consistently within a narrow band of oscillation probably due to seasonal effects. Hydrogeochemically, high-As shallow groundwaters derived from black sands are associated with elevated DOC, HCO_3, Fe, NH_4-N and PO_4-P and with a relatively low concentration of Mn and SO_4. Opposite to this, shallow aquifers composed of red and off-white sediments providing As-safe groundwater and are associated with low DOC, HCO_3, Fe, NH_4-N and PO_4-P and relatively higher Mn and SO_4. Groundwaters sampled from intermediate deep and deep piezometers which were found to be low in As, are characterized by much lower DOC, HCO_3, NH_4-N and PO_4-P compared to the shallow aquifers. Shallow groundwaters are mostly Ca-Mg-HCO_3 type and intermediate deep and deep aquifers' groundwaters are mostly Na-Ca-Mg-Cl-HCO_3 to Na-Cl-HCO_3 type.

A sediment color tool was also developed on the basis of local driller's color perception of sediments (Black, White, Off-white and Red), As concentration of tubewell waters and respective color of aquifer sediments. A total of 2240 sediment samples were collected at intervals of 1.5 m up to a depth of 100 m from all 15 nest locations. All samples were assigned with a Munsell color and code, which eventually led to identify 60 color varieties. The process continued in order to narrow the color choices to four as perceived and used by the local drillers for identification of the targeted As-safe aquifers. Munsell color codes assigned to these sediments render them distinctive from each other which reduces the risk for misinterpretation of the sediment colors. During the process of color grouping, a participatory approach was considered taking the opinions of local drillers, technicians, and geologists into account. In addition to the monitoring wells installed in the piezometer nests, results from 87 other existing drinking water supply tubewells were also considered for this study. A total of 39 wells installed in red sands at shallow depths producing As-safe water providing strong evidence that red sediments are associated with As-safe water. Average and median values were found to be less than the WHO guideline value of 10 μg/L. Observations for off-white sediments were also quite similar. Targeting off-white sands could be limited due to uncertainty of proper identification of color, specifically when day-light is a factor. Elevated Mn in red and off-white sands is a concern in the safe water issue and emphasizes the necessity of a better understanding of the health impact of Mn. White sediments in shallow aquifers are relatively uncommon and seemed to be less important for well installations. Arsenic concentrations in more than 90% of the shallow wells installed in black sands are high with an average of 239 μg/L from 66 wells installed in black sediments. It is thereby recommended that black sands in shallow aquifers must be avoided. This sediment color tool shows the potential for enhancing the ability of local tubewell drillers for the installation of As-safe shallow drinking water tubewells.

Considering the long-term goal of the water safety plan to provide As-safe and low-Mn drinking water supply, this study also pioneered hydrogeological exploration of the intermediate deep aquifer (IDA) through drilling up to a depth of 120 m. Clusters of tubewells installed through site optimization around the monitoring piezometer showed a similar hydrochemical buffer and proved IDA as a potential source for As-safe and low-Mn groundwater. Bangladesh drinking water standard for As (50 μg/L) were exceeded in only 3 wells (1%) and 99% (n=240) were found to be safe. More than 91% (n=222) were found to comply with the WHO guideline value of 10 μg/L. For Mn, 89% (n=217) of the wells show the concentration within or below the previous WHO guideline value of 0.4 mg/L, with a mean and median value of 0.18 and 0.07 mg/L respectively. The aquifer explored in the Matlab area shows a clear pattern of low As and low Mn. The availability of similar sand aquifers elsewhere at this depth range could be a new horizon for tapping safe drinking water at about half the cost of deep tubewell installations.

All findings made this study a comprehensive approach and strategy for replication towards arsenic mitigation and scaling-up safe water access in other areas of Bangladesh and elsewhere having a similar hydrogeological environment.

Keywords: Bangladesh, drinking water, arsenic mitigation, local tubewell driller, sediment color tool, low-manganese, Intermediate Deep aquifer.