Using Data From the Arsenic Problem in Bangladesh

(Martin Stute, Barnard College).
martins@ldeo.columbia.edu

Summary:
The Arsenic in drinking water issue in Bangladesh presents a unique opportunity to motivate studying hydrogeology in context of water resources issues in the developing world. Students learn about health and social issues besides basic hydrogeology and data analysis with Excel and/or Arc GIS. The module focuses on the feasibility of using deeper wells as a source of drinking water and examines how pumping might affect the distribution of Arsenic.

Introduction:
In many parts of the world, groundwater has proved to be a reliable source of drinking water that, unlike surface water, typically is not contaminated with human pathogens. In several South Asian countries, however, a massive switch of rural consumption to untreated groundwater supplied by millions of wells over the past few decades has turned into a disaster. In Bangladesh alone, an estimated 50 million people have been exposed to As levels that exceed the WHO guideline in drinking water of 10 μgL^{-1} by up to two orders of magnitude. There are still many open questions regarding the mechanisms of As mobilization, e.g. how much of an anthropogenic influence there is and what can be done about the problem. Potential solutions include well switching, use of surface waters, rain water harvesting, filtering and installation of deeper wells.

There is a significant body of literature that describes the issues. A very comprehensive study is that of the British Geological Survey, which is available on the Internet (BGS and DPHE, 2001).

The module
This module looks at the feasibility of using deeper wells as a source of low As water. The data sets are described in detail by van Geen et al. (van Geen et al., 2003; van Geen et al., 2002).

Students are being introduced to background information about the Arsenic problem in Bangladesh in lecture format. This includes health aspects and the history of the issue. They also have been using the sand tank groundwater model distributed by the University of Wisconsin Stevens Point (http://www.uwsp.edu/stuorg/awra/h2omodel.html) to develop an intuitive understanding of groundwater flow and transport and are familiar with basic hydrogeological concepts. They inject a dye into the shallow aquifer of the model and study how pumping effects the migration of the Arsenic plume (Fig 1).

Students get an Excel spreadsheet that contains the longitude, latitude, and depth of 6000 wells and a satellite image that shows the area of investigation. They use Arc GIS software to plot data on the satellite image (Fig. 2), or alternatively plot the data as a function of longitude and latitude as a bubble plot in Excel. They find that the distribution

of As in many regions is very heterogeneous. They then select sub-regions and look at the depth distribution and find that often there is a gap in the depth population of wells which turns out to be due to a clay layer varying in thickness that separates the shallow aquifer from the deep aquifer. The depth distribution (Fig. 3) of As also shows a characteristic pattern with most of the elevated As concentrated in the top 30 meters.
Students then discuss remediation options, in particular the possibility of switching to neighboring wells and using deeper groundwater as an alternative source of drinking water. They find that in many regions there are safe wells within a few hundred m of the high As well. However, it is not clear how long these wells will remain low in dissolved As and there are social barriers as well to use the neighbors well. They then determine a depth below which As concentrations are low in their region and elevate the risk of using deeper groundwater for drinking water and irrigation. They find that personal use is resulting in only ~1cm $year^{-1}$ of water use, while irrigation (~1 m $year^{-1}$) would considerably lower the water table and potentially could contaminate the deeper aquifer as well. The conclusion is that if deeper groundwater is utilized it's use should be limited to personal use.

Assignments:

With using GIS

- Copy the excel spreadsheet with the well data and the Ikonos satellite image onto your computer.
- Plot the location of the wells on the map and color code by As concentration
- Plot As concentration versus depth for all wells.
- Select wells in a circle of 0.5 km radius in a region of your choice and plot As concentration versus depth.
- Characterize the spatial variability of As concentrations
- Answer the following questions for your sub-region:
    - How far would people have to travel to the next safe well?
    - To what depth would a new well have to be drilled to tap groundwater that is low in As?
    - Determine how much water (in cm per year) would be removed if all drinking water and/or all water for irrigation would be pumped from the deeper aquifer. Assume a population density of 2600/km2, an average drinking water consumption of 10 liters $person^{-1}day^{-1}$, and a demand for irrigation of 1 $m^3person^{-1}day^{-1}$.
    - What are potential issues with using neighboring wells and deeper wells? (Tip: Think about how pumping affects the migration of dyes in the sand tank model.)
    - What is your recommendation in terms of managing groundwater resource in Bangaldesh?

Without using GIS

- Copy the excel spreadsheet with the well data onto your computer.
- Plot the location of the wells as a function of longitude and latitude and As concentration as a bubble plot

- Plot As concentration versus depth for all wells.
- Select wells in a square of 1 km^2 in a region of your choice and plot As concentration versus depth. Tip: Use Excel's 'If function'.
- Characterize the spatial variability of As concentrations
- Answer the following questions for your sub-region:
    - To what depth would a new well have to be drilled to tap groundwater that is low in As?
    - Determine how much water (in cm per year) would be removed if all drinking water and/or all water for irrigation would be pumped from the deeper aquifer. Assume a population density of $2600 km^{-2}$, an average drinking water consumption of 10 liters $person^{-1} day^{-1}$, and a demand for irrigation of 1 $m^3 person^{-1} day^{-1}$.
    - What are potential issues with using neighboring wells and deeper wells? (Tip: Think about how pumping affects the migration of dyes in the sand tank model.)
    - What is your recommendation in terms of managing groundwater resource in Bangaldesh?

