Groundwater Quality: Bangladesh

This is one of a series of information sheets prepared for each country in which WaterAid works. The sheets aim to identify inorganic constituents of significant risk to health that may occur in groundwater in the country in question. The purpose of the sheets is to provide guidance to WaterAid Country Office staff on targeting efforts on water-quality testing and to encourage further thinking in the organisation on water-quality issues.

Background

Bangladesh has a total area of around 144,000 square kilometres and lies within the Bengal Basin of South Asia. It is bordered on most sides by India, and by Burma in the south-east. Bangladesh has a tropical monsoon climate with a high annual rainfall of 1000–2000 mm or more, falling mainly during June–September. The wettest place in the world, Cherrapunji, lies just to the north of Bangladesh in the Meghalaya Hills of India. Around a third of the country floods annually during the monsoon season, a factor which hinders economic development considerably. Bangladesh has a large area of surface water in the form of the major Padma (Ganges), Jamuna (Brahmaputra) and Meghna Rivers and their tributaries. These originate in the highlands (including the Himalaya) of northern India and beyond. The land is mainly a flat-lying alluvial plain with hill country in the south-east (Chittagong Hill Tracts). Elevation varies from 1230 m in Keokradong (south-east) to sea level. Much of the land is within 5 m of mean sea level.

The economy is dominantly based on agriculture with around 73% of landuse being arable. Around 31,000 square kilometres of land is irrigated and rice constitutes the single most important crop.

Geology

The surface geology of Bangladesh is dominated by young (Holocene) alluvial and deltaic sediments deposited by the major river systems of the Bengal Basin, much of it deposited within the last 6000–10000 years. These deposits are several hundreds of metres thick and the Basin has been one of the most rapidly accreting delta systems in the world. Surface sediments in the north include mainly coarse-grained mountain-front alluvial fan deposits (the 'Tista Fan'). Sediments in much of lowland central Bangladesh are alluvial sands and silts, while in the south closest to the coast, the sediments are predominantly deltaic silts and clays (Figure 1). The deposits become generally more fine-grained towards the lowland south.

The surface geology of north-central Bangladesh comprises the so-called 'Barind and Madhupur Tracts' (Figure 1). These are up-faulted terraces of older (Pleistocene) sediments which are more strongly weathered than the surrounding alluvium. The sediments present within the Barind and Madhupur Tracts (which include at depth the Dupi Tila Formation, a productive sandstone aquifer) also underlie much of the younger alluvial sediment at depths of the order of 150–200 m or more. However, the distribution and extent of the older sediments at depth is as yet poorly known.

The geology of the Chittagong Hill Tracts in south-

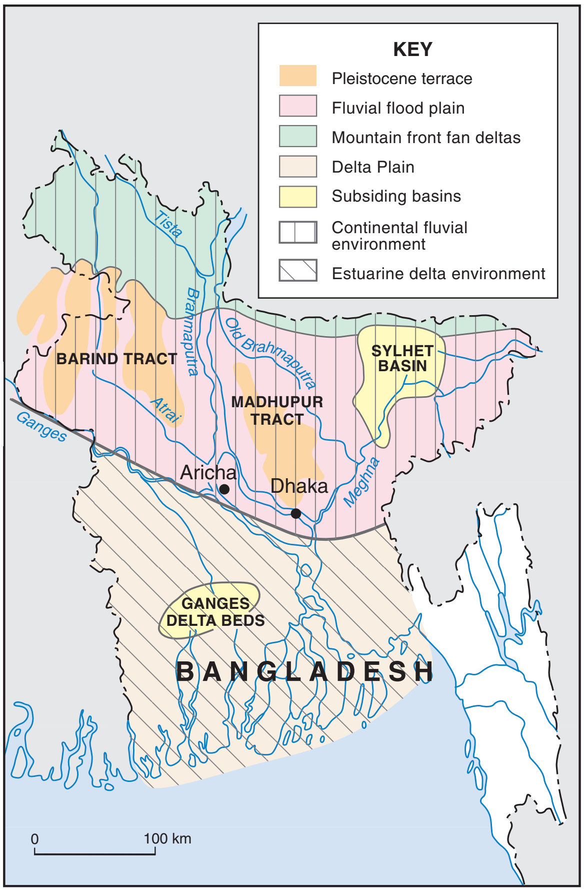

Figure 1. Simplified geology and geomorphology of Bangladesh (BGS and DPHE, 2001).

east Bangladesh is distinctive: sediments exposed in this region are dominantly older (Tertiary) folded and indurated deposits of sandstone, silt and limestone.

