Comment on "Arsenic Mobility and Groundwater Extraction in Bangladesh" (II)
Alexander van Geen, *et al.*
Science **300**, 584c (2003);
DOI: 10.1126/science.1081057

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

Harvey *et al*. (*1*) recently presented detailed vertical profiles for groundwater arsenic and a suite of other water and sediment properties from a study site in southern Bangladesh. This information, supplemented with carbon isotopic data (^{13}C and ^{14}C) for dissolved organic carbon (DOC) and dissolved inorganic carbon (DIC), was used to support the notion that the DOC introduced into subsurface aquifers with groundwater recharge could lead to reduction or dissolution of iron oxyhydroxides and the subsequent release of associated arsenic into groundwater. This is an important issue for tens of millions of people in Bangladesh and other South Asian countries, who are at risk of contracting various cancers from drinking water with elevated arsenic levels (*2*). The process of arsenic mobilization could be much more dynamic than previously thought if, as Harvey *et al.* have proposed (*1*), the leading agent for arsenic release from iron oxyhydroxides is indeed DOC penetrating sandy aquifers on time scales of tens of years rather than particulate organic carbon deposited over several thousand years throughout the Ganges-Brahmaputra-Meghna delta (*3, 4*). On the basis of particulate and dissolved sulfur data, Harvey *et al*. also have effectively laid to rest the argument that the oxidation and dissolution of particulate sulfide is the dominant cause of elevated arsenic in groundwater, at least for their study site.

We are troubled, however, by the argument that groundwater pumping for irrigation increased the penetration of DOC into the subsurface and therefore caused the release of arsenic into the groundwater. We believe that the data in (*1*) and related information from other regions of Bangladesh could be equally well explained without invoking a response of groundwater arsenic to irrigation pumping. This is an important point, because policy-makers in Bangladesh and elsewhere should not be confronted with the false dilemma of elevated arsenic in groundwater caused by irrigation or insufficient agricultural production.

The Harvey *et al*. data appear to be inconsistent with recent mobilization of arsenic by irrigation pumping, if their model of vertical flow is taken at face value. As Harvey *et al*. point out, the concentration of radiocarbon in the atmosphere increased to unprecedented levels starting in the 1950s because of atmospheric testing of nuclear bombs (*5*). The penetration of radiocarbon above pre-testing levels in subsurface aquifers is an indicator of groundwater recharge over the past 50 years. The onset of this particular anthropogenic perturbation therefore preceded the onset of massive irrigation in Bangladesh by about 25 years. According to their vertical flow model, this would mean bomb-produced ^{14}C should have penetrated at least to the depth of maximum arsenic mobilization if this feature was indeed caused by an enhanced supply of DOC linked to irrigation. Yet, according to figures 1A and 3 in (*1*), the maximum in arsenic mobilization is observed at about 40 m depth, while only the two shallowest radiocarbon samples, at 3 and 19 m, indicate addition of bomb radiocarbon. Thus, the Harvey *et al*. data do not necessarily indicate a direct connection between arsenic mobilization and increased irrigation pumping in their study area.

Even if the portion of the Harvey *et al.* argument that we dispute were correct in their study area, there is convincing evidence that it does not apply to other parts of Bangladesh. Tritium (^3H) is another radionuclide whose concentration in the atmosphere increased dramatically in response to atmospheric bomb testing (*6, 7*). The distribution of ^3H in water has therefore also been used extensively to study oceanic circulation as well as groundwater recharge. A recent report from the International Atomic Energy Agency (*8*) lists eight samples with significantly elevated arsenic levels that do not contain any detectable ^3H. We have collected and analyzed an additional 49 groundwater samples from other wells in Bangladesh that include a set of 5 paired arsenic and ^3H analyses indicating high arsenic levels without detectable ^3H (*9, 10*). The implication of the combined data set is that over a dozen carefully analyzed samples indicate that Bangladesh groundwater was elevated in arsenic well before the onset of massive irrigation. We therefore believe that increased irrigation over the past 25 years is unlikely to have caused widespread arsenic mobilization in Bangladesh groundwater through the sequence of steps proposed by Harvey *et al*. in their otherwise very valuable contribution.

Alexander van Geen
Lamont-Doherty Earth Observatory
Columbia University
Route 9W
Palisades, NY 10964, USA
E-mail: avangeen@ldeo.columbia.edu

Yan Zheng
Lamont-Doherty Earth Observatory
and *Queens College,*
City University of New York
Flushing, NY 11367, USA

Martin Stute
Lamont-Doherty Earth Observatory
and *Barnard College, Columbia University*
3009 Broadway New York, NY 10027, USA

Kazi Matin Ahmed
Department of Geology
University of Dhaka
Dhaka 1000, Bangladesh

References and Notes

1. C. F. Harvey *et al.*, *Science* **298**, 1602 (2002).
2. D. G. Kinniburgh, P. L. Smedley, Eds., *Arsenic Contamination of Groundwater in Bangladesh* (British Geological Survey Report WC/00/19, 2001; www.bgs.ac.uk/arsenic/Bangladesh).
3. R. Nickson *et al.*, *Nature* **395**, 338 (1998).
4. J. M. McArthur *et al.*, *Water Resour. Res.* **37**, 109 (2001).
5. I. Levin *et al.*, *Radiocarbon* **27**, 1 (1985).
6. W. Weiss, J. Bullacher, W. Roether, "Evidence of pulsed discharges of tritium from nuclear energy installations in central European precipitation: Behaviour of Tritium in the Environment" (International Atomic Energy Agency, Vienna, 1979), pp. 17–30.
7. M. Stute, "Tritium (^3H) in precipitation in Bangladesh" in *Groundwater Contamination in the Bengal Delta Plain of Bangladesh* [Royal Technical Institute (KTH) Special Publication TRITA-AMI Report 3084, 2001], pp. 109–117.
8. P. K. Aggarwal *et al.*, "Isotope hydrology of groundwater in Bangladesh: Implications for Characterization and Mitigation of Arsenic in Groundwater" (IAEA-TC Project Report, BGD/8/016, International Atomic Energy Agency, Vienna, 2000; www.iaea.org/programmes/ripc/ih/publications/bgd_report.pdf).
9. Y. Zheng *et al.*, *Appl. Geochem.*, in press.
10. M. Stute, P. Schlosser, unpublished data.
11. Our work in Bangladesh has been supported by grant P42ES10349 of the U.S. NIEHS/Superfund Basic Research Program and NSF grant EAR 0119933.

2 December 2002; accepted 3 March 2003