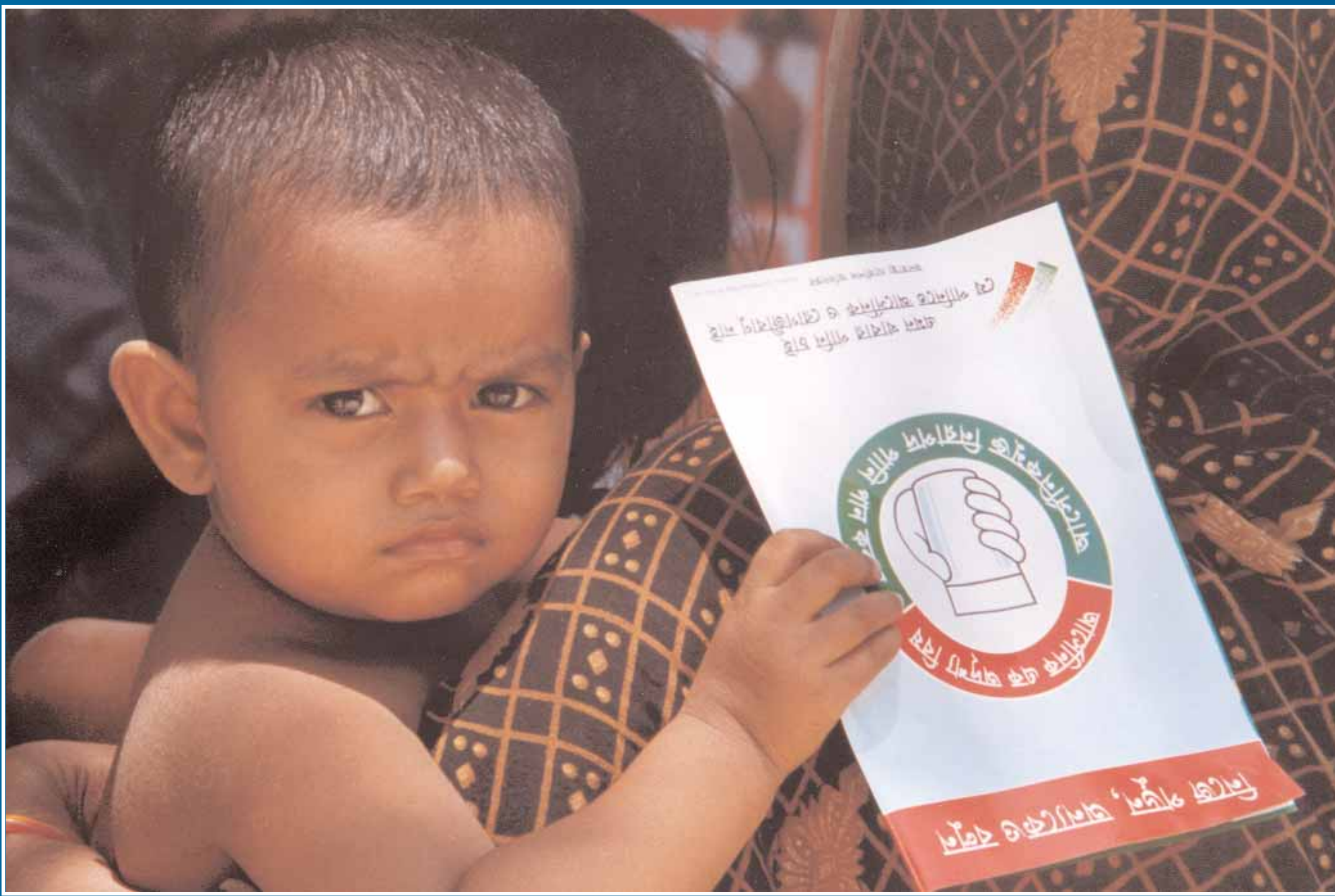
Not Just Red or Green

An Analysis of Arsenic Data from 15 Upazilas in Bangladesh



Jan Willem Rosenboom

November 2004

Department of Public Health Engineering, MLGRD&C

APSU Arsenic Policy Support Unit

unicef

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Photograph of Figure 1.10 by the author

Contributors

Lead Author and Report Editor:

Jan Willem Rosenboom

Consultant Public Health Engineer

Phnom Penh, Cambodia.

Contributing Authors:

Chapter 1: Introduction

Kazi Matin Ahmed, PhD

Professor

Department of Geology

University of Dhaka.

Chapter 3: KAP Data

Malgosia Madajewicz

Assistant Professor

School of International and Public Affairs and Economics

Columbia University

Alexander Pfaff

Associate Professor

School of International and Public Affairs and Earth Institute

Columbia University

Reviewers

Prof. Kazi Matin Ahmed

Department of Geology

University of Dhaka

Prof. M. Feroze Ahmed

Dept. of Civil Engineering

Bangladesh University of Engineering and Technology (BUET)

Carel de Groot

Sector Programme Coordinator

DPHE-DANIDA

Dhaka, Bangladesh

Han Heijnen

Regional Advisor Water, Sanitation and Health

WHO-SEARO

New Delhi, India

Guy Howard

International Specialist

Arsenic Policy Support Unit

Department of Public Health Engineering (DPHE)

Dhaka, Bangladesh

S.M. Ihtishamul Huq

Executive Engineer Planning and Coordination Division

Dept. of Public Health Engineering

Dhaka, Bangladesh

Rick Johnston

Project Officer Water and Environmental Sanitation

UNICEF

Dhaka, Bangladesh

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Exchange rate used: 58 Bangladesh Taka (Tk.) equal 1 US Dollar (US$).

Abbreviations

AAN	Asia Arsenic Network
APSU	Arsenic Policy Support Unit
BAMWSP	Bangladesh Arsenic Mitigation Water Supply Program
BGS	British Geological Survey
BMI	Body Mass Index (kg/m^2)
BRAC	Bangladesh Rural Advancement Committee (an NGO)
BWDB	Bangladesh Water Development Board
CEGIS	Center for Environmental and Geographic Information Services (formerly known as EGIS)
DANIDA	Danish International Development Agency
DCH	Dhaka Community Hospital (an NGO)
DFID	Department for International Development
DGHS	Directorate General for Health Services
DPHE	Department of Public Health Engineering
DTW	Deep TubeWell
DW	Dug well
EGIS	See CEGIS
FP	False Positive
FN	False Negative
FTK	Field Test Kit
GIS	Geographic Information System
GOB	Government of Bangladesh
GPS	Global Positioning System
GS	Grameen Shikkha (an NGO)
GSB	Geological Survey of Bangladesh
HH	HouseHold
JICA	Japan International Cooperation Agency
KAP	Knowledge, Attitudes and Practices
LGD	Local Government Division
LGED	Local Government Engineering Division
MICS	Multiple Indicator Cluster Survey
MLGRD&C	Ministry of Local Government Rural Development and Cooperatives
NAMIC	National Arsenic Mitigation Information Centre
NGO	Non-Governmental Organization
NPV	Negative Predictive Value
PPV	Positive Predictive Value
QA	Quality Assurance
QC	Quality Control
TP	True Positive
TN	True Negative
UHC	Upazila Health Complex
UNF	United Nations Foundation
UNICEF	United Nations Children's Fund
USGS	United States Geological Survey
WARPO	Water Resources Planning Organization
WHO	World Health Organization

Executive Summary

Bangladesh groundwater is plentiful and easily accessible at shallow depths. It is also of much better microbiological quality than the surface water sources which were traditionally used for drinking and other domestic purposes. Public education campaigns pointing this out got underway in the 1970s and were extraordinarily successful. By the early nineties, more than 90% of the rural population had access to presumably clean ground water. The discovery of arsenic however (in 1993) put a dent into this success story. Close to one-third of all shallow tubewells in Bangladesh exceed the national standard for permissible arsenic concentration of 50 µg/L. The latest available figures[1] show access to improved water supplies in rural areas to be down to 68%.

In response to the discovery of arsenic, the Government of Bangladesh (GOB), and a variety of national and international organizations started arsenic measurement and mitigation programmes. UNICEF Bangladesh started its arsenic mitigation work in 1998, in partnership with the Department of Public Health Engineering (DPHE). In 2001 the third phase of the UNICEF/DPHE arsenic mitigation programme got under-way, covering 15 subdistricts or upazilas in the most heavily arsenic affected areas of the country. Like most other mitigation programmes, this one also consisted of four components:

1. A public communication campaign to raise awareness;
2. Testing of all wells for arsenic using field test kits;
3. Identification of patients showing symptoms of arsenicosis (caused by chronic exposure to arsenic);
4. Mitigation of impact of arsenic through provision of improved (arsenic safe) water supplies.

[1] WHO/UNICEF (2004), Joint Monitoring Programme for Water Supply and Sanitation: Meeting the MDG drinking Water and sanitation target: a mid-term assessment of progress.

This report presents an analysis of data collected through the UNICEF/DPHE 15 upazila arsenic mitigation programme, and in particular:

- Well screening data;
- Patient data;
- Results of a baseline and follow-up survey of arsenic related Knowledge, Attitudes and Practices (KAP);
- Spatial data on wells and patients obtained through a dedicated GPS survey in three of the 15 upazilas.

One of the objectives of the data analysis was to document findings-showing the distribution of contaminated wells, the distribution of arsenic concentrations, affected population, levels of arsenic awareness, etc.

Furthermore, Bangladesh urgently needs to find effective approaches to arsenic mitigation. The available data were examined for relationships within (e.g. arsenic concentration and well depth) and between (e.g. arsenic concentration and development of symptoms) datasets in the expectation that patterns or relationships can be used to advantage in mitigation planning and policy development.

Finally, there is a growing number of other countries in Asia and elsewhere which are also affected by higher than permissible arsenic concentrations in groundwater. For those countries there may be lessons that can be learned from the mass screening work done in Bangladesh, and for that reason the whole process of data collection and management is also described and analysed.

1 Study Area Characteristics

All 15 upazilas are located in the southern half of Bangladesh. They cover 10 administrative districts, and some summary statistics related to the area are provided in the table below. More than 4.5 million people live in the project area, representing 3.6% of Bangladesh's population.

Table 1: Administrative and population data in the 15 upazilas.

Administrative Division					Population			
District	Upazila	Unions[1]	Villages[1]	Area (Km^2)	House holds[2] (x1000)	Male[3] (x1000)	Female[3] (x 1000)	Total (x 1000)
Barisal	Babuganj	6	78	165	25	81	78	159
Brahmanbaria	Bancharampur	16	141	217	43	159	156	315
Brahmanbaria	Nabinagar	21	217	354	64	230	227	457
Chandpur	Haim Char	6	48	174	21	70	68	138
Chandpur	Shahrasti	9	176	154	31	105	113	218
Chuadanga	Damurhuda	8	147	308	37	131	123	254
Comilla	Barura	15	315	242	53	177	189	366
Comilla	Homna	14	227	180	37	122	128	250
Comilla	Muradnagar	23	367	339	72	371	253	624
Faridpur	Bhanga	12	287	216	41	126	125	251
Jessore	Manirampur	17	248	445	60	198	192	390
Madaripur	Rajoir	10	196	229	38	120	120	240
Madaripur	Shib Char	19	266	322	58	184	175	359
Munshiganj	Serajdikhan	14	188	180	38	136	132	268
Narail	Kalia	13	200	317	36	113	110	223
10 Districts	**15 Upazilas**	**203**	**3,101**	**3,842**	**654**	**2,323**	**2,189**	**4,512**
Bangladesh	507	4,484		147,570	25,362	62,700	60,400	123,100

[1] From UNICEF well database
[2] Census 1991. Bangladesh Bureau of Statistics, December 2002
[3] Estimated 1999, from census data 1991. Bangladesh Bureau of Statistics, December 2002.

The 15 Upazilas are grouped based on their dominant surface geology and geomorphology. Five major geologic-geomorphic units characterize these upazilas. Six of them are located in the deltaic silt (dsl) and deltaic sand (dsd) unit of the Ganges delta plains. Five of the upazilas are in the alluvial silt (asl) and alluvial silt and clay (asc) units of the Meghna floodplains. Two upazilas are placed within a Chandina alluvium (ac) unit of the Meghna deltaic plain. One is located within tidal deltaic deposits (dt) of the Ganges delta, and the last one consists of estuarine deposits (de), located in the Mid-Meghna river area of the country. Figure 1 shows the location of the 15 upazilas, as well as the geomorphology unit and proportion of arsenic affected wells in each.

The geomorphology and the near-surface geology of these areas are quite diverse. The surface areas of Damurhuda, Manirampur, Kalia, Bhanga, Rajoir, and Shib Char, which are located within the Ganges delta generally comprise of sand and silt at the top. Located within the Meghna floodplains and Padma floodplains, the surface deposits of Serajdikhan, Nabinagar, Bancharampur, Muradnagar, and Homna are predominantly silty with occasional clay deposits. Barura and Shahrasti are located in the lower Meghna floodplains, and marsh clay and peat units. Estuarine deposits are present in the Haim Char area. The Babuganj area, characterized by tidal deltaic deposits, is located within the fluvio-tidal transitional Ganges deltaic region.