Groundwater Availability

Groundwater is abundant in Bangladesh and the aquifers are highly productive. The sediments are predominantly non-indurated and easy to drill by hand, at least to shallow levels. Water tables vary across the country but are typically shallow at around 1–10 m below the ground surface. These factors have made groundwater an attractive and easily accessible resource and have led to a rapid proliferation in the use of groundwater over the last few decades. Today, 97% of the population relies on groundwater for potable supplies and groundwater is also an important source for irrigation and industry. Groundwater levels across Bangladesh become depressed during the dry season, but the aquifers replenish fully during the monsoon. Exceptions occur beneath the major cities, especially Dhaka, where large-scale abstraction has led to long-term drawdown of the water table.

The number of tubewells in Bangladesh is not known but estimates put the number at around 6–11 million. The vast majority of these are private tubewells, which penetrate the shallow alluvial aquifers to depths typically of 10–60 m. Irrigation boreholes typically tap deeper aquifers in the region of 70–100 m depth. In some areas, notably the south and the Sylhet Basin of north-east Bangladesh (Figure 1), deep tubewells abstract groundwater from depths of 150 m or more. In the south, the deep tubewells have been installed to avoid high salinity at shallower levels (BGS and DPHE, 2001). Shallow hand-dug wells occur in some areas, though they are much less common than tubewells.

Groundwater Quality

Overview

The growth in use of groundwater over the last few years has seen a drastic reduction in the incidence of water-borne diseases that were largely the result of use of traditional surface sources. Groundwaters are much less prone to bacterial contamination than surface waters, although shallow wells and especially dug wells are at increased risk relative to deeper, well-constructed tubewells. Despite the advantages offered by groundwaters in terms of bacterial quality, it has emerged in the last few years that groundwater in many parts of the shallow alluvial aquifer of Bangladesh has a severe problem with arsenic contamination. This is the single most important groundwater-quality problem known in Bangladesh and has potentially serious long-term consequences for health. Mitigation of arsenic problems is a major issue nationally and will continue to be so for many years. A national survey of groundwater quality in Bangladesh has recently been carried out by BGS in collaboration with DPHE and with DFID support. Analysis of the groundwater quality in this report is largely drawn from the chemical database from that study (BGS and DPHE, 2001).

Although arsenic is the major inorganic constituent of health concern, problems in the groundwaters also exist with high concentrations of iron and manganese. Boron is problematic in some higher-salinity areas in southern Bangladesh. Limited analyses of uranium also suggest that this may be a problem in some groundwaters, though the health consequences of uranium at the concentrations found are poorly understood. Other inorganic constituents investigated appear not to be of serious health concern. Concentrations of ammonium are very high in many samples and these may cause some acceptability problems. Little is known about the concentrations of pesticides in the groundwaters, although they are widely used.

Arsenic

High arsenic concentrations are found in the groundwaters from the shallow alluvial and deltaic aquifer. Concentrations have been found in the range <1–1500 μg/l in the National Hydrochemical Survey of some 3500 Bangladesh groundwaters described by BGS and DPHE (2001). Concentrations are found to be highly variable over short distances (e.g. within villages) and on present evidence, it is difficult or impossible to predict the concentration of arsenic in a given well. Ultimately, testing of all wells used for drinking water will be necessary to ensure that groundwaters are safe. Despite this extreme variation at a local scale, there are visible trends on a regional scale that relate closely to geological controls. Figure 2 shows the regional variations in arsenic concentrations across Bangladesh. The data have been smoothed (to a 5 km grid) to highlight the main features. The distribution indicates that the worst-affected areas of the shallow alluvial/deltaic aquifer occur in the south and south-east regions, centred on Chandpur District. We estimate that up to 57 million people are drinking water with an arsenic concentrations greater than the WHO guideline value of 10 μg/l and up to 35 million drinking water with concentrations in excess of the Bangladesh standard of 50 μg/l (BGS and DPHE, 2001; Table 1).

