1 Introduction

The definitive history of the discovery of the Bengal Basin groundwater arsenic problem has yet to be written. In retrospect, there were certainly early indications but these were often not widely reported or their significance was not fully appreciated. A useful summary is given in Smith et al. (2000).

The first reported case of arsenic-contaminated groundwater (greater than 50 μg As L^{-1}) from the Bengal Basin was recorded in 1978 in West Bengal (Acharyya et al., 2000) and the first cases of arsenic poisoning there were diagnosed in 1983. These early cases of arsenic-induced skin lesions were identified by K.C. Saha then at the Department of Dermatology, School of Tropical Medicine in Calcutta, India (Saha, 1995; Smith et al., 2000). The first patients seen were from West Bengal but by 1987 several patients had already been identified who came from neighbouring Bangladesh (Smith et al., 2000).

The contamination of groundwater by arsenic in Bangladesh was first confirmed by the Department of Public Health Engineering (DPHE) in Chapai Nawabganj in late 1993 following reports of extensive contamination in the adjoining area of West Bengal. The issue of arsenic contamination in West Bengal achieved international recognition in 1995 when the School of Environmental Studies (SOES) at Jadavpur University, Calcutta hosted an international conference on the subject. Arsenic-affected patients from both West Bengal and Bangladesh were presented to the participants.

Since the mid-1990s, SOES in conjunction with Dhaka Community Hospital have conducted field investigations over much of Bangladesh including a large number of water analyses and tissue analyses. In February 1998, DCH and SOES held an international conference on arsenic in Dhaka that once again raised public awareness of the issue.

BGS first became involved in the groundwater arsenic issue in Bangladesh when it was awarded a grant by the UK Department for International Development (DFID) to study arsenic contamination of groundwater in Bangladesh and Argentina. Initial investigations were carried out in Chapai Nawabganj in February 1997. These confirmed the high arsenic contamination of groundwater in that area and established the reducing nature of the groundwaters. The data obtained pointed away from the pyrite oxidation hypothesis then being promoted by West Bengal scientists.

In early 1997, a World Bank Fact Finding Mission under the leadership of Professor Guy Alaerts visited Bangladesh to investigate the possible scope for assisting the Government of Bangladesh with the arsenic mitigation effort. Two BGS geoscientists accompanied that mission. At that time, the scale of the problem was not known and the mission identified a number of activities, one of which was a Rapid Investigation Programme to map what were then believed to be the worst-affected areas of Bangladesh and to identify the cause of the arsenic contamination.

Shortly after the World Bank visit, the DPHE with UNICEF assistance carried out a massive screening programme of wells for arsenic across the whole of Bangladesh using simple field-test kits. Some 23,000 wells were randomly tested by DPHE staff. The results of this survey showed for the first time the scale of the problem and identified the centre of the worst-affected area as an area south-east of Dhaka. Northern Bangladesh was also found to be substantially 'uncontaminated' in terms of the prevailing Bangladesh drinking water standard for arsenic (50 μg L^{-1}). However, some hot spots had been found in northern Bangladesh, including Chapai Nawabganj, largely because arsenic patients had been identified there. Subsequent testing has confirmed the overall pattern that emerged from this survey.

Since that time, many Bangladeshi and international organisations have become involved in the groundwater arsenic problem. It has been widely reported in the national and international press. This interest continues. In 1998 as a result of the World Bank Fact Finding Mission, the Government of Bangladesh was offered a $44 million World Bank loan in order to set up an arsenic mitigation programme. DPHE was identified as the lead Government Department and seconded a senior official to lead the programme. BAMWSP, the Bangladesh Arsenic Mitigation Water Supply Project, was created for this purpose.

The present BGS-DPHE project, funded by DFID, began its Rapid Investigation Phase, or Phase I, in January 1998. Mott MacDonald Ltd provided the local Team Leader and much logistical support for this Phase of the project. The principal aims of Phase I were to: (i) compile, review and database existing groundwater and sediment arsenic data from Bangladesh; (ii) review Bangladesh geology and hydrogeology; (iii) carry out a systematic groundwater quality survey using laboratory analyses of what were then believed to be the 41 worst-affected districts of Bangladesh (out of 64 districts); (iv) carry out detailed geochemical investigations in three Special Study Areas, and (v) model the movement of groundwater and arsenic in a typical Bangladesh situation. Phase I was completed in December 1998 and a six-volume report produced in early 1999. A summary of the results and the arsenic data were also put on the web.