Like many other parts of the country, the Holocene fluvio-deltaic and coastal sediments form prolific aquifers in the studied upazilas. The aquifer systems can be broadly divided into three units: (i) an upper shallow aquifer occurring mostly within 50 - 60 m of the surface, and which is extensively arsenic affected; (ii) a lower shallow aquifer extending up to 200m in depth which is substantially arsenic free, but which is in hydraulic contact with the upper shallow unit and so may become contaminated over time (through vertical "leakage"), and (iii) a deep aquifer of Pleistocene fine to medium sands which yields arsenic safe water, and is expected to remain safe because in most places it is separated from the lower shallow aquifer by a clay aquitard.

2 Data sets

All field work and data collection was organized by a total of eight local NGOs. The work was completed between late 2001 and mid- 2002. There are three groups of data: well data, patient data and KAP data. The primary dataset consists of the original well screening results, numbering more than 31,000. This dataset contains complete construction, ownership and usage information on all wells, as well as arsenic test results obtained using MERCK "sensitiv" Field Test Kits (FTK). The primary well dataset is supplemented by a second dataset containing almost 6,000 laboratory test results used to confirm FTK readings. The third well-related dataset consists of GIS survey results for three upazilas: Bhanga, Muradnagar and Serajdikhan. This last one contains longitude and latitude for all 70,000 screened wells in those upazilas.

Patient screening results for 14 of the 15 upazilas were received, although only the data for seven of those proved to be usable. The final dataset consists of KAP survey data for the 15 upazilas, with some 2,900 baseline survey responses and a bit more than 1,500 follow-up survey responses.

[1] From UNICEF well database
[2] Census 1991. Bangladesh Bureau of Statistics, December 2002
[3] Estimated 1999, from census data 1991. Bangladesh Bureau of Statistics, December 2002.

Key findings 3

General

Data collection and management

The observable quality of available data is mostly very good; almost 97% of all well data was without problem. However, the experience of setting up a mass screening programme in 15 upazilas offers some lessons for other organizations or countries facing a similar need. Training and supervision of testers is important. It appears that a group of testers in one upazila marked all wells which showed 50 ppb of arsenic red instead of green. Related to this is a need to:

- Minimize perverse incentives. Both well testers and data entry operators were paid for each well tested/entered. This leads to the existence of "phantom wells" in the field and in the database. Paying field workers for a certain amount of time may lead to other problems. There is no perfect solution to this, but effective field supervision and data validation should form part of any screening program.

- Establish a standard (national) database based on the use of standard data collection forms. In the 15 upazilas, the use of a database matching the (pre-existing) national data collection form greatly simplified the exchange of data with the national database administered by the National Arsenic Mitigation Information Centre (NAMIC). Incorporating automatic data validation procedures into a database will greatly improve the quality and reliability of entered data.

- Establish a working system for uniquely identifying wells. To effectively use a database, each well should be assigned a unique identifying number. The approach chosen in the fifteen upazilas (i.e. attaching a well serial number to an existing code for the union the well is in) does not work (up-to-date geographical codes are difficult to get, and testing teams are unable of keeping track of serial numbers used already). A far better approach would have been to make use of uniquely numbered data collection forms.

- Provide a durable record of well number and test details to the well owner will facilitate physical identification of wells at a later date (e.g. for the purpose of repeat testing). Incorporate lists of location names into the database prior to beginning field work. Names of upazilas, unions and villages are spelled differently by different people. Obtaining existing lists, or creating them, and incorporating them into the database (so that only one way to spell each name is available) will greatly improve data quality. In the 15 upazilas, name lists down to union level (but not village level) were available.

- Ensure a link between patient data and data on wells. In the 15 upazilas, the patient data set is not linked to the well dataset. In consequence, it is not possible to link patients to specific water sources. This hampered later analysis.

- Carefully consider the design of a national data collection form. No nationally used form will be able to satisfy everyone, but a good deal of effort should go into the design of the best possible form. The data collection form used in the 15 upazilas suffered from two shortcomings: It was ambiguous in the way wells were categorized (e.g. including "deep" and "shallow" as categories without specifying the depth separating the two, or including depth and usage categories in the same question), and it did not allow a clear distinction of types of institutional wells (e.g. a marking of all wells at a school). Thoughtful design up front allows easier and more meaningful analysis later.

- Establish clear procedures for quality assurance and quality control. In the 15 upazilas, guidelines existed for the confirmation of 3% of all Field Test Kit results by laboratory. These did not include checks on laboratory performance however (duplicate samples, analysis of trip blanks). Better defined procedures could have increased the confidence in the results obtained from the laboratories.

Analysis of data - summary or detail?

In first instance, available data were analyzed at the upazila level. In an effort to find out whether stronger relationships or patterns would be visible when data were looked at in more detail, wells and patients were examined in more depth for a total of three unions from Bhanga, Muradnagar and Serajdikhan upazila. Although there are large differences between the three selected unions, analysis at this level did not reveal any patterns which were not already obvious at the upazila level. The most useful aspect to examining union level data was the use of maps showing well contamination patterns. This is described in a separate paragraph in the "Well data" section. It is important to realize that this does not mean that low-level analysis of data is useless; after all, this study looked for larger patterns in large datasets. Very local decisions should continue to be based on local data. But upazila level summary of data appears to provide sufficiently relevant information to use for area planning.

Well Data

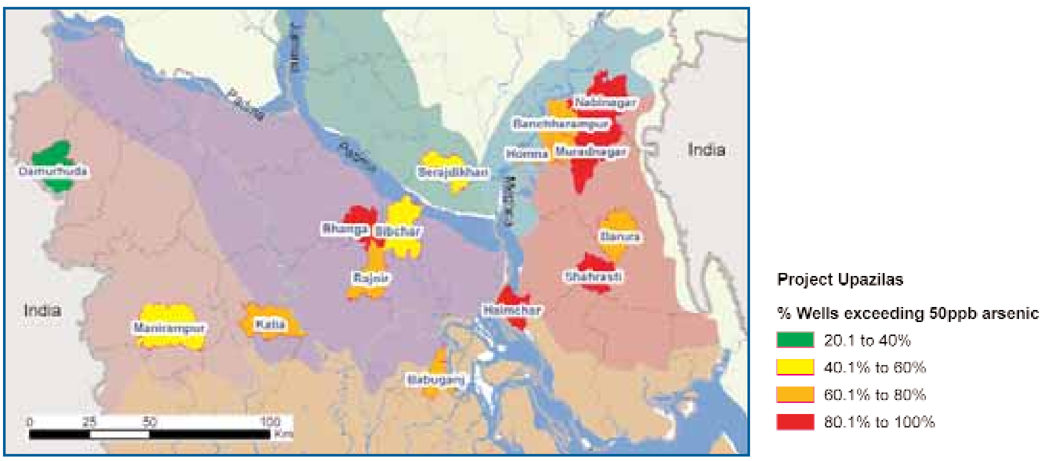
Types, ownership and status of wells

The vast majority of wells (88%) are privately owned, with government wells accounting for a further 10%. Institutional wells (at schools, mosques and such) account for almost 8% with the rest classified as "household well". Only 4% of all wells were found to be out of order at the time of the survey, although institutional and government owned wells scored lower here with more than 20% not functioning. Non-functional wells were not tested for arsenic, and all subsequent figures relate to wells found to be operational when the screening took place.

The extent of arsenic contamination in the 15 upazila area

Of the 316,951 wells tested, 65.5% (207,582 wells) exceed the 50 ppb national arsenic standard. In the remaining 109,369 wells, arsenic levels are within acceptable limits. In 29% of the arsenic-safe wells, no arsenic could be detected at all. The remainder (77,619 wells) had anywhere between 10 to 50 ppb of arsenic in their water. Crucially, 44% of all wells exceed 100 ppb of arsenic, and 39% exceed 250 ppb. A full 29% of wells shows 500 ppb of arsenic in their water. Because 500 ppb (0.5 mg/L) is the highest point of the test kit scale, the actual concentration of arsenic in those wells may be higher still. So not only is the proportion of contaminated wells much higher than the national average of about 27%, the arsenic concentrations in the affected wells also are very high.

Figure 1: Location of the 15 upazilas and the percentage of wells exceeding 0.05 mg/L of arsenic in each.



Also see full scale map with legend on page 56

Exposed population

Selecting all functioning household wells used for domestic purposes (290,457 wells, leaving out institutional and irrigation wells), and making the assumption that each well is only used by the owner and his family, coverage in the 15 upazila area reaches 50%, with on average 8 users per well. The lowest coverage is evident in Babuganj (20%) and Haim Char (24%). Highest coverage is attained in Damurhuda, with 73%.

Besides family size, the well database also lists the number of users for each well, as reported by the owner. Adding up the reported users for all domestic wells, coverage in the 15 upazilas reaches (over) 100%. There are 64 wells per 1,000 people, with on average only 18 users per well. Reported user numbers are inversely related to well density; where the number of wells per 1,000 people goes down, reported number of users per well goes up. In the upazila with the lowest well density (Babuganj, with 30 wells per 1,000 people) the number of users per well still only reaches 50. In other words, with a high density of wells, and low user numbers per well, possibly losing the use of a large proportion of wells due to arsenic contamination need not put any physical limitations on access to water for the whole community. There is sufficient spare capacity to share wells without unduly increasing waiting time at the pump, provided that arsenic-affected and arsenic-safe wells are geographically "mixed" rather than clustered. The fact that reported user numbers seem to go up and down with the density of wells provides further support to the idea that more sharing of wells may be going on than is sometimes assumed.

Of all well users three and a half million are exposed to arsenic concentrations above 50 ppb. Fifty percent of users (2.5 million) are exposed to concentrations exceeding 100 ppb. Muradnagar is the upazila with the largest exposed population at any level (which is explained by the large overall user population together with a very high well contamination rate of 93%).

There are a total of 574 villages where every single well exceeds the permissible arsenic level. Muradnagar and Shahrasti account for a large proportion here, since in almost all villages in these upazilas do 80% or more of wells exceed 50 ppb of arsenic. The Bangladesh national arsenic mitigation policy mandates emergency intervention in all villages where 80% or more of the wells are affected. In the 15 upazila area 1,724 such villages exist (58% of the total).

Given the fact that the cognitive development of children is negatively affected by arsenic, reducing exposure for this vulnerable group is important. An investigation of the data shows that in 72% of all schools that could be identified in the 15 upazilas all wells exceed the permissible concentration of arsenic. This is a total of 1,447 schools which need urgent mitigation measures.

Arsenic in relation to well age

Well construction slowly started in the 1970s, and strongly accelerated in the 1980s. In the last year for which data was available, some 30,000 wells were constructed in the 15 upazilas. The vast majority of this construction concerns private wells. Worrying is that half of all wells were constructed since 1995, while arsenic was first discovered in 1993. The ever-accelerating rate of new tubewell construction seems to indicate that people either do not worry about arsenic, or believe that new wells are free of danger.

Although new tubewells are not by definition arsenic safe, the data show that tubewells older than 25 years have a significantly higher arsenic concentration than younger wells. Related to this is the finding that older wells have a higher chance of exceeding the permissible arsenic level (75% for wells older than 25 years, against 65% for all wells). Given the slow groundwater flow and small amounts of water extracted by handpumps, this change over time could be explained by a slowly expanding "zone of influence" around new wells.

Arsenic in relation to well depth

The vast majority of wells (75%) is completed in the range of 50 - 150 ft (15 - 45 m). The deepest wells are found in Serajdikhan, and the largest range of well depths in Rajoir. In more than half the upazilas (Damurhuda, Bhanga, Shib Char, Nabinagar, Homna, Shahrasti, Haim Char and Babuganj) the interquartile range of well depths is around 10 meters (i.e. 50% of all wells do not differ more than 10 meters in depth from each other).

Looking at trends in well depths, it is clear that over time there is very little variation in the depths to which wells are completed. The only observable changes are a slight drop in the percentage of very shallow wells (less than 15 feet deep), and a slight rise in the proportion of deep wells (deeper than 500 feet). The drop in very shallow wells reflects a move away from dug wells (which tend to be of lesser microbiological quality). The fact that between 50 - 250 ft well depth, the percentages of wells completed to a particular depth are constant over time means that the higher arsenic concentrations in older wells cannot be explained by assuming that older wells are shallower; they are not.

The largest number of wells exceeding 50 µg/L of arsenic is also found in the 50 - 150 ft depth range, and looking at the proportion of wells beyond the arsenic standard in this interval confirms that it is generally a poor choice for locating arsenic safe water. The adjacent intervals (15 - 50 ft and 150 - 250 ft) are better, but still not good, choices.

Generally speaking, wells deeper than 500 ft (152 m) offer a good chance of finding arsenic safe water. Exceptions are Bancharampur, Homna and Muradnagar, where 46% to 80% of reportedly deep wells exceed the arsenic standard. Because well depths were not measured at the time of testing, these anomalous results should be investigated further before they are accepted.