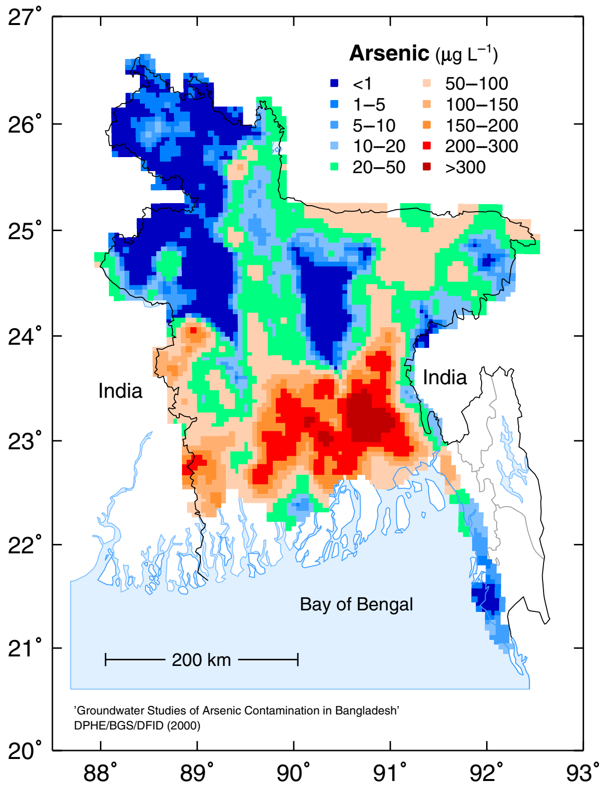

Figure 2. Smoothed map of arsenic concentrations in groundwaters from Bangladesh (from BGS and DPHE, 2001).

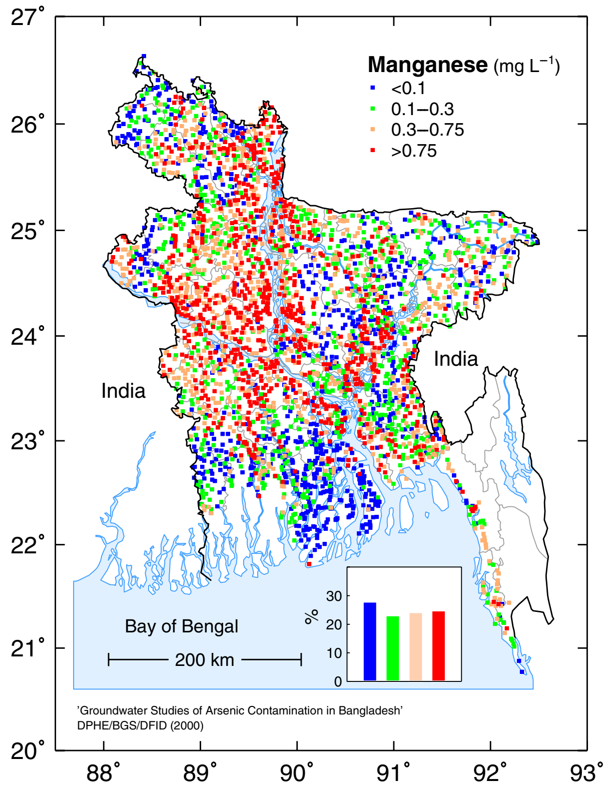

Figure 3. Distribution of manganese in groundwaters (from BGS and DPHE, 2001).

Figure 2 indicates that low concentrations of arsenic are generally found in groundwaters from north-western Bangladesh where the sediments are relatively coarse-grained alluvial fan deposits (Tista fan). However, localised hot-spots with high concentrations have also been found in northern Bangladesh, perhaps related to local variations in sediment or hydrogeological characteristics (e.g. Jamalpur, Pirgacha, Rangpur).

