Executive summary

A survey of well waters (n=3534) from throughout Bangladesh, excluding the Chittagong Hill Tracts, has shown that water from 27% of the 'shallow' tubewells, that is wells less than 150 m deep, exceeded the Bangladesh standard for arsenic in drinking water (50 $\mu g\ L^{-1}$). 46% exceeded the WHO guideline value of 10 $\mu g\ L^{-1}$. Figures for 'deep' wells (greater than 150 m deep) were 1% and 5%, respectively. Since it is believed that there are a total of some 6–11 million tubewells in Bangladesh, mostly exploiting the depth range 10–50 m, some 1.5–2.5 million wells are estimated to be contaminated with arsenic according to the Bangladesh standard. 35 million people are believed to be exposed to an arsenic concentration in drinking water exceeding 50 $\mu g\ L^{-1}$ and 57 million people exposed to a concentration exceeding 10 $\mu g\ L^{-1}$.

There is a distinct regional pattern of arsenic contamination with the greatest contamination in the south and south-east of the country and the least contamination in the north-west and in the uplifted areas of north-central Bangladesh. However, there are occasional arsenic 'hot spots' in the generally low-arsenic regions of northern Bangladesh. In arsenic-contaminated areas, the large degree of well-to-well variation within a village means that it is difficult to predict whether a given well will be contaminated from tests carried out on neighbouring wells.

The young (Holocene) alluvial and deltaic deposits are most affected whereas the older alluvial sediments in the north-west and the Pleistocene sediments of the uplifted Madhupur and Barind Tracts normally provide low-arsenic water. Water from dug wells from a highly contaminated hot spot in northern Bangladesh was also found to normally comply with the WHO guideline value for arsenic and so could be a possible source of low-arsenic water, given the appropriate sanitary precautions.

The arsenic is of natural origin and is believed to be released to groundwater as a result of a number of mechanisms which are poorly understood. This release appears to be associated with the burial of fresh sediment and the generation of anaerobic (oxygen-deficient) groundwater conditions. It probably occurred thousands of years ago. The arsenic is thought to be desorbed and dissolved from iron oxides which had earlier scavenged the arsenic from river water during their transport as part of the normal river sediment load. We call this the iron oxide reduction hypothesis. Natural variations in the amount of iron oxide at the time of sediment burial may be a key factor in controlling the distribution of high arsenic groundwaters. Limited evidence suggests that the isolated arsenic hot spots found in northern Bangladesh occur in areas containing sediments particularly rich in iron oxides, and their accompanying adsorbed arsenic load.

While there is evidence for sulphide minerals in some of the sediments, and in some cases indirect evidence for their oxidation, there is no support for the 'pyrite oxidation' hypothesis in which pyrite oxidation in the zone of water table fluctuation is assumed to release arsenic and ultimately to be responsible for the groundwater arsenic problem. There is no evidence to support the proposition that the groundwater arsenic problem is caused by the recent seasonal drawdown of the water table due to a recent increase in irrigation abstraction.

Monitoring of groundwaters at two-weekly intervals at a number of sites, and at different depths, has shown some variation with time but there is as yet no convincing evidence for seasonal changes. Dramatic changes in contamination are not expected within such a short timescale. A monitoring programme should be undertaken at a range of sites to monitor possible long-term changes. In the three contaminated areas studied in most detail, the arsenic concentration increases most rapidly between 10–20 m below ground level.

While arsenic is the single greatest problem in Bangladesh groundwaters, other elements of concern from a health point of view, are manganese, boron and uranium. Some 35% of the groundwaters sampled exceeded the WHO guideline value for manganese (0.5 $mg\ L^{-1}$). The spatial pattern of the arsenic and manganese problem areas was significantly different and only 33% of shallow well waters complied with the WHO guideline values for both arsenic and manganese.

It is unlikely that the regional pattern of arsenic contamination revealed by this, and other studies, will substantially change as more testing refines the picture. There is therefore an urgent need for the arsenic mitigation programme to provide, as a priority, a safe source of drinking water in the worst-affected areas which have now been clearly identified.

Deep groundwaters, where available, appear to offer a long-term source of safe drinking water. Experience gained so far indicates that the great majority of these would not only pass the current Bangladesh standard for arsenic but would pass all other existing national and international standards and guidelines for arsenic. The likelihood of a manganese exceedance is also much lower in these deep groundwaters. Most of the deep groundwaters tested in our surveys were from the southern coastal region where the shallow groundwaters are affected by salinity and these deep groundwaters may not be typical of those from elsewhere in Bangladesh. Therefore the nationwide availability and sustainability of this resource needs to be established in terms of quality, quantity and sustainability. The possible impact of the large-scale abstraction of irrigation water on the deep aquifer also needs to be considered.

From a worldwide perspective, drinking water derived from aquifers showing similar characteristics to those of the Bengal Basin should be considered 'at risk' and need to be systematically tested for arsenic.