At an arsenic contamination rate of 11%, dug wells offer a lower risk alternative to shallow tubewells, although they are not completely risk free. They have clearly lost in popularity though, seeing that their average age is almost 42 years. Research by the Arsenic Policy Support Unit has shown that there is a high chance of risk substitution with dug wells; 94% of dug wells recently tested showed thermotolerant coliforms (APSU 2004).

In summary, arsenic and depth variations show a mixed picture. The northeast upazilas in the Ganges and Meghna floodplain (Bancharampur, Homna, Muradnagar, Nabinagar and Serajdikhan) are relatively distant from the present coastline, and in general the ground water is fresh, even at great depths. In the five upazilas in this area, the chances of finding arsenic safe water in wells more than 50 feet deep are pretty small, except for Nabinagar and Serajdikhan in the 500 - 1000 feet depth range.

In contrast to the northeast floodplain area, most of the other areas show a pattern of high arsenic except in the 250 - 1000 feet ranges, and in some cases the 150 - 250 feet range as well (Shib Char and Barura).

Damurhuda in the West is unique in that it shows uniformly low proportions of arsenic affected wells through all depth ranges. Either arsenic never dissolved in the water in the first place, or it has become (re-)fixed in the sediment over time.

Practically, this variation means that there is no "one size fits all" solution to the arsenic problem. Every (new) well still needs to be tested, and approaches to alternative water supplies and (for example) decisions about the continued use of shallow wells will need to be made based on a review of local data, and a judgment by responsible authorities or individuals.

Patterns of well contamination: using maps

Considering well depth across one upazila or even one union provides some information about intervals which offer a chance at providing arsenic safe water. However, the most directly useful approach is the creation of local maps, indicating the position of all wells and their arsenic concentrations. In some of the unions where this approach was used, distinct areas showed up which were either predominantly arsenic safe, or predominantly arsenic unsafe. Preparing maps is easily accomplished using GPS receivers, but could also be done locally using pen and paper. The approach holds promise from a mitigation planning perspective. The value of maps in awareness raising activities is also likely to be significant. A mapping exercise was carried out in three of the 15 upazilas, after the completion of well screening. In addition to providing information on contamination patterns, the mapping proved to be useful from a quality control perspective.

Table 2: Access to arsenic safe water by users of red wells

	Red well users with access to a green well within a distance of …			
Union	**… 25 m**	**… 50 m**	**… 75 m**	**… 100 m**
Rasunia	34%	65%	86%	94%
Bhanga	7%	20%	32%	43%
Jahapur	5%	11%	17%	23%

The implication of this table is that sharing of wells as a short-term mitigation measure (as promoted through public communication campaigns) is not necessarily possible in heavily affected areas. In Rasunia union 94% of red wells may be within 100 meters of a green well, but in Jahapur union this is only 23%. More direct ways of emergency mitigation may need to be found to reduce arsenic exposure in heavily affected communities in the short term.

The performance of field test kits

Availability of laboratory and test kit data allowed test kit performance to be evaluated. A total of 6,341 laboratory test results from 14 upazilas were examined. Grouping the results showed 6.9% false positives (a sample tested in excess of 50 ppb by field test kit, but tested below 50 ppb in the laboratory), and 6.7% false negatives (negative FTK result with a positive laboratory result). The aggregate results hide large variations among upazilas, and results from Muradnagar upazila are considered problematic because of the big difference between the percentage "red" wells found during blanket screening, and the percentage "red" wells found during the later confirmation testing.

However, all in all, test kit sensitivity[1] stands at 88%, and specificity[2] at 84%. Overall, 86% of all test kit results identify the correct category for the well (either "green" below 50 ppb, or "red" above that). With these numbers, the continued use of test kits should not be at issue. The Merck "sensitiv" arsenic test kit is no longer widely used in Bangladesh, and it would be helpful to obtain comparative results for kits currently in use. Continued development could mean that better results can be obtained using newer kits.

Patient Data

Identification of patients with symptoms of arsenicosis

Identification of patients follows the WHO protocol approved by the Government of Bangladesh (GOB). In first instance this relies on the observation of dermatological changes (keratosis and melanosis) considered to be diagnostic of arsenicosis. Suspected cases can become "confirmed" cases based on the result of laboratory tests for arsenic in hair, nails and urine.

Two different approaches to patient identification were used: house to house surveys, where each house is visited by a doctor and all occupants are examined, and health-camps, where people can go voluntarily (and free of cost) to be examined for symptoms.

[1] Sensitivity: when the well is truly unsafe, how likely is the kit to say red?
[2] Specificity: when the well is truly safe, how likely is the kit to say green?

Either way, suspected cases are provided with anti-oxidant vitamins, and skin cream, and are referred to the Upazila Health Complex (UHC) for follow-up care.

In the health camps, the first identification was done by village health workers, with the final confirmation provided by doctors. A 75% false positive identification rate by health workers seems to indicate they are a poor choice for the task.

Prevalence of arsenicosis in the 15 upazilas

A total of 2,682 patients were identified in the 15 upazilas. In every upazila for which a breakdown by sex is available, the number of male patients exceeds the number of female patients. Overall, there are 3 male patients for every two female ones. This is also true for the upazilas without individual sex disaggregation; the DGHS reported 51.1% male, and 48.9% female patients. This apparent discrepancy is likely a reflection of the fact that access to health care is more restricted for women than for men, so fewer women end up being diagnosed. A real difference in prevalence rates could be caused by behavioural influences which are known to increase susceptibility to arsenicosis, such as smoking.

For each 1,000 people exposed to arsenic in drinking water above 0.05 mg/L, there are 0.78 arsenicosis patients in the 15 upazilas. Prevalence ranges from 2.6 per thousand in Damurhuda, to 0.2 per thousand in Barura and Manirampur. The highest prevalence figures occur in the upazilas with the lowest percentage of wells contaminated above the standard (Damurhuda with 20% affected wells and prevalence of 2.6/1000, and Shib Char with 45% affected wells and prevalence of 2.0/1000). Not considering these two upazilas, there is a significant positive correlation between arsenic exposure level (measured as mean arsenic concentration in wells) and arsenicosis prevalence.

Patient characteristics

A more detailed analysis was only possible for data from seven upazilas, since additional data from the other eight was either not available or had no metadata description (i.e. coded data are available but not the explanation of the codes).

Mean age for patients is 36 years, and 68% have either no education, or primary education only. Among the patients, 78% of wells exceed the arsenic standard (vs. 66% for the 15 upazilas as a whole). There is no correlation between the duration of water use and the duration of arsenicosis symptoms. There is no discernable pattern in the severity of symptoms vs. their duration; if anything, severity seems to diminish over time. However, only 2% of patients (32 in total) have had symptoms for more than ten years and this is a small number to base any conclusions on. Changes in water use practices over time, as well as mortality should be investigated as possible explanations for the small number of long-term patients and their diminishing symptoms.

The majority of patients (71%) have used well water for longer than they have owned a well themselves. This points to a need to consider a complete history of water use when interviewing patients; actual exposure to arsenic may predate current water use.

An investigation of arsenic levels in nails and urine shows 55% of patients have elevated urinary arsenic levels (>40 µg/L), and 95% of all patients have elevated nail arsenic levels (>1 mg/kg), ranging from 0.5 mg/kg (normal) to 13 mg/kg.

A large proportion of patients (35%) is underweight. There is no data on a control group, and it is not clear whether this finding is in any way unusual. A recent prevalence comparison study concluded that poor nutritional status may increase an individual's susceptibility to chronic arsenic toxicity, or alternatively, that arsenicosis may contribute to poor nutritional status. It was not able to resolve causality (Milton, Hasan et al. 2004).

KAP Survey Data

Survey set-up and data analysis

Prior to well and patient screening, a baseline arsenic Knowledge, Attitudes and Practices (KAP) survey was carried out in the 15 upazilas. After the completion of all field work, a follow-up survey was carried out. The format of the baseline and follow-up was identical, but different people were interviewed both times. A total of 4,453 observations (2,909 baseline and 1,544 follow-up) were analyzed. Specifically, the analysis considered seven arsenic-related knowledge questions, four attitude questions, two practice and action questions, and four willingness to pay questions.

Correct answers to the knowledge, attitude and practice questions were tabulated, disaggregated by high income, high education, and low income, low education respondents. In addition, regression analysis tried to control for observed differences in income and education between baseline and follow-up respondents (as a group, the follow-up respondents differed from the baseline respondents, in that they have higher education, and slightly higher income and wealth).

Knowledge, attitudes and practices

Results suggest that the follow-up group is more knowledgeable about problems related to arsenic contamination than is the baseline group. The education campaign carried out in the 15 upazilas is a possible reason for this change. Also, we see that the increase is more pronounced among the low income, low education group. This group was much less aware than the richer, more educated group in the baseline, thus there was simply more room for an increase in this group. However, the larger increase may also suggest that the education campaign is indeed playing a role, helping the poorer and less educated to catch up.

Dissemination seems to have influenced attitudes in all four questions about attitudes. Changes in practice are hard to evaluate, given a very low response rate to the practice and action questions during the baseline survey.

The response rates for knowledge, attitudes and practice questions rose significantly between baseline and follow-up surveys. The increase in the response rates can itself be considered an effect of the dissemination program. Those who did not respond during the baseline survey probably did not know the correct answers and hence opted not to respond.

Knowledge levels vary across the districts, and it would be interesting to explore why this is so. A possible explanation could be that dissemination programs, as well as baseline surveys, started at different times in different districts - because of the time-lag, the level of knowledge could vary across the districts. There might have been enough diffusion of knowledge through the electronic and print media in the districts where the surveys started late or where the survey was conducted over a longer period of time. In such cases, respondents are likely to be more familiar with the interview questions and are hence likely to know the correct answers by the time they were interviewed.

Regression analysis

In the regression analysis, the variable indicating the baseline or follow-up survey is significant in all questions that were considered, indicating significant changes in "before" and "after" which could be explained by the communication campaign. Education, income and marital status are significant in a number of the knowledge related questions, while in the attitude questions education alone is the most relevant predictor. Income and to a ing, well maintenance and new water supply installation. Gender is a significant explanatory variable for willingness to pay, as well as the "amount to pay" for maintenance of a new well. Women are less likely to respond positively to "willingness to pay" questions. This is not surprising, seeing that women would generally not be in control of household finances, and thus may be reluctant to commit to more expenditure.

4 Summary remarks

Implications for Policy Development and Mitigation

The 15 upazila data have confirmed the enormous variation that exists in arsenic levels from place to place. Overall well contamination rate may be close to 66%, but that average hides variations from a low of 20.2% to a high of 98.4%. In each of the upazilas there are communities where 100% of the tubewells exceed the arsenic limit, as well as communities where none of the tubewells do. The obvious initial conclusion is that there is no "one size fits all" solution to the problem. Based on the data presented here, mitigation approaches and national policy development should at a minimum pay attention to the following:

- Invest time and effort in collecting and analyzing locally available data. Use local data in deciding whether shallow tubewells or deep wells should be offered as mitigation options. Blanket rules applied nationally would needlessly constrain feasible options;

- Where emergency mitigation measures are to be used, use not only the percentage of wells exceeding the standard as selection criterion. It appears that absolute level of exposure plays a role in the prevalence of arsenicosis, and it should be part of the decision making;

- Ensure the inclusion of schools in mitigation plans. Children form a vulnerable group, and reducing exposure for them means taking into account all places where they potentially use water;

- Improved guidelines for patient data collection and -management (including a link to well data and the collection of case control data) would increase the usefulness of future health data.

Follow-up to this report

1. This report presents a first comprehensive look at the data from the 15 upazilas, and more work could be done on it. This is especially true for data at the local level. More of the data can be considered at union level, especially with a view to formulating locally appropriate advice for mitigation options.

2. The well data show rather high contamination rates for deep well in three upazilas. The total number of deep wells in those upazilas with arsenic above 50 ppb is small, only 65. It would be advisable to visit those wells, to measure their depth, and to re-test the arsenic level. Results would usefully to inform the debate on the continued use of deep wells.

3. On the health side, it would be useful to pursue the existence of a data set on a control group of non-patients. If such data exist and can be obtained, a comparative analysis of the two datasets should be completed, rather than a description of patient data only, as done in chapter three.

4. Lastly, it would be useful to look across Bangladesh's borders for a moment. Arsenic contamination in groundwater affects at least nine countries in South- and Southeast Asia. Bangladesh is the country with most experience in addressing this problem, certainly from a perspective of mass screening of wells and identifying patients. Based on this experience, and given the probable need to implement similar surveys in other countries, it would be helpful if a field guide for setting up screening programmes could be developed.

Introduction

It is a well known fact by now that -starting from the mid 1970s- Bangladesh has been extraordinarily successful in increasing access to improved water sources for its predominantly rural population. Traditionally, rural communities relied on (almost always polluted) surface water from village ponds and rivers. By the early 1990s however, more than 90% of rural Bangladeshis used ground water for drinking. The driver of this change were private providers who could install a tubewell in a short time at a cost affordable to many households.