Low arsenic concentrations are also found in groundwaters abstracted from the older Dupi Tila aquifer in the Barind and Madhupur Tracts (Figure 2).

Deep groundwaters (from tubewells with well depth >150 m) analysed in the BGS and DPHE (2001) study also had mostly low arsenic concentrations. Only 4.6% of 326 samples collected had arsenic concentrations greater than 10 µg/l. However, the sample set of deep groundwaters from the BGS and DPHE (2001) survey was mainly from the extreme south (Barisal) or north-east (Sylhet) areas. It is not known how representative these are of the deep aquifers as a whole in Bangladesh and more, accurate, surveys of deep groundwater need to be carried out. A limited number of samples collected from tubewells in Dhaka city, which also abstracts from the Dupi Tila aquifer at depths in excess of 200 m, also found concentrations of arsenic to be very low (7 samples, all <0.5 µg/l). Deep groundwaters therefore offer potential as alternative drinking-water sources, although studies need to be made on the long-term sustainability of the deep aquifer.

From a limited number of samples of groundwaters from dug wells (from Chapai Nawabganj thana), it is apparent that these also have low arsenic concentrations, typically 10 µg/l or less. These therefore also offer potential as alternative potable-water sources, but their applicability may be limited by yield and seasonal drawdown problems and they are also more vulnerable to bacterial contamination.

Iron and manganese

Groundwater surveys also indicate that iron and manganese are present in high concentrations. Concentrations have been found at up to 25 mg/l and 10 mg/l respectively, with averages for iron of 3 mg/l (median 1 mg/l) and for manganese of 0.5 mg L^{-1} (median 0.3 mg/l). The high values are related to the anaerobic conditions dominant in the aquifers. Although high iron in drinking water is not a health problem, it may be unacceptable to users at such high concentrations.

Manganese on the other hand, is regarded as a potential health problem in waters and WHO have set a guideline value of 0.5 mg/l for this element. A large percentage of wells in Bangladesh fail this guideline. From the BGS and DPHE (2001) National Hydrochemical Survey, 39% of shallow tubewells and 2% of deep tubewells exceeded the WHO guideline value. The distribution of high manganese concentrations in the groundwaters is shown in Figure 3. High concentrations are found in most areas, but particular high-manganese areas are seen in the current Brahmaputra and Ganges floodplains. The distribution generally does not correspond with that of arsenic. This means that groundwaters with acceptable concentrations of arsenic may not have acceptable concentrations of manganese (Figure 4). In this case, a policy on groundwater quality needs to be made with respect to both these elements, and perhaps other chemical constituents. It is notable that groundwaters from the deep aquifer contain relatively low concentrations of both arsenic and manganese.

Bacterial contamination and nitrate

Despite the significant improvement in bacterial quality afforded by groundwater over surface water sources, many groundwaters from tubewells in Bangladesh show higher than acceptable concentrations of bacterial contaminants. In a parallel study to that carried out by DPHE/BGS/MML (1999), Hoque (1998) investigated the concentrations of faecal coliforms in some 2000 tubewells across Bangladesh. Around half were found to fail the WHO guideline value (i.e. contained detectable coliform counts). This appears related to a number of factors, including proximity of latrines or drains to the tubewells, tubewell depth or method of completion, and factors such as the practice of tubewell priming may also be involved.

Nitrate concentrations analysed in Chapai Nawabganj, Faridpur and Lakshmipur (BGS and DPHE, 2001) were mostly low. High concentrations were usually restricted to a few shallow wells which also showed other evidence of surface pollution.

Many of the groundwaters also contain high concentrations of ammonium, often in excess of 1 mg/l (as N). Much of this is believed to be naturally-derived, although some may be related to pollution: Hoque (1998) observed a significant correlation between ammonium and faecal coliform counts. Although not regarded as a direct health concern, high ammonium concentrations in the groundwaters may give rise to complaints of adverse taste and odour from the users. Ammonium may also compromise water treatment and disinfection procedures.

