

## Flowpaths of groundwater from arsenic contaminated zone to deeper aquifers under development stresses

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Groundwater has been used extensively as the main source of drinking and irrigation water supply in Bangladesh with the coverage of about 98 and 80% respectively. In the early 1990s, high arsenic was noticed in shallow groundwater and about three million tubewells have been detected with arsenic concentrations more than the Bangladesh drinking water standard of 50  $\mu\text{g/l}$ . Pumping water mainly from the lower part of the shallow and upper part of the main aquifers (BWDB-UNDP 1982) during the dry irrigation period, water levels in all three aquifer units upto about 300 m depths response to the pumping stresses. Generally, the water from the shallow arsenic contaminated aquifer has a higher head than water in the deeper zones, and water from the shallow aquifer may move downward into the deeper fresh water zones by leakage and vertical percolation. Still >50% of cultivable land in the country has the potential for irrigation. Increased irrigation abstraction of groundwater in future may enhance arsenic contamination in deeper aquifers.

A three-dimensional modular finite difference groundwater model is used to simulate groundwater flow of multi-layered aquifer system in southeastern Bangladesh focusing flow paths and travel time from recharge areas and arsenic contaminated zone to deeper aquifers. The problem addresses simulation results from computer models of groundwater flow systems, and observes the response of the systems to different development stresses and variations in values of geologic conditions i.e. horizontal ( $K_h$ ) and vertical ( $K_v$ ) hydraulic conductivities. The model simulated results indicate that aquifer system in the studied area is generally stable under current development stress and anisotropy is the primary hydrogeologic control on the flowpath length and travel time. Maintaining current trend of installing irrigation wells in lower part of the shallow aquifer may be continued to protect the main aquifer from moving water from the arsenic contaminated zone.

## Biogenic sulfur gases, MIF-S, and the rise of free oxygen

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Mass-independent fractionation of sulfur isotopes in Archean sediments implies that (1) sulfur was processed photochemically in the atmosphere by uv light at wavelengths that today are absorbed by ozone, and (2) there was a mechanism for keeping one flavor of fractionated atmospheric sulfur from recombining with its complement before it reached the sediments. UV photolysis of  $\text{SO}_2$  or  $\text{CS}_2$  can give rise to such fractionations, with one of the flavors preserved in elemental sulfur (S<sub>8</sub>), which is insoluble in water and hence plausibly kept separate. Photochemical models indicate that efficient S<sub>8</sub> production requires: (1) very low levels of tropospheric  $\text{O}_2$ ; (2) a source of sulfur gases to the atmosphere at least as large as the volcanic  $\text{SO}_2$  source today; and (3) a sufficiently high abundance of methane or another reduced gas. The widening envelope of mass-dependent sulfur fractionation toward the end of the Archean indicates that the oceanic sulfate pool was growing large. Sulfate reducers outcompete methanogens. Hence we consider the possible role of biogenic sulfur gases such as  $\text{H}_2\text{S}$ , DMS, OCS, and  $\text{CS}_2$  at the end of the Archean. To the extent that sulfur gases replaced  $\text{CH}_4$  or  $\text{H}_2$  as the reduced complement of photosynthetic  $\text{O}_2$  they worked to favor the creation of an  $\text{O}_2$  atmosphere. Atmospheric sulfate hazes generated from the biogenic sulfur gases may have played a part in triggering global ice ages. The ozone shield erected by a weakly oxic atmosphere tends to make atmospheric sulfur gases relatively stable, which raises the possibility that OCS can be an effective Proterozoic greenhouse gas.