Equally well known is the fact that by the mid 1990s this miracle developed a bit of an after-taste with the discovery of naturally occurring inorganic arsenic in Bangladesh's shallow aquifers. Estimates indicate that 29 million people in the country are exposed to arsenic levels above the national standard of 50 µg/L (or parts per billion, ppb) (Ahmed 2003 p. 57). This number rises to more than 40 million when the WHO guideline value for arsenic of 10 µg/L[1] is used.

Arsenic exposure

Arsenic is a ubiquitous element. It is found in soil and rock, water and the atmosphere. Arsenic can exist in more than one valence state, and occurs in both organic and inorganic forms. It can occur in drinking water in levels up to several mg/L. Drinking arsenic contaminated ground water primarily exposes consumers to the two inorganic arsenic species: the reduced form AsIII (arsenite) and the oxidized form AsV (arsenate). The trivalent species is uncharged under natural conditions, and as such is more mobile than the pentavalent form. Besides through drinking water, some further exposure may occur through the consumption of vegetables, rice and meat but in general arsenic intake via these routes is not high. In some foods (e.g. fish and shellfish) the arsenic present is in organic forms which are non-toxic. It should be noted though that the importance of food as a source of dietary arsenic in Bangladesh is not well characterised at present. The inorganic arsenic so widely present in Bangladesh's ground water was mobilized through natural processes.

[1] This report will use the different units (ppb, µg/L or mg/L) depending on source data context.

Starting from 1997, more and more data on arsenic contamination of ground water in Bangladesh became available. Two national surveys (UNICEF/DPHE 51,000 tests, BGS 3,534 tests) established the scale of the problem, and were soon followed by more comprehensive arsenic mitigation projects (UNICEF/DPHE five upazila project 1998, BAMWSP Phase I six upazilas 1998).

By the year 2000, mitigation efforts were either underway or being planned in a large number of heavily affected sub-districts or *upazilas*[1]. Mitigation projects usually have at least the following components:

1. A communication campaign to raise awareness;
2. Screening of all wells for the presence of arsenic;
3. Identification of arsenicosis patients;
4. Assistance for affected communities with obtaining arsenic-safe water for domestic use.

Large amounts of well- and patient data became available through this blanket coverage approach. These data are normally used for programmatic decision making (e.g. where to focus water supply efforts), but little systematic description and analysis to inform this decision making were undertaken.

In 2001, UNICEF Bangladesh started the implementation of an arsenic mitigation project covering 15 upazilas. The lead GOB partner for the implementation of this project was the Department of Public Health Engineering (DPHE) under the Ministry of Local Government, Rural development and Cooperatives (LGRD&C). Field work was performed by eight local NGOs.

In the course of this project, additional data were collected beyond the usual well contamination and patient information. An arsenic "Knowledge, Attitudes and Practices" (KAP) survey was carried out twice; once as baseline and once as post-intervention follow-up. In addition, longitude and latitude of all wells in three of the fifteen upazilas were determined using handheld GPS receivers. Additional information on the location of patients was collected in one upazila.

[1] The upazila or sub-district is an administrative unit. Bangladesh is divided into four divisions, 64 districts (or zila), 507 upazilas (also called thanas) and roughly 4,500 unions. The upazila is the lowest administrative level where government departments are individually represented, and the planning unit for arsenic mitigation. Unions are the lowest level for any government representation.

In a project implemented through the Arsenic Policy Support Unit (APSU), the available data sets for the 15 upazilas were analyzed. This report contains the results of the data analysis.

Reasons for writing this report

The idea behind preparing this report was three-fold:

- To document findings-show the distribution of contaminated wells, the distribution of arsenic concentrations, affected population, levels of arsenic awareness, etc;

- To explore and identify any relationships among and between datasets-considering aspects of well age, well depth, location and such;

- To identify key issues of importance for policy development and implementation of arsenic measurement and mitigation programmes in Bangladesh and other countries.

Chapters two through five cover the first two objectives, while chapters six and seven addresses the last one, as explained in the next section.

Report Organization

The first chapter contains a description and introduction to the 15 upazila area, from the perspective of location, size, population, climate and geology. Some basic comparative information from the BGS/DPHE survey (BGS and DPHE 2001) is also presented here.

Chapter two presents the well data, constituting the bulk of this report. Information on the use of test kits can also be found here. This chapter is followed by an overview of the available patient data in chapter three. Chapter four revisits well and patient data for three upazilas (Bhanga, Muradnagar and Serajdikhan) in more depth, taking the analysis from upazila level down to union level.

Chapter five contains an analysis of the KAP survey data, presented at district level. The majority of this chapter was contributed by a team of researchers from the School of International and Public Affairs at Columbia University.

A discussion of some of the findings is contained in chapter six, while chapter seven presents a brief summary of findings and recommendations.

A Note on Data Sources and Software

All well screening data, patient data, GIS survey data and patient data were obtained from UNICEF in September of 2003[1]. The original data were collected between July 2001 (KAP baseline) and May 2002 (KAP follow up and last well testing). A more detailed description of the datasets collected through the UNICEF program is given in the next chapter.

The theme data used for preparation of most of the maps presented in chapters one (landuse, elevation, water bodies) and four (union detail) was developed by the National Water Resources Development Project under the Ministry of Water Resources. As best as can be determined at this point, the theme data on administrative and political boundaries used in the maps was prepared by the Local Government Engineering Department (LGED). The maps showing geo-morphology and surface geology units was produced using data from version 1.0 of the USGS Open File Report 97-470H (2001) obtained on CD from the US Geological Survey. The geological map is identical to the Geological Map of Bangladesh 2001, as presented in the aforementioned report.

Well data, GIS and KAP data were obtained in Access 2000 format, patient data in Excel spreadsheets. Most analysis was performed using SPSS 11. The report graphics were prepared using Excel 2003, SPSS 11 and Grapher 5. Maps were produced using ArcGIS 8. The original data and a number of derived data sets and maps are included on a CD accompanying this report. Please see the readme file on the CD for details of the data included.

How Should the report be used, and Who is it for

It is good to realize that the well data do not represent a sample of all available wells. All wells that existed at the time were tested. Thus there is no "confidence interval" other than that caused by measurement inaccuracy. This has consequences for the treatment of the data when reaching conclusions about the situation in the tested upazilas. When the results from the 15 upazilas are generalized to come to conclusions about the

[1] Prior to this date, all data had already been provided to the National Arsenic Mitigation Information Centre (NAMIC), effectively placing it in the public domain.

overall national situation we are on shakier ground. In this case the data set represents a sample of the national well population but with a distinct geographical clustering, not an even (or even random) distribution. Drawing valid general conclusions may well be possible, although the precise statistical parameters to apply in this case may be difficult to determine.

In any case, an effort was made to present the data from the perspective of arsenic measurement and mitigation, and the focus tends towards the practical, not the scientific. This results partly from limitations in quality of available data, and partly from the need of the moment. Decisions need to be taken on how to proceed with water supply projects, what options to consider, where to focus. Information to support this decision making is not always available, or worse, contradictory. By reviewing one of the largest bodies of data available in Bangladesh to date, we hope that this report can contribute to sound, evidence based decision making in arsenic mitigation in the country and the region. The time for mass well and patient screening in Bangladesh may be over, but other countries[1] in the region are only now getting started on larger scale screening programmes. This first description and analysis of experience with mass screening in Bangladesh could help improve the quality and cost effectiveness of such efforts.

Consequently, this report is primarily aimed at those organizations and individuals who are engaged in the planning, design and implementation of arsenic measurement and mitigation efforts. A secondary audience would be made up of those researching arsenic in the environment to develop a better understanding of its occurrence and health effects.

The use of boxes

Throughout this report, boxes like this one have been incorporated into the text. They are most often used to provide background information about data, approaches used in analysis and such. Reading the boxes is optional, but can aid understanding of general concepts or descriptions used in the text.

[1] Besides Bangladesh, arsenic has also been found in the ground water of Cambodia, China, India, Laos, Myanmar, Nepal, Pakistan and Vietnam.

1 Area and Data Set Description

1.1 Introduction

This chapter provides an outline of the main features of the 15 upazilas which make up the project area. Some basic data are provided on location, population, climate, land use, elevation and geology. A classification of the upazilas into five groups is presented, based on predominant surface geology. This grouping is used throughout the report for purposes of data organization and comparison.

In addition, the data sets used in the preparation of this report are described in some detail, and where this is possible, some indication of overall data quality is given.

1.2 Administration and Population

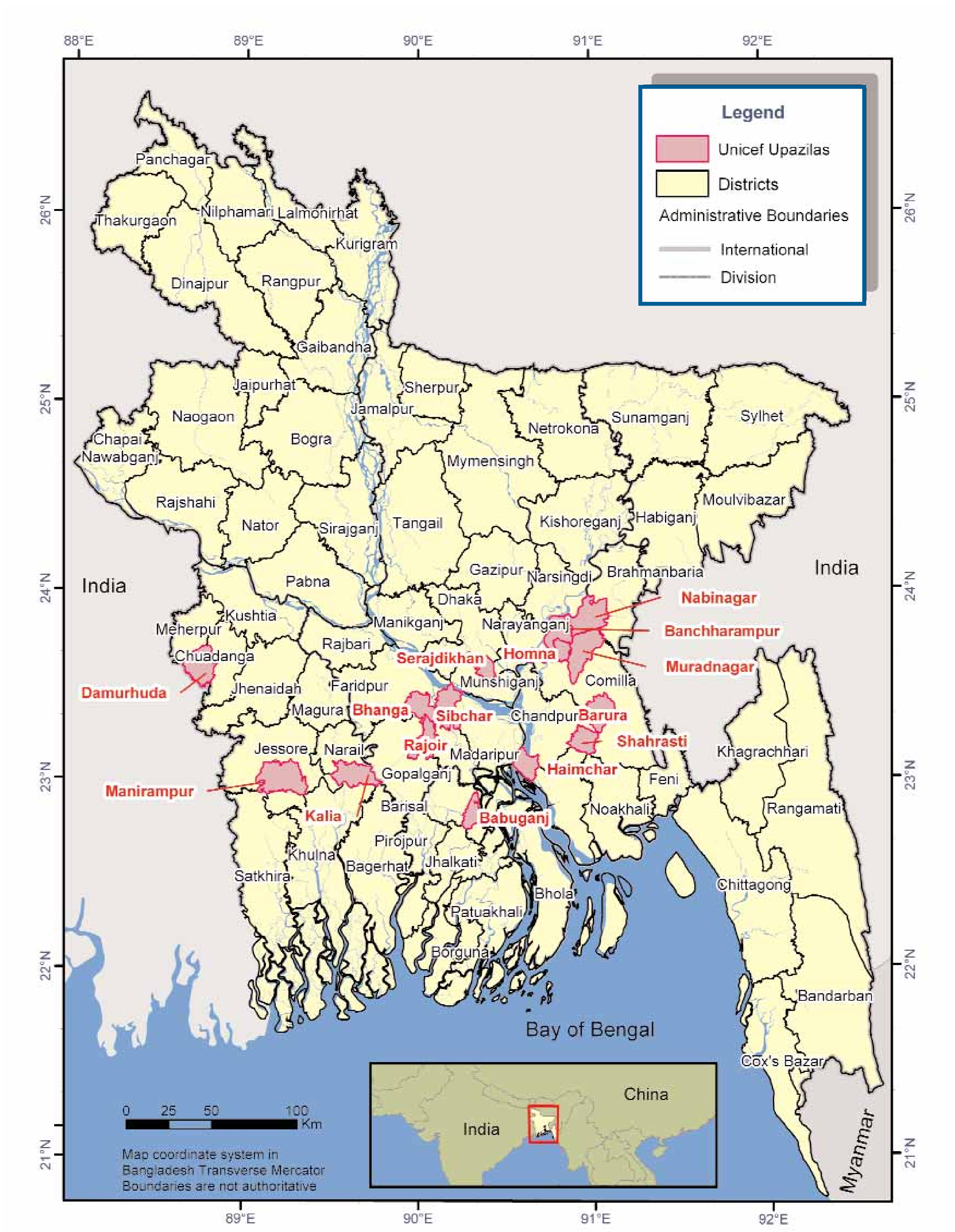
All 15 upazilas are located in the southern half of Bangladesh. Their precise locations and names are shown on the map in figure 1.1 on page 26. They cover 10 administrative districts, and some summary statistics related to the area are provided in table 1.1. More than 4.5 million people live in the project area, representing 3.6% of Bangladesh's population. The 15 upazilas represent 2.6% of Bangladesh's surface area.

Table 1.1: Administrative and population data in the 15 upazilas.