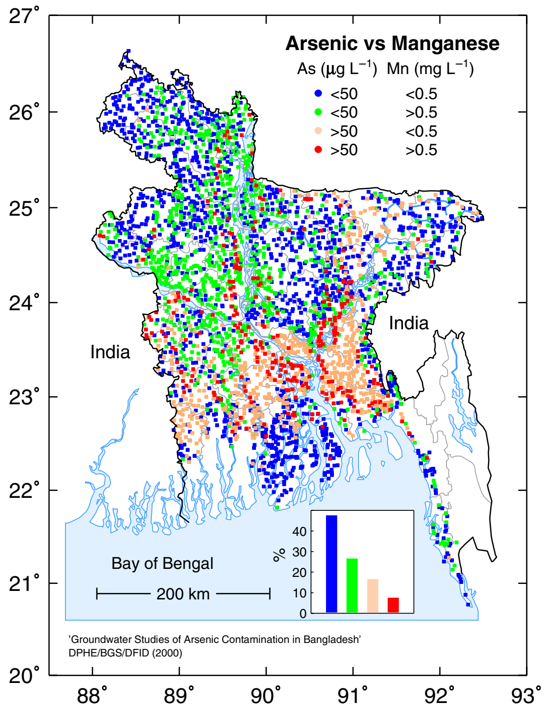

Figure 4. Variation in arsenic and manganese concentrations in the Bangladesh groundwaters (from BGS and DPHE, 2001).

Other trace metals

Table 1 gives a list of the inorganic constituents in drinking water for which WHO guideline values have been set, together with the corresponding Bangladesh standard values (maximum concentrations) and the relative concentrations found in Bangladesh groundwaters by the BGS and DPHE (2001) study. Of the other inorganic constituents measured, boron was found to exceed the WHO provisional guideline value of 0.5 mg/l relatively frequently, though only in the more saline groundwaters of southern (near-coastal) Bangladesh. Nationally, 2.8% of shallow groundwaters and 29% of deep groundwaters sampled exceeded the WHO guideline value (Table 1).

Few data are available for uranium in the Bangladesh groundwaters, although results from around 270 samples collected from Chapai Nawabganj, Faridpur and Lakshmipur by BGS and DPHE (2001), showed concentrations up to 47 µg/l with 30% of samples having more than the WHO provisional guideline value of 2 µg/l (the average value found was 2.8 µg/l). Highest values were generally found in more aerated groundwaters, especially dug wells (data from Chapai Nawabganj) which are shallow and open to air. The health risks of uranium in drinking water at the microgram-per-litre level are not well-established but an evaluation

Table 1. Summary of inorganic constituents in Bangladesh groundwaters from the National Hydrochemical Survey (NHS) relative to WHO health-based and aesthetic guideline values (GVs), as determined by BGS and DPHE (2001).

Parameter	Chem. symbol	WHO GV (mg/l)	Banglad. standard (mg/l)	% exceedance Shallow aquifer		% exceedance Deep aquifer		Comments
				WHO GUIDE LINE VALUE	**Bangladesh standard**	**WHO GV**	**Bangladesh standard**	
Chemicals of health significance								
Antimony	Sb	0.005 (P)	–	–	–	–	–	Not measured in NHS. SS data suggest not a problem
Arsenic	As	0.01 (P)	0.05	46	27	4.6	0.9	Serious problem
Barium	Ba	0.7	0.1?	0.2	28	1.2	26	Occasional problem
Beryllium	Be	NAD	–	–	–	–	–	Not measured in NHS. Rarely detected in SS (always <0.1 μg/l)
Boron	B	0.5 (P)	1.0	2.8	0.4	29	8	Occasional problem especially in more saline waters
Cadmium	Cd	0.003	0.005	–	–	–	–	NHS data not sensitive enough. SS found no exceedances
Chromium	Cr	0.05 (P)	0.05	0.2	0.2	<1	<1	SS data: essentially no problem
Copper	Cu	2 (P)	1	0	0	0	0	SS confirms no problem
Fluoride	F	1.5	1	–	–	–	–	SS and BWDB indicates if anything too low esp. in NW
Lead	Pb	0.01	0.05	–	–	–	–	NHS data not sensitive. Results from SS suggest not a problem
Manganese	Mn	0.5 (P)	0.1	39	79	2	22	Widespread exceedances, sometimes of large magnitude
Molybdenum	Mo	0.07	–	–	–	–	–	NHS data not sensitive enough. Results from SS suggest not a problem
Mercury	Hg	0.001	–	–	–	–	–	Not measured
Nickel	Ni	0.02 (P)	0.1	6	0.1	0.9	0.3	Rare problem. Not exceeded in SS
Nitrate	NO_3	50	10	–	–	–	–	Not measured in National Hydrochemical Survey. SS indicates very low in most groundwaters. Greatest problem likely in shallow, polluted wells
Selenium	Se	0.01	0.01	–	–	–	–	Not measured in NHS but 20 samples were all <0.0005 mg/l
Uranium	U	0.002 (P)	–	–	–	–	–	Not measured in National Hydrochemical Survey; SS results suggest a significant exceedance especially in more oxidising waters
Substances that may give rise to complaints from consumers								
Aluminium	Al	0.2	0.2	1.7	1.7	6	6	Normally below 0.1 mg/l
Ammonia	NH_3	1.5	–	–	–	–	–	Frequent exceedances
Iron	Fe	0.3	0.3–1.0	68	55	32	15	Frequent exceedances
Potassium	K	10	12	10	8	4	2	Occasional problem especially in southern Bangladesh
Sodium	Na	200	200	8.5	8.5	49	49	Serious problem in coastal areas
Zinc	Zn	3	5	0	0	0.3	0.3	Not a serious problem

