TECHNICAL COMMENTS

Comment on "Arsenic Mobility and Groundwater Extraction in Bangladesh" (I)

Harvey *et al*. (*1*) suggested that the elevated arsenic levels found in Bangladesh aquifers are caused by desorption of arsenic solids accompanying the influx of fresh, labile carbon-laden recharge water. They further concluded that rapid aquifer recharge is only a recent phenomenon, resulting from extensive irrigation pumping over the last 25 years. This latter conclusion was based on their observation of "young carbon" to depths of about 30 m, indicating relatively quick vertical travel times of ~7 to 28 years (compared with flow times preceding the advent of irrigation pumping). Harvey *et al*. then used short-term water level records to estimate excess recharge resulting from irrigation pumping. However, they did not cite any specific evidence for their assumption of a drastic increase in dry-season vertical flow. Here, we show that irrigation has had at best a negligible impact on vertical groundwater flow and, therefore, arsenic concentrations in Bangladesh aquifers.

Our studies (*2, 3*) agree with the conclusion in (*1*) that desorption due to continuing recharge causes elevated arsenic concentrations in Bangladesh aquifers. Strontium isotope data and groundwater age estimations (*3–5*) indicate that arsenic concentrations generally increase with increasing groundwater residence time in the aquifer. As we have shown previously (*2, 5*), the exponential increase in irrigation pumping since the mid-1970s did not significantly change stable oxygen and hydrogen isotope compositions of shallow groundwaters between 1979 and 1999. This indicates that the source and mechanism of recharge remained essentially the same during this period (domestic and irrigation wells from across Bangladesh were used in these surveys, and some wells were common to both surveys). The depth of tritium penetration in 1979 was about 45 m, and bomb tritium was clearly present at depths of ~22 m (Fig. 1). These data suggest vertical travel times of ~20 to 27 years, to depths of about 45 m under pre- and post-irrigation pumping conditions in 1979 and 1999 [assuming piston flow and pre-bomb atmospheric tritium levels of 5 tritium units (TU)], similar to those estimated by Harvey *et al*. (*1*). Alkalinity and stable carbon isotope values were also similar in the 1979 and 1999 investigations (*6*), which indicates that carbon loadings and biogeochemical processes related to organic carbon oxidation and carbonate dissolution remained the same before and after significant irrigation pumping. Based on these isotopic data, we conclude that irrigation pumping in Bangladesh is not necessarily responsible for the transport of fresh recharge or labile carbon loadings to depths of 30 m or more, contrary to the assumption made by Harvey *et al*. (*1*).

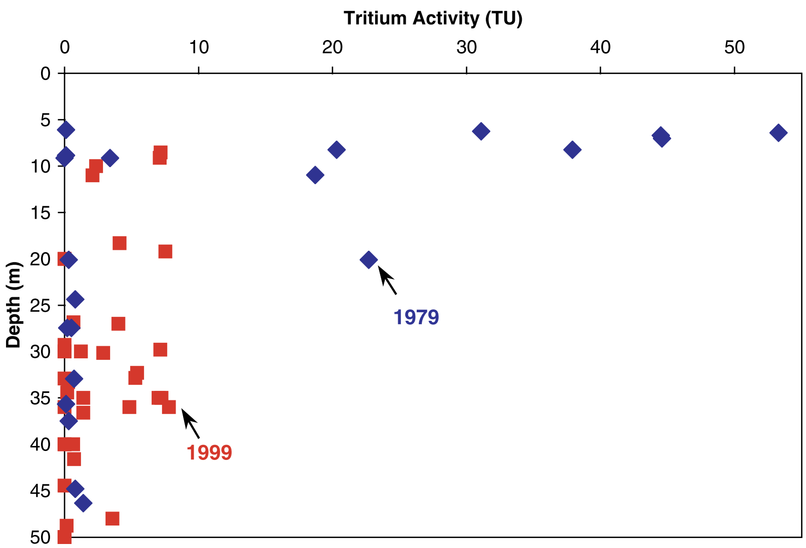

Fig 1. Tritium concentrations in Bangladesh groundwater in 1979 and 1999. Domestic or irrigation wells from northwestern and southern Bangladesh were sampled in both events. Measurable tritium concentrations (~1 TU) in 1979 clearly indicate the presence of modern recharge to depths of ~45 m, while bomb tritium is observed at depths of 22 m. Tritium profiles indicate similar vertical travel times in pre- and post-irrigation pumping periods.