Administrative Division					Population			
District	Upazila	Unions[1]	Villages[1]	Area (Km^2)	House holds[2] (x1000)	Male[3] (x1000)	Female[3] (x 1000)	Total (x 1000)
Barisal	Babuganj	6	78	165	25	81	78	159
Brahmanbaria	Bancharampur	16	141	217	43	159	156	315
Brahmanbaria	Nabinagar	21	217	354	64	230	227	457
Chandpur	Haim Char	6	48	174	21	70	68	138
Chandpur	Shahrasti	9	176	154	31	105	113	218
Chuadanga	Damurhuda	8	147	308	37	131	123	254
Comilla	Barura	15	315	242	53	177	189	366
Comilla	Homna	14	227	180	37	122	128	250
Comilla	Muradnagar	23	367	339	72	371	253	624
Faridpur	Bhanga	12	287	216	41	126	125	251
Jessore	Manirampur	17	248	445	60	198	192	390
Madaripur	Rajoir	10	196	229	38	120	120	240
Madaripur	Shib Char	19	266	322	58	184	175	359
Munshiganj	Serajdikhan	14	188	180	38	136	132	268
Narail	Kalia	13	200	317	36	113	110	223
10 Districts	**15 Upazilas**	**203**	**3,101**	**3,842**	**654**	**2,323**	**2,189**	**4,512**
Bangladesh	507	4,484		147,570	25,362	62,700	60,400	123,100

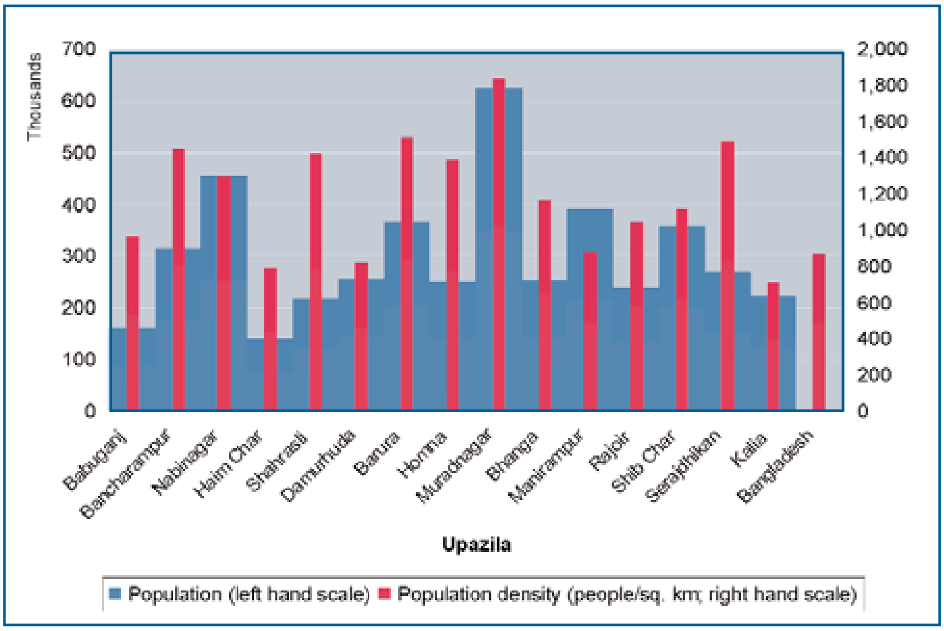
[1] From UNICEF well database
[2] Census 1991. Bangladesh Bureau of Statistics, December 2002
[3] Estimated 1999, from census data 1991. Bangladesh Bureau of Statistics, December 2002.

Figure 1.1: Location of the 15 upazilas.



The available upazila population figures are old. The last national census was carried out in 2001, and population figures for the country as a whole as well as per division are available. However, population figures by upazila had not yet been released at the time of writing. Thus, the figures presented in table 1.1 are based on projections made by the Bangladesh Bureau of Statistics in 1999, based on data from the 1991 census (BBS 2002). While unlikely to be very accurate, they will give a good general indication of population density in the project area.

Figure 1.2: Population in the 15 upazilas



Since data on numbers of households and population are from different years, it is not possible to make meaningful comparisons between the project area and national figures. But as can be seen from table 1.1 and the graph in figure 1.2, the project area is not very uniform in its characteristics. Average village population varies from 875 (Bhanga) to 2,875 (Haim Char). Population density varies from 703 per square kilometre in Kalia (just below the national figure of 834 per sq km) to 1,841 per sq km in Muradnagar.

1.3 Land use and climate

Bangladesh is extremely vulnerable to flooding, while at the same time depending on annual flooding of wetlands and floodplains for partial recharge of ground water levels.

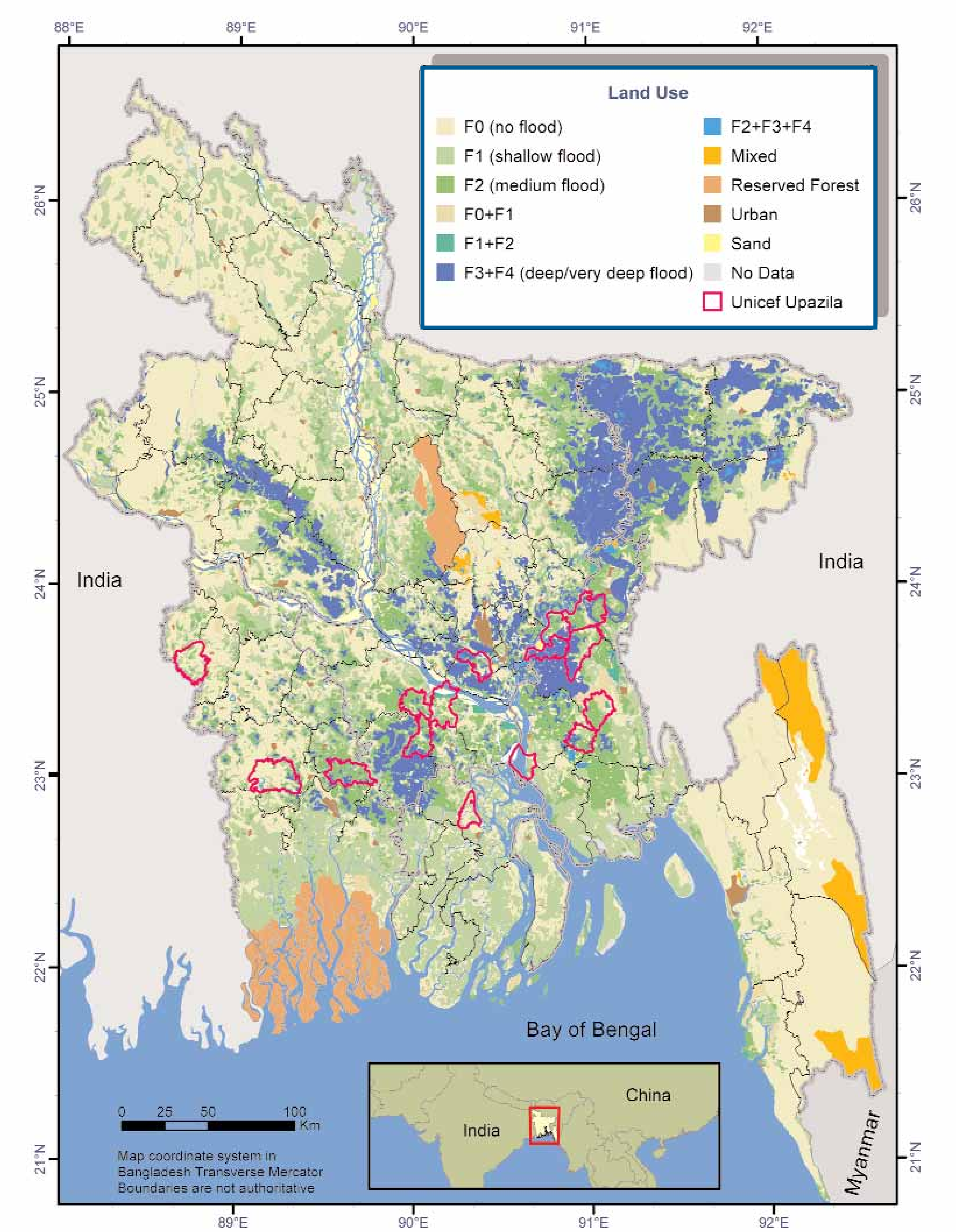
The land classification as developed by the Water Resources Planning Organization (WARPO) is presented in figure 1.3 on the next page. The classification is detailed in table 1.2, and the map shows varied flood susceptibility for all upazilas except Manirampur and Damurhuda, which are predominantly at low risk for flooding. In the project area as a whole, medium low land (medium flood susceptibility) is the dominant land type with 29% of total surface area. Twenty percent of the project area is susceptible to deep or very deep floods, while a combined 41% does not flood at all, or floods only to shallow depth., closely followed by high land with 23%. Low and very low land (F3 + F4) make up 19% of the total.

Table 1.2: WARPO land use classification

Classification	Land type	Flood type	Flood depth (m)
F0	high	None	0 - 0.3
F1	Medium high	Shallow	0.3 - 0.9
F2	Medium low	Medium	0.9 - 1.8
F3	Low	Deep	1.8 - 3.6
F4	Very low	Very deep	> 3.6

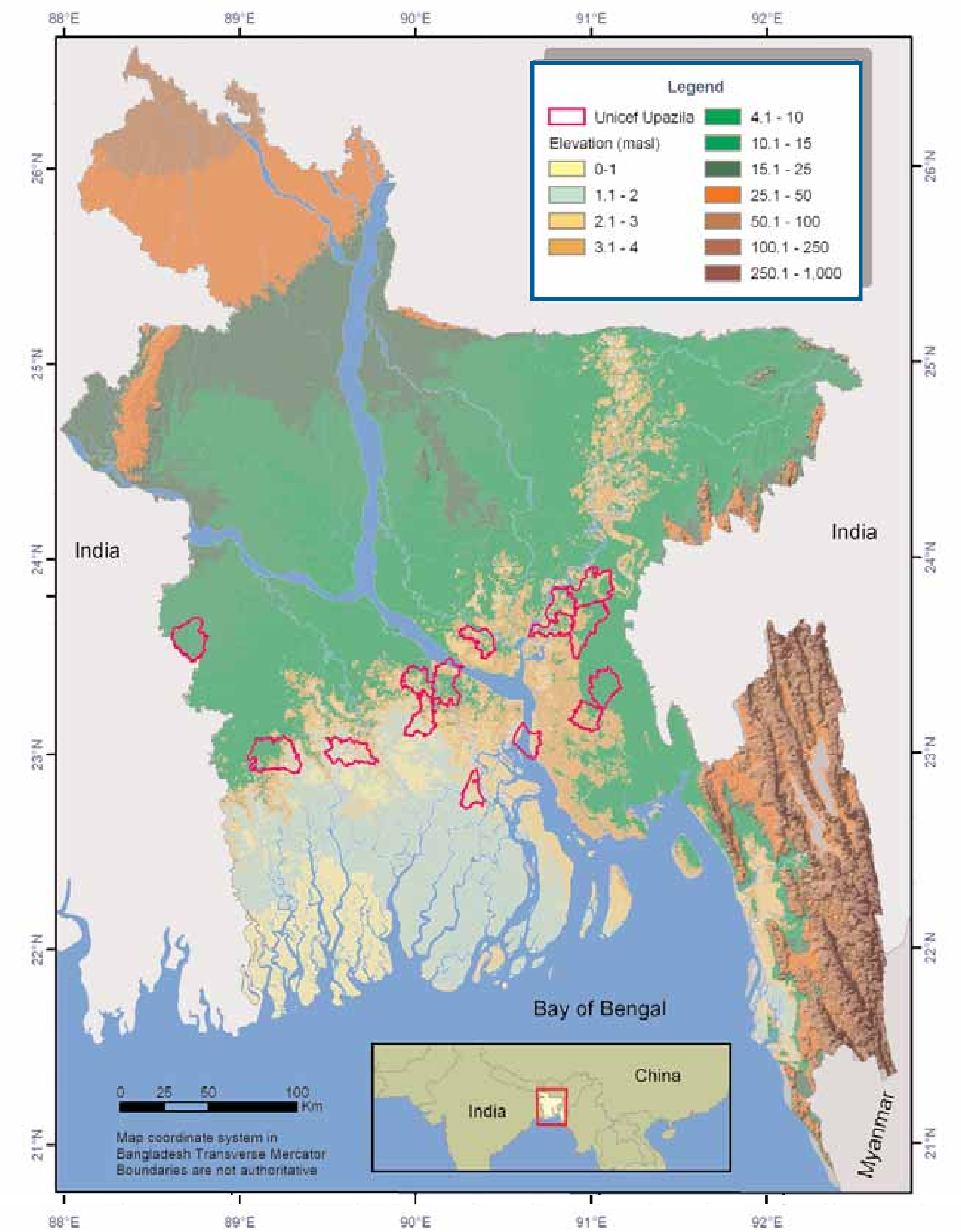
The elevation map of figure 1.4 on page ... shows clearly how flat Bangladesh really is. There is a gradual rise in elevation moving from south to north, but that mainly shows up because of the small subdivisions used in the map preparation (divisions of 1 meter from sea level to 4 meters). In the project area, elevation is generally less than 5 meters above mean sea level except in Damurhuda and Manirampur on the western side, and Barura and Muradnagar in the east. Elevation in these four upazilas reaches up to 10 masl.