– no reliable data.
(P) – Provisional WHO guideline maximum value.
NAD – No adequate data to permit recommendation of a health-based guideline value.
NHS – DPHE/BGS National Hydrochemical Survey.
BWDB – water-quality survey of tubewells in the Bangladesh Water Development Board monitoring network.
SS – Special Study Areas survey (Chapai Nawabganj, Faridpur, Lakshmipur upazilas).

should be made of the uranium concentrations typically found in Bangladesh groundwaters.

Of the other elements considered by the BGS and DPHE (2001) study, rare exceedances were observed for nickel, chromium, lead and barium above WHO guideline values, although these were usually not significantly above guideline values and are therefore not considered a major problem. A limited number of samples analysed for selenium found none above the analytical detection limit of 0.5 μg/l (Table 1). It is possible that some selenium is present in the more aerated shallow groundwaters, though concentrations are not expected to be problematic.

No data are available for mercury in Bangladesh groundwaters. Apart from in groundwaters affected by industrial pollution, concentrations of mercury are expected to be low and significantly less than the WHO guideline value of 1 μg/l. However, in the anaerobic environment of the groundwaters, there is a possibility of the presence of some mercury. A reconnaissance survey of mercury concentrations in the groundwaters would help to establish if a potential problem exists.

Fluoride

The observed range of fluoride in groundwaters analysed by BGS and DPHE (2001) was 0.01–0.73 mg/l. All these values are relatively low but lowest concentrations are found mainly in north-west Bangladesh and the Chittagong coastal region. None of the samples exceeds the WHO guideline value for fluoride in drinking water of 1.5 mg/l. Indeed, many are in the range where fluoride deficiency, and development of dental caries, may become a problem.

Iodide

Concentrations of iodide in groundwaters analysed from Bangladesh have a range of 0.004–5.84 mg/l (BGS and DPHE, 2001). The regional distribution of concentrations is variable, but highest values are typically found in southern Bangladesh where salinity is higher. In this area, the iodide is seawater-derived. Lower values are mainly in the northern parts of the country. Studies elsewhere suggest that concentrations at the lower end of the observed range can be insufficient for dietary requirements without other sources of dietary iodine. Some parts of northern Bangladesh may be prone to iodine-deficiency disorders as a result.

Data sources

BGS and DPHE, 2001. Arsenic contamination of groundwater in Bangladesh. BGS Technical Report, WC/00/19.

DPHE/BGS/MML, 1999. Groundwater Studies for Arsenic Contamination in Bangladesh. Report to Government of Bangladesh and DFID. British Geological Survey and Mott MacDonald.

Hoque, B.A. 1998. Biological contamination of tubewell water. International Center for Diarrhoeal Disease Research, Bangladesh.

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