Long-term records of water level fluctuation provide further evidence for the lack of significant irrigation pumping impacts on dry-season vertical hydraulic gradients in Bangladesh. Fig. 2 shows weekly measurements of water level between 1967 and 1997 in a 31-m deep observation well in the Faridpur area, southwest of the capital city of Dhaka (*3*). This hydrograph is typical of shallow aquifer observation wells across Bangladesh (*3*). It shows that seasonal fluctuations of about 5 m in the water level of shallow aquifers, where elevated arsenic concentrations are observed today, have occurred consistently over the 30-year period—even during the late 1960s, before significant groundwater withdrawals by irrigation pumping. For the location shown in Fig. 2, the mean depth to groundwater remained at about 3.7 m, but the standard deviation decreased from 2 m between 1967 and 1983 to 1.6 m between 1984 and 1997. Lower seasonal fluctuations over the last 25 years, when extensive irrigation pumping took place, clearly indicate that vertical hydraulic gradients and dry-season recharge did not increase during the dry season, refuting the basic premise for the conclusion reached in (*1*). By using a 5-year record (1985 to 1990) from a similar observation well to argue that irrigation pumping has resulted in substantial increase in recharge, Harvey *et al*. may have presented a flawed analysis—unless it could be shown that seasonal fluctuations were much less in the pre-irrigation pumping period. However, this appears unlikely, based on the isotopic data (*3, 5*) and our review (*3*) of water level records of a number of observation wells across Bangladesh similar to that shown in Fig. 2.

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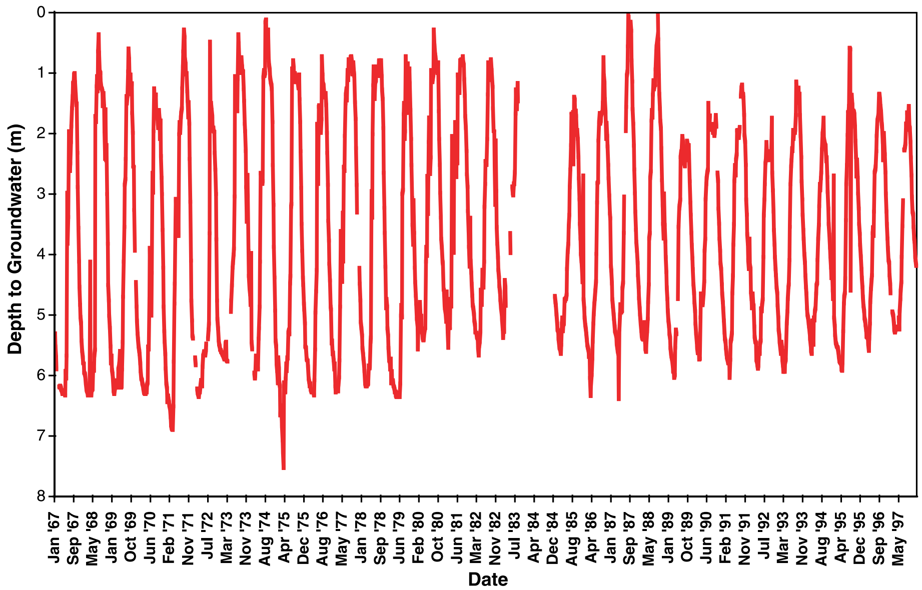

Fig. 2. Water-level fluctuations in observation well FA-01 (depth = 31 m) located in Thana Faridpur, southwest of Dhaka (*3*). Seasonal fluctuations of nearly 5 m are observed between 1967 and 1997, before and after the advent of irrigation pumping. The standard deviation of seasonal fluctuation is slightly lower for the period between 1984 and 1997, indicating that vertical hydraulic gradients may have decreased due to irrigation pumping and return recharge—in contrast to the increase proposed by Harvey *et al*.

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References

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6. IAEA, unpublished data.

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