Resources:

BGS and DPHE, 2001. Arsenic contamination of groundwater in Bangladesh. British Geological Survey Technical Report WC/00/19. British Geological Survey, Keyworth. http://www.bgs.ac.uk/arsenic/bangladesh/reports.htm

University of Wisconsin student chapter of the American Water Resources Association Groundwater Model project (http://www.uwsp.edu/stuorg/awra/h2omodel.html)

van Geen, A., Ahmed, K.M., Seddique, A.A. and Shamsudduha, M., 2003. Community wells to mitigate the arsenic crisis in Bangladesh. Bulletin of the World Health Organization, 81(9): 632-638.

van Geen, A. et al., 2002. Promotion of well-switching to mitigate the current arsenic crisis in Bangladesh. Bulletin of the World Health Organization, 80(9): 732-737.

Background information on As in Bangladesh can be found at: http://www.ldeo.columbia.edu/~martins/hydro/lectures/bang_as_lec.html (login: hydro, password ordyh)

Please contact me (martins@ldeo.columbia.edu) if you are interested in using this data set. A. van Geen and M. Becker at Columbia University contributed to this exercise.

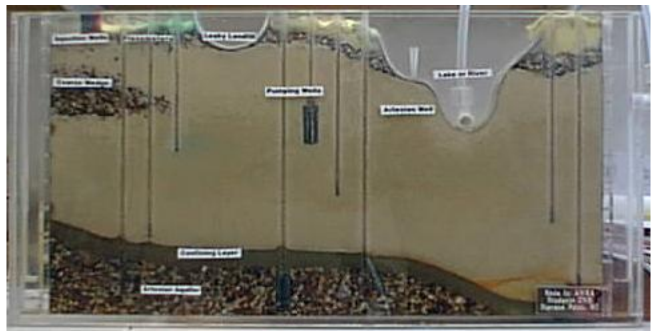

Figure 1 Sandtank model to demonstrate the influence of pumping on contaminant transport.

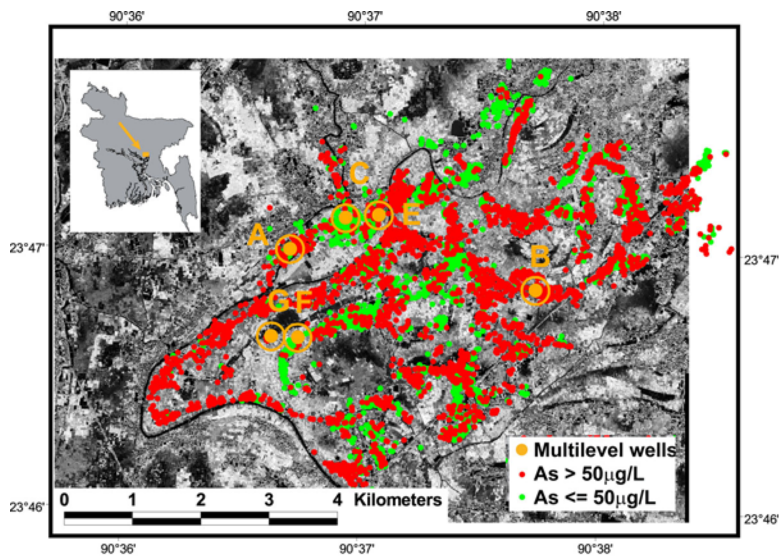

Figure 2 Spatial Distribution of As in ~6000 wells in Araihazar, Bangladesh. The Bangladesh drinking water standard for As is 50 ug/L.

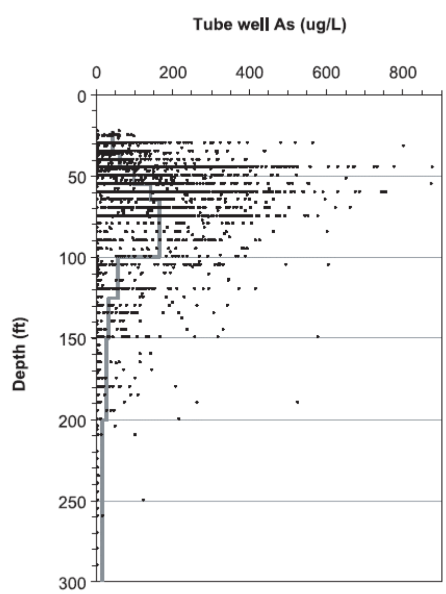

Figure 3 Distribution of As as a function of depth for 6000 wells in Araihazar, Bangladesh.