Figure 1. 3: Land use map of Bangladesh



Source: WARPO

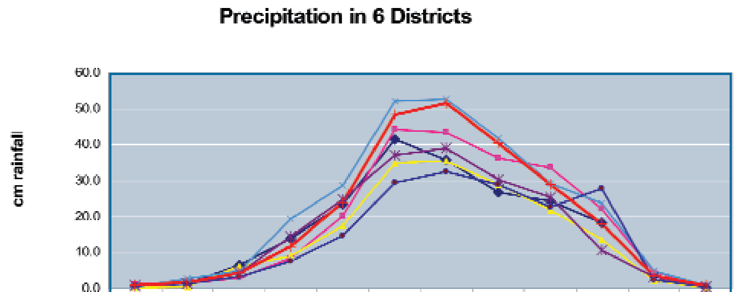
Figure 1. 4: Elevation in meters above average sea level



Source: WARPO

Average annual rainfall for the country is 2,338 mm per year. Monthly rainfall data for six of the ten districts in which the 15 upazilas are located are shown in figure 1.5. The May-October monsoon season is clearly seen in the figure. Comilla district is the wettest of the six, with an annual average rainfall of 2,613 mm (112% of the national average), while Chandpur and Jessore are "driest" (relatively speaking) with around 1,710 mm in a year, or 73% of the national average.

Figure 1.5: Average annual rainfall in selected districts



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Brahmanbaria	0.8	1.5	6.6	14.0	23.3	41.4	35.7	26.7	24.2	18.3	3.5	0.2
Barisal	1.2	1.5	3.1	8.5	20.3	44.1	43.3	36.3	33.5	22.2	4.5	0.7
Chandpur	0.3	0.6	6.4	9.1	17.4	34.9	35.6	28.9	21.7	13.5	2.2	0.3
Comilla	0.7	2.7	5.0	19.3	28.6	52.2	52.7	41.6	29.1	23.8	4.9	0.7
Faridpur	0.8	1.4	4.4	14.4	24.8	37.2	39.1	30.2	25.3	10.7	3.2	0.5
Jessore	0.9	1.4	3.3	7.8	14.7	29.4	32.6	28.9	22.6	27.8	2.5	0.6
NATIONAL AVG.	0.97	1.64	4.45	11.81	23.89	48.18	51.58	40.47	28.85	17.90	3.42	0.73

Source: Rashid, H. 1991 "Geography of Bangladesh. 2nd ed." University Press, Dhaka

Regional Geography 1.4

Bangladesh is called "the land of rivers" with good reason. The country is largely formed by the delta of the Padma (Ganges), Jamuna (Brahmaputra) and Meghna rivers. The delta extends into the state of West Bengal in India, together forming the Bengal Basin. The Ganges enters Rajshahi district on the western border with India, and flows south-east as the Padma. When it enters Manikganj district it is joined by the Jamuna River, and continues south-east. In the southern part of Munshiganj it is joined by the Meghna River, turns south, and flows towards the Bay of Bengal (fig. 1.6). In Bangladesh, the Bengal Basin contains sediments dating back to the Cretaceous period (144-65 million years ago), but even the more recent Pleistocene and Holocene sediments are kilometers thick (DPHE/BGS/MML 1999). These recent fluvial and deltaic sediments form highly productive aquifers; fresh groundwater can be found in the top hundred meters almost all over the country (the exception is the coastal zone, where salinity is a problem). Although wells of up to 350 m. depth exist, domestic wells seldom exceed 80 meters (indeed, in the project area, 87% of wells are less than 45 m. deep). The deeper wells are generally found in the northeast (where shallow aquifers do not exist, or exhibit poor yields) and the southern coastal region (to avoid the salinity problems mentioned earlier).

Geological Time

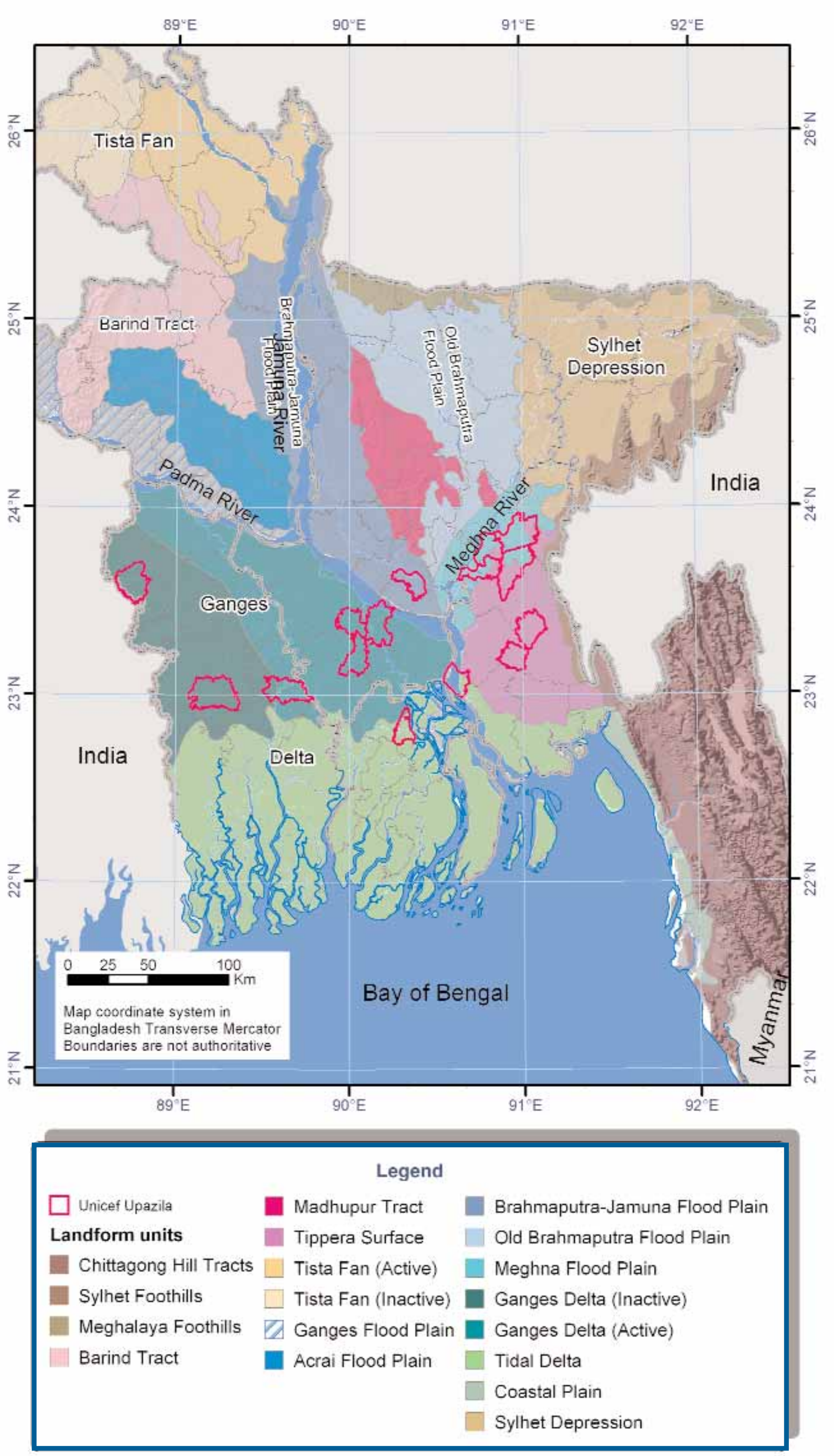
Few discussions about Bangladesh's aquifers and geology take place without mentioning geological time scales. Geological time is nothing more than the break up of the earth's history into a hierarchical set of divisions. The main divisions are (in order of scale): Eons, Era's, Periods and Epochs. We currently live in the Holocene Epoch of the Quaternary Period. The picture shows the Periods and Epochs from the Cretaceous to the present.

Geological periods and epochs

Years ago	Period		Epoch	Events
10,000	Quaternary		Holocene	Modern humans
2 million			Pleistocene	Ice ages
5 million	Tertiary	Neogene	Pliocene	Mountain uplift, cool climate
24 million			Miocene	Widespread grasslands, grazing mammals, apes, whales
34 million		Paleogene	Oligocene	Browsing mammals
55 million			Eocene	Warm climate, modern mammals
65 million			Paleocene	Cool climate, age of mammals begins, primates
144 million	Cretaceous			Last dinosaurs, flowering plants

In terms of physical geography, Bangladesh is broadly divided into three units. Tertiary Hills, Pleistocene Terraces, and Recent Plains (Ahmed 2003). The Recent Plains can be subdivided further, and main units as well as subdivisions are shown in the map of figure 1.6. The 15 upazilas are primarily situated in flood plain and delta deposits. Various surveys have shown that these are among the most heavily arsenic contaminated units.

Figure 1. 6: Major landforms of Bangladesh



Source: USGS Open file report 97-470H

1.4.1 Geology

The 15 Upazilas are grouped based on their dominant surface geology and geomorphology as summarized in Table 1.3. Five major geologic-geomorphic units characterize these upazilas. Six of them are located in the deltaic silt (dsl) and deltaic sand (dsd) unit of the Ganges delta plains. Five of the upazilas are in the alluvial silt (asl) and alluvial silt and clay (asc) units of the Meghna floodplains. Two upazilas are placed within a Chandina alluvium (ac) unit of the Meghna deltaic plain. One is located within tidal deltaic deposits (dt) of the Ganges delta, and the last one consists of estuarine deposits (de), located in the Mid-Meghna river area of the country. The locations of various upazila is shown on the geological map of Bangladesh (Figure 1.7 on the next page).

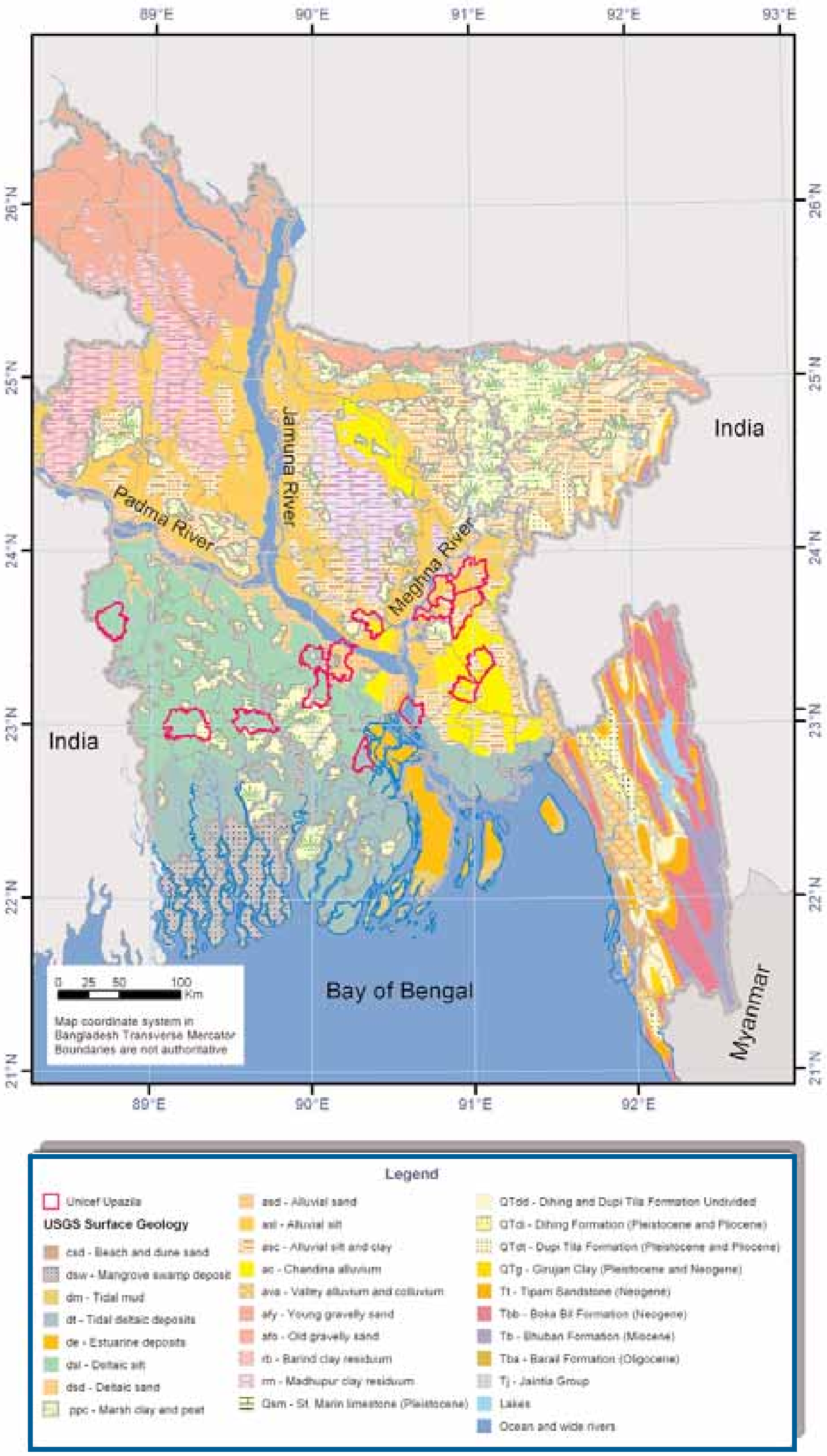
Table 1.3: Classifications of the 15 upazilas according to surface geology

Group	Major Surface Geological Unit	Physical Geography	District	Upazila (% of surface area belonging to major geological units)
1	Deltaic silt (dsl) and deltaic sand (dsd)	Inactive Ganges Delta	Chuadanga	Damurhuda, 100%
			Narail	Kalia, 83%
			Jessore	Manirampur, 75%
		Active Ganges Delta	Faridpur	Bhanga, 79%
			Madaripur	Rajoir, 66%
				Shib Char, 82%
2	Alluvial silt (asl) and alluvial silt and clay (asc)	Ganges Floodplain	Munshiganj	Serajdikhan, 63%
		Meghna Floodplain	Brahmanbaria	Bancharampur, 83%
				Nabinagar, 90%
			Comilla	Homna, 80%
				Muradnagar, 84%
3	Chandina alluvium (ac)	Meghna Delta (Tippera Surface)	Comilla	Barura, 69%
			Chandpur	Shahrasti, 82%
4	Estuarine deposits (de)	Active Meghna Floodplain	Chandpur	Haim Char, 57%*
5	Tidal deltaic deposits (dt)	Tidal Delta	Barisal	Babuganj, 88%

(*) 48% of Haim Char's surface area is shown as covered by water, 30% as dt, 9% as de. Assuming that water cover is not permanent, and can be classified as estuarine deposit, the total adds up to 57%.

