Arsenic contamination of groundwater in Bangladesh

Shallow groundwater with high arsenic concentrations from naturally occurring sources is the primary source of drinking water for millions of people in Bangladesh. It has resulted in a major public health crisis with as many as 70 million people possibly at risk. The International Atomic Energy Agency (IAEA) is supporting international efforts and the Government of Bangladesh to find alternative, safe and sustainable sources of drinking water.

A pump painted in red indicates that the water is contaminated with arsenic.

A public health disaster

Efforts to reduce the number of people, especially children, dying from diarrhoea and other water-borne diseases from contaminated surface water has resulted in a huge increase in the number of tube wells sunk over the last two decades. There are now about 0.9 million public and 1.6 million private wells and more than 90% of the population use groundwater for drinking. Until the discovery of arsenic in groundwater in 1993, well water was regarded as safe. But now:

- Arsenic contamination of groundwater has affected 59 of the 64 districts in Bangladesh where arsenic levels have been found to be above the nationally accepted limit.
- It is reported that above 21 million people are currently exposed to arsenic contamination and approximately 70 million people may be at risk.

Arsenic poisoning

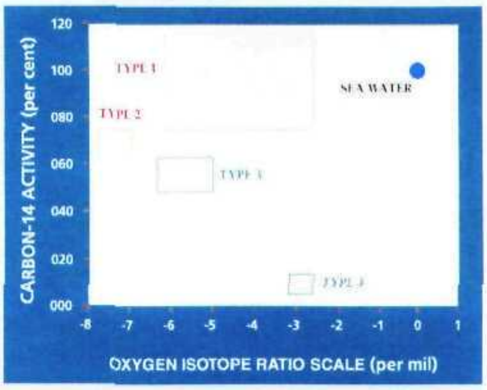
It can take many years for the effects of drinking arsenic-contaminated water to show and the true extent of the problem is therefore not yet known. Nevertheless, evidence of chronic arsenic toxicity is accumulating and includes melanosis (abnormal black-brown pigmentation of skin), hyperkeratosis (thickening) of palm and sole, gangrene and skin cancer. Malnutrition and hepatitis B, both of which are prevalent in Bangladesh, accentuate the effects of arsenic poisoning. Many victims are children who have been consuming the poisoned water since birth and children under 15 constitute 45 percent of the population. Of over-riding importance to public health is the need to find adequate and sustainable sources of arsenic-free water.

***Type 1:** Arsenic-bearing Shallow (depth<70m), Replenished by rain & flood waters, Modern.*

***Type 2:** Arsenic-bearing, Higher salinity, Recharge from river water, Modern.*

***Type3:** Arsenic-free, Deeper (~150m), Low salinity, Several thousand years old.*

***Type 4:** Arsenic-free, Deep (-300m), Old (-20000 years)*



Shallow and deep groundwaters can be categorized into four distinct isotopic signatures.

Where does the arsenic come from?

The source of the arsenic in groundwater in Bangladesh is natural and arises because the water flows through arsenic-rich sediments. The exact mechanism by which the arsenic is transferred into the water is not yet fully understood. It had been thought that the increase in groundwater use in recent years may have increased the level of arsenic contamination. However, isotopic data shows that this is not the case. The isotopic 'fingerprint' (see box) of arsenic-bearing groundwater shows that it pre-dates the relatively recent increase in the number of tube wells.

The Model Project

It is imperative to find alternative, safe sources of water as quickly as possible and yet, before committing substantial financial investment to exploit them, it is essential to be sure that they would continue to supply the population with safe drinking water. Isotope hydrology provides precise, scientific and low cost information to help guide decisions about managing water supply. An IAEA demonstration project on the applicability of isotope hydrology techniques, in support of the Bangladesh Arsenic Mitigation in Water Supply Project (BAMWSP) which is led by the World Bank, was designed to answer the following questions:

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- When existing deep wells are found to be contaminated, is the water in these wells coming from the deep aquifers alone or is it a mixture of shallow (contaminated) and deep (uncontaminated) waters?
- Would deeper aquifers remain free from arsenic contamination if these were to be developed as alternative sources of drinking water?
- How is arsenic getting into the water?

Preliminary investigations yielded significant hydro-geological information that could not have been obtained by other means. (See box: *Conclusions of Preliminary Investigations*). Having successfully demonstrated the value of isotope hydrology, the Agency is now supporting a continuation and extension of the work in close collaboration with the Bangladesh Atomic Energy Commission and the Bangladesh Water Development Board. This will result in a well-trained national team who will be capable of using isotope hydrology to carry on the survey of arsenic contamination in groundwater. A laboratory will be upgraded to provide high quality chemical analysis of water and sediment samples. Together, these efforts will help to identify clean water sources for drinking and irrigation.

Conclusions of preliminary investigations

- High arsenic concentrations are present mostly in shallow groundwater (at depths less than 70 metres). Deep wells with high arsenic concentration are likely to contain shallow groundwater in the well and do not necessarily imply the contamination of deep aquifers.
- Shallow groundwater is being recharged with a residence time of tens of years while deep groundwater may not be recharging under present conditions.
- Deeper groundwater is effectively isolated from the shallow groundwater under the present hydrologic conditions. However, depth itself is not a safe criterion for considering a deep tube well to be contaminated, or arsenic-free, now or in the future.
- Presently uncontaminated water from deeper wells (depths of approximately 100 metres) may not remain so over a long period of time. Increased exploitation of deep groundwater (depths of approximately 300 metres) appear to be possible without fear of arsenic contamination from shallow aquifers. However, the potential for groundwater mining is evident and the sustainability of the resources needs to be fully evaluated.
- Isotopic data indicate that the exponential increase in groundwater exploitation between 1979 and 1999 has not affected the overall hydrodynamics of the shallow and deep aquifers and, by implication, arsenic mobilization processes.

Water 'fingerprints'

During evaporation and condensation of water, the concentration of oxygen and hydrogen isotopes (naturally-occurring atoms of different weight) change. Water vapour rising from the oceans carries a lower concentration of heavy isotopes than sea water. When the resulting clouds release water, the heavy isotopes fall out first. As clouds move inland, their isotopic composition again changes, and the water acquires individual and characteristic 'fingerprints' in different environments. There are other isotopes in rainwater whose concentration decreases with time. These isotopes in surface or groundwater can be measured to determine the "age" or residence time of water within a particular water body.

In brief, isotopes can be used to:

- estimate the size of an underground reservoir of water in an aquifer system;
- determine how quickly the resource is replenished and therefore the rate at which it can be sustainably used;
- provide estimates of the degree of mixing and interconnection of groundwater in complex aquifer systems.

Integration of isotope techniques in the hydro-geologic characterization work in Bangladesh can provide information rapidly and at much lower cost than is possible with non-isotopic techniques alone. Every effort should be made to help the people of Bangladesh who are currently suffering from the effects of arsenic-contaminated water and those who, without help, will suffer in future.

A common occurrence in Bangladesh, a man suffering from arsenicosis.

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Designed and produced by WRENmedia, Fressingfield, Eye, Suffolk IP21 5SA, UK