Phase II of the present project continued from Phase I. The remainder of Bangladesh, excluding the three Chittagong Hill Tract districts, was surveyed and the detailed studies in the three Special Study Areas located in Chapai Nawabganj, Faridpur and Lakshmipur continued. This included the installation and monitoring of sets of piezometers placed at different depths. These were sampled at two-weekly intervals for nearly a year and provided the first detailed data for the variation of Bangladesh water quality with depth and with time. The complete set of water samples collected during the arsenic survey were also analysed for a wide range of inorganic constituents to give detailed maps for the variation in a range of water quality parameters. These have been collated to give the National Hydrochemical atlas of Bangladesh. A rapid survey of a single village in south-east Bangladesh also enabled us to test a more sensitive and more accurate field-test kit, the Arsenator, designed by Professor Kosmus, Karl Franzens University, Graz, Austria. It also provided some quantitative indication of the nature of the spatial variation in groundwater quality at the village scale. We have also undertaken a world-wide review of arsenic occurrence, a detailed re-evaluation of the geology and sedimentology of Bangladesh aquifers, some further hydrogeological and hydrochemical modelling, geostatistical interpretation of some of our chemical data and an initial study of the mineralogy and geochemistry of Bangladesh sediments.

Phase II of the project finished at the end of March 2000 and a seminar presenting the principal findings was given in Dhaka on 30th March 2000. The full results of the project are presented in four volumes. This volume forms the main report and is accompanied by the National Hydrochemical atlas, a separate 20-page Summary Report and a data volume. The Summary, a large number of water quality maps and the point source water quality data were placed on the BGS website and made available for downloading at the end of May 2000. It is intended to mirror this on a local web site when available and to make the complete report available in paper form, on CD and on the web.

It is now clear that the scale of the groundwater arsenic problem in Bangladesh is very large and that many important questions remain to be answered. First and foremost is the need to provide an immediate source of safe drinking water in the worst-affected areas. This needs to be followed by a longer-term programme to provide viable long-term sources of safe drinking water. Our national map for arsenic, along with the data of others, provides a basis for choosing the priority areas for rapid action.

There are still important scientific questions to answer. These include the nature of the mineral source of arsenic in the sediments, how it is released into the groundwater, why the problem is so severe in Bangladesh and how the extent and severity of the contamination will change in the future. These questions are not merely academic but have important implications for the future water resources strategy of Bangladesh. If, as has been strongly promoted by some, the increased seasonal drawdown of the water table as a result of recent irrigation abstractions were responsible for the problem, then this immediately puts the use of groundwater for irrigation in conflict with its use for drinking water. Any substantial diminution of irrigation would have serious implications for the food self-sufficiency of Bangladesh and the rural economy. We do not believe that this is the primary cause but such assertions can only be countered by reasoned argument and we hope that this report contains the data to support such arguments.

Then there is the problem of the deep aquifer. Our studies, and those of others, have shown that the deep aquifer in southern Bangladesh is overwhelmingly ‘arsenic-free’. But there have been persistent reports from West Bengal that deep wells often become contaminated within a few years. This too has serious implications since the deep aquifer appears to offer one of the viable long-term options for water supply in some of the arsenic-affected areas of Bangladesh. Questions over possible slow, long-term changes will take a long time to answer but the monitoring programmes required need to be put in place now.

It is often assumed that arsenic analysis is reasonably straightforward, even tedious. We have been fortunate in having a good set of ‘tools’ at our disposal and yet even so, it has been a continual struggle to ensure high-quality data. Many laboratory methods for arsenic determination exist and a wide range of field-test kits have been tested in Bangladesh and elsewhere. Many of the existing field-test kits are not sensitive or reliable enough to fully achieve their role, and setting up and maintaining reliable laboratories for arsenic determinations in Bangladesh remains a challenge. Reliable arsenic analyses are clearly essential, and should never be taken for granted. The new generation of field-test kits now emerging looks more promising.