The geomorphology and the near-surface geology of these areas are quite diverse. The surface areas of Damurhuda, Manirampur, Kalia, Bhanga, Rajoir, and Shib Char, which are located within the Ganges delta generally comprise of sand and silt at the top. Located within the Meghna floodplains and Padma floodplains, the surface deposits of Serajdikhan, Nabinagar, Bancharampur, Muradnagar, and Homna are predominantly silty with occasional clay deposits. Barura and Shahrasti are located in the lower Meghna floodplains, and marsh clay and peat units. Estuarine deposits are present in the Haim Char area. The Babuganj area, characterized by tidal deltaic deposits, is located within the fluvio-tidal transitional Ganges deltaic region.

Figure 1. 7: Geological map of Bangladesh



Source: USGS Open file report 97-470H

1.4.2 Aquifer Systems

Like many other parts of the country, the Holocene fluvio-deltaic and coastal sediments form prolific aquifers in the studied upazilas. The aquifer systems can be broadly divided as follows:

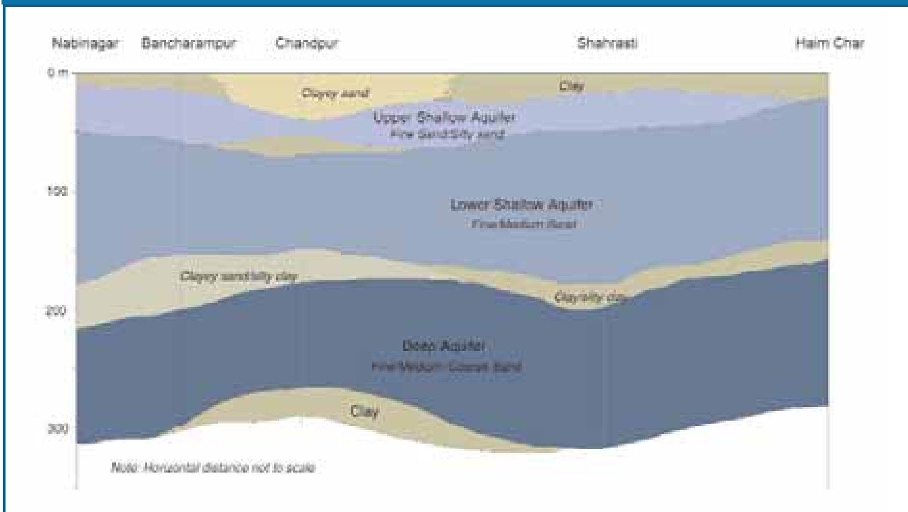
Table 1.4: Classifications of aquifiers in Bangladesh

Aquifer Unit	Geological Unit	Arsenic Status
Upper Shallow Aquifer	Holocene Alluvium: fine to very fine sand with occasional silts and clay	Most of the shallow hand tube wells yield water with arsenic above the acceptable limit
Lower Shallow Aquifer	Holocene Alluvium: Fine to medium sands with occasional coarse sands and gravels	In most cases arsenic concentrations are below the limit. As there is no hydraulic barrier beneath the upper shallow aquifer, vertical leakage of arsenic is likely if water is extracted at a high rate
Deep Aquifer	Late Pleistocene: Fine to medium sands. Separated from the upper aquifer system by a clay aquitard in most places	Arsenic safe

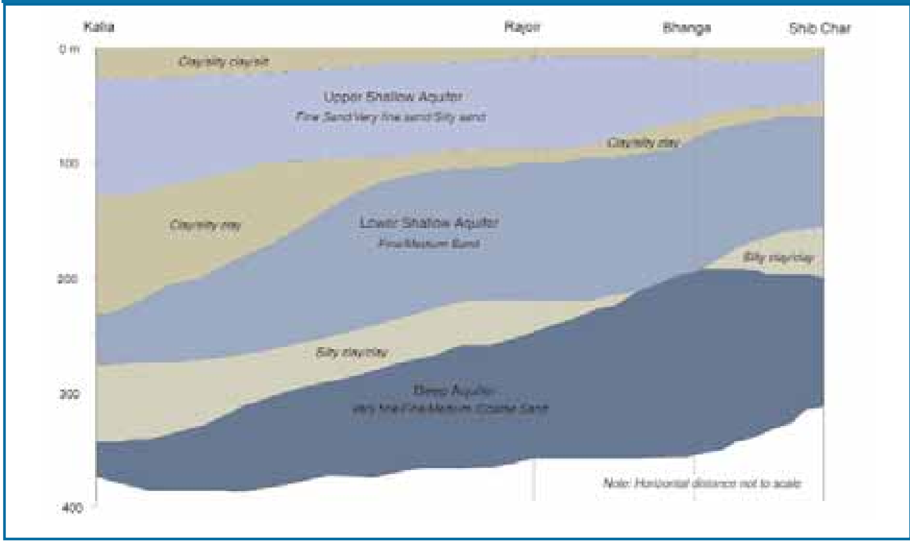
The conceptual cross sections (Figure 1.8) prepared with BWDB and DPHE bore logs show that the multilayer aquifer system as outlined above exists throughout the studied upazilas.

Figure 1.8: Conceptual hydrogeological sections: 'A' shows the common aquifer system of the Meghna Delta Region covering the upazilas Nabinagar, Bancharampur, Chandpur, Shahrasti, and Haim Char; and 'B' for the Ganges Delta Region covering the upazilas Shib Char, Bhanga, Rajoir, Kalia.

A



B



The thickness of individual units varies from place to place. The upper shallow aquifer occurs mostly within 50 - 60 m whereas the lower shallow aquifer extends up to more than 200 m. The deep aquifer system is separated by a clay aquitard whose thickness varies from place to place. The aquitard is found to not exist in Bhanga upazila. The deep aquifer occurs at a depth of more than 200 m in all of the studied upazilas. The depth generally increases towards the south.

Groundwater levels 1.4.3

Groundwater occurs at very shallow depth in the fluvio-deltaic sediments of the Ganges-Brahmaputra-Meghna river systems. Water levels fluctuate with annual recharge / discharge conditions, showing an annual maximum in October and minimum levels in April / May. Water level hydrographs for all the broad geological regions under investigation have been prepared with Bangladesh Water Development Board long term monitoring data (Figures 1.9 a, b, c).

Water level fluctuations are largest in the Ganges Deltaic region, and smallest in the coastal plains. No declining trend is visible in any of the studied upazilas.

Figure 1.9a: Water level hydrographs of the Ganges Delta region

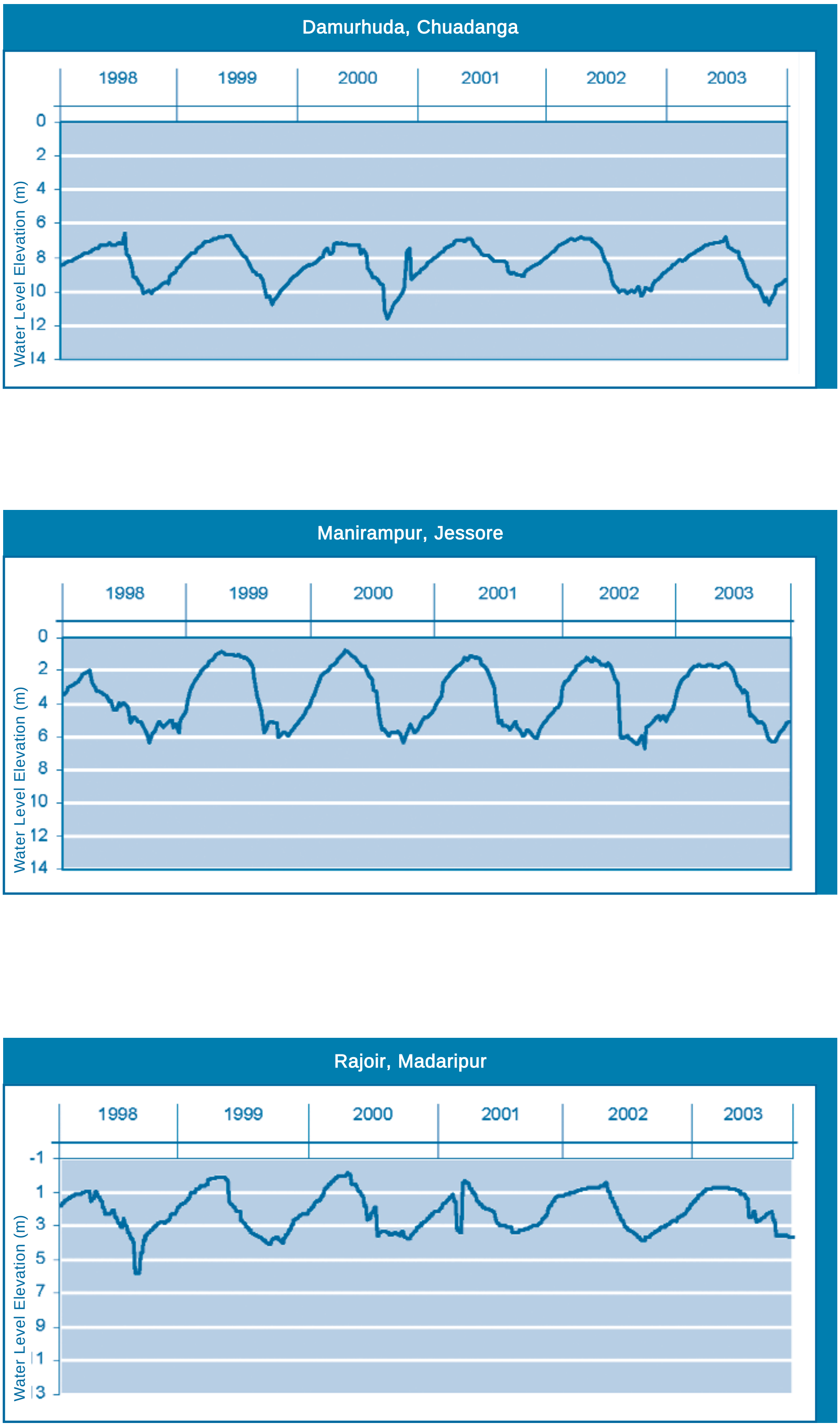
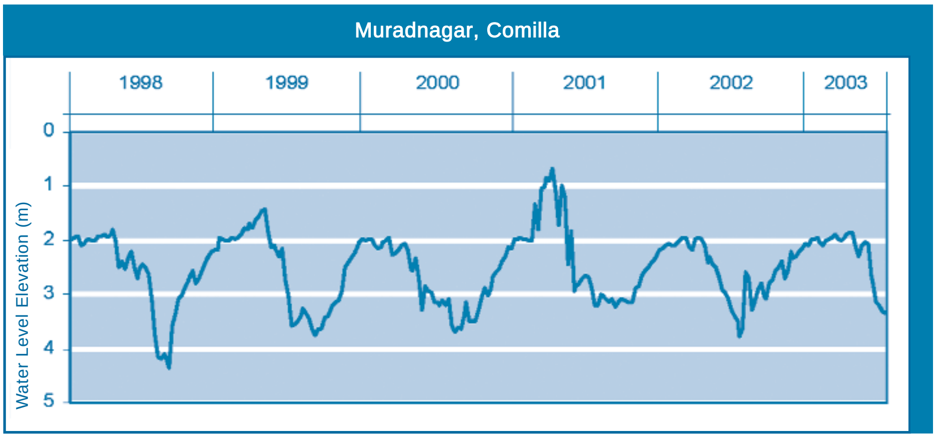


Figure 1.9b: Water level hydrographs of the Meghna Delta region



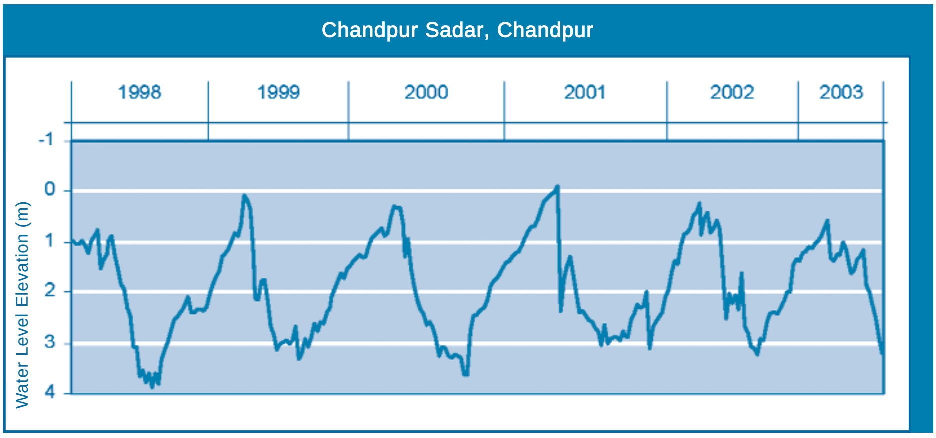
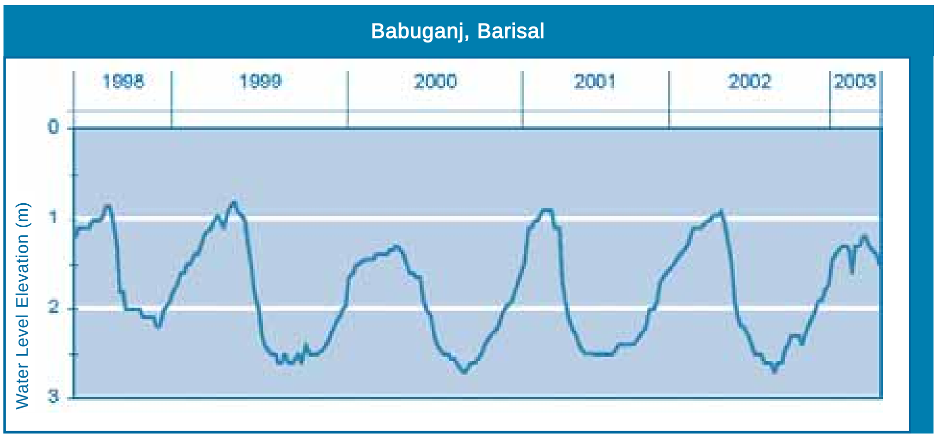


Figure 1.9c: Water level hydrographs of the Coastal Plain region



1.5 Data set description

A total of six datasets were used in the preparation of this report. Three of those relate to wells, two relate to arsenicosis patients, and one deals with the KAP survey data.

1.5.1 Well data

A total of 331,462 operational wells were tested for arsenic, using field test kits. These test data form the primary well data set. The second data set consists of laboratory confirmation tests carried out on a number of the wells. Lastly, between January and March of 2002, the coordinates of some 70,000 wells in three of the 15 upazilas were determined through a GPS survey. The spatial data set resulting from this survey is well data set number three.

Well dataset 1: Original testing data

Well testing was done by teams of two testers. For each ward[1], one testing team was trained. This equals nine teams per union, since each union has nine wards by definition. Testers were recruited from the area to be tested, so they were familiar with the village(s) they covered. Testers were trained in test kit use and testing procedure by the NGO contracted for the particular upazila; NGO staff in turn had been trained by UNICEF and DPHE staff.

Table 1.5: Well testing by NGOs

NGO Implementing Partner	Upazilas Covered
BRAC	Barura Bhanga Haim Char Manirampur
CDIP	Nabinagar
DCH	Serajdikhan
EPRC	Kalia
Grameen Shikkha	Muradnagar Shahrasti
GUP	Rajoir Shib Char
ISDCM	Bancharampur Damurhuda Homna
NGO Forum	Babuganj

[1] A ward is an imprecisely defined administrative unit. The most useful approach is to think of a ward being approximately the size of one village. Large villages can cover more than one ward however, while two small villages could both be in the same ward.

The testing team recorded location and ownership details for each well, as well as a range of data on the well itself (such as year of construction, depth, etc). Details of the testing team and test date were also recorded. The location, household and well information collected is listed below:

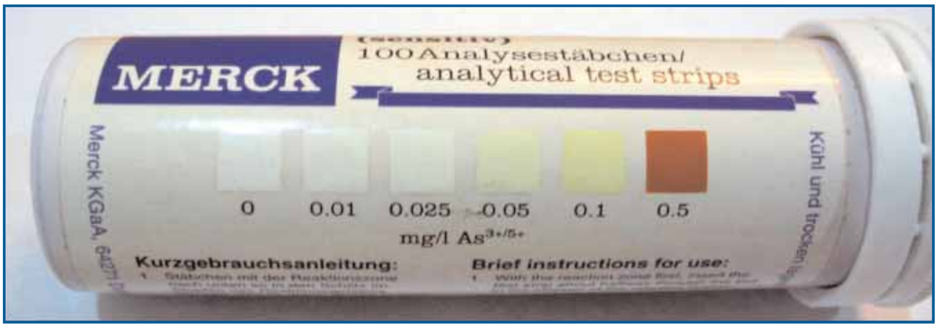
- Location (District, Upazila, Union, Village, Ward);
- Use (individual/institutional);
- Owner details (name and address) as well as family size, disaggregated by sex;
- Ownership (government, NGO, Community, Private, Other);
- Type of well (Shallow, Deep, Tara, Dug, Irrigation, Other);
- Year of construction;
- Depth in feet;
- Number of users;
- Brand of test kit used;
- Arsenic level according to test kit;
- Pump spout colour.

These data were recorded on the standard record sheet developed by BAMWSP and other agencies (An English translation of this form is included in Annex 2). The written information was transferred to a stand-alone MS-ACCESS database developed by UNICEF. The data for individual upazilas were aggregated into one master database by UNICEF. The aggregated data were subsequently forwarded to the National Arsenic Mitigation Information Centre (NAMIC) for further national aggregation and use.

Test kits used

All tests were completed using the second generation Merck field test kit (also known as the Merck "sensitiv" kit). Like all field test kits, determination of the arsenic concentration in a water sample is done by the visual comparison of colour on a test strip with a coloured scale provided with the kit. The tip of the test strip is impregnated with Mercury Bromide. This reacts with the arsenic hydride formed when sulphuric acid and zinc powder are added to the sample. The used Merck kits show five gradations on the colour scale, corresponding to 0- 0.01-0.025-0.05-0.1 and 0.5 mg/L of total inorganic arsenic. Figure 10 shows the gradations. Testers were trained to record 'in-between' values when the colour of the strip did not match exactly with the colours printed on the scale (for example recording 0.04 mg/L if the actual colour of the strip fell somewhere between the 0.025 mg/L and the 0.05 mg/L patches on the test kit). In practice however, most testers did not interpolate values, but recorded only the values printed on the kit (see the data in chapter two).

Figure 1.10: Merck 'sensitiv' test kit colour scale



Data validation and storage

Sheer size of the data set, as well as the method of collection and subsequent processing meant ample scope for the introduction of errors existed.

The database used automatic data entry validation routines as much as possible, which prevented a number of obvious sources of error (such as the use of non-numerical data for numerical fields, the entry of excessive well-depths, invalid dates of construction, etc. It also enforced uniform spelling of district and upazila names). Both manual and automated inspection of the data subsequent to entry eliminated many of the remaining visible errors that were correctable (such as different spellings for the same village name). Some errors are visible, but cannot be corrected without field proofing (e.g. a well depth of 12,000 feet). Those remain in the database, but may be discarded for certain types of data analysis. Invisible errors (such as those resulting from coding mistakes) obviously remain. Section 2.2. in the next chapter contains an analysis of the overall quality of the data used.

The largest issue with the well database is that arsenic concentrations for all wells in Rajoir and Shib Char were coded by the testers. In other words, instead of recording the arsenic concentration as listed on the test kit, a numerical score between 1 and 5 was assigned based on the actual concentration. The test kits used have a six-part scale, and there is no one-to-one relationship between code and arsenic concentration. According to the staff of the responsible NGO, a code of 1 meant an arsenic concentration below 50 µg/L. Codes 2 - 5 meant various levels of exceedence of the 50 µg/L standard. This issue affects a total of 42,389 wells. For analysis purposes, it is still possible to determine accurately which wells are "green" and which are "red". However, it is no longer possible to accurately reflect the concentration in any analysis[1].

Well dataset 2: Laboratory data

All participating NGOs were required to submit 3% of all samples to a laboratory for testing, and to provide an analysis of the results. In principle the NGOs were free to choose any laboratory able to perform arsenic measurements, but they were encouraged to select the nearest available laboratory to the project area. In practice, a number of NGOs transported samples to Dhaka for analysis, while others used the DPHE zonal laboratories.

A total of 5,779 laboratory test results matched with field test kit results were received from 10 upazilas. A further 601 field test kit results with 3 laboratory test results per field test were received for four upazilas. In this case, the NGO performed laboratory tests three times during different parts of the year, to look for seasonal variations. While the laboratory data are interesting, and will be presented in chapter two, they cannot be used for comparison with test kit data, since the dataset does not specify when the field tests were performed.

Well dataset 3: GIS well data

To investigate the usefulness of employing handheld GPS receivers during well screening, UNICEF decided to test their use in three of the 15 upazilas. During the period January - March 2002, all wells in Bhanga, Muradnagar and Serajdikhan upazilas were visited by a survey team, and their coordinates recorded by GPS. Field data and observations were checked against the well database, and missing or mismatching data were flagged, and corrected where this was possible. A total of 69,743 wells were surveyed in this way, and some of the available data will be used for a more detailed look at some of the heavily affected unions in the surveyed upazilas (chapter 4).

[1] In order to be able to include the Rajoir and Shib Char wells in the statistical analysis, the arsenic scores were recoded to arsenic levels. Where relevant, this will be mentioned in the text.

1.5.2 Patient data

Patient surveys were undertaken by Dhaka Community Hospital (DCH) in seven upazilas, by DCH together with the Directorate General of Health Services (DGHS) in another seven upazilas, and by DGHS alone in 1 upazila (Shahrasti).

Table 1. 6: Patient screening agencies

Patient screening	Upazilas
DCH	Bhanga Haim Char Manirampur Muradnagar Nabinagar Serajdikhan Shib Char
DCH+DGHS	Babuganj Bancharampur Barura Damurhuda Homna Kalia Rajoir
DGHS	Shahrasti

While the original approach to patient screening involved house-to-house visits by doctors trained to identify arsenicosis symptoms, the 15 upazila project saw an innovation in the use of health camps. Health camps would be set up in a union centre for a given period of time, and relied on people visiting the centre, rather than the doctors visiting each individual household. This change in approach was faster and cheaper, since people without any symptoms would be less likely to ask for a check-up. At the same time, this approach may have led to patients being missed because they did not come forward. Women and girls in particular could have been less likely to visit a health camp than men and boys.

Patient data from the seven upazilas covered by DCH were entered into SPSS (a statistical software package). The data were made available to UNICEF in Excel format, although the metadata description is incomplete. The patient data from the eight other upazilas were never received in full. These limitations will be further clarified in chapter three.

GIS patient data

During the GPS well survey in Serajdikhan, the approximate position of patient households was also determined by GPS receiver. These data will be used in chapter four to investigate links between water sources and health outcomes in some more detail. However, only conclusions will be presented, not the data themselves, to guard patient confidentiality[1].

KAP Survey Data 1.5.3

The NGOs responsible for arsenic mitigation activities (table 1.5) also carried out a survey twice in each upazila. The survey was designed by UNICEF, and aimed to measure the knowledge levels, attitudes and behavioural patterns of people in arsenic affected upazilas. The baseline study was carried out between July and September of 2001, prior to any other activities. The follow-up survey, completed after all awareness raising and screening activities had been carried out, took place between March and May of 2002.

A total of 2,909 baseline responses and 1,544 responses from the follow-up survey were entered into a database developed for the purpose by UNICEF. The databases were subsequently made available to the School of International & Public Affairs at Columbia University, who undertook a detailed analysis. This analysis is presented in Chapter five, supplemented by additional observations.

[1] It is also for reasons of patient confidentiality that all identifying information (name, address, etc.) were removed from the patient data set used in the analysis.

Well Data in Broad Outline

2

2.1 Introduction

A total of 316,951 wells were tested in the 15 upazilas. In this chapter we present an overview of all available data about those wells, largely summarized at the group (see annex 1) and upazila level. The data given here are mostly straight counts from the database, with some cross tabulation. This overview, together with some reflections on overall size and quality of the data set should allow the reader to develop a good understanding for what is on hand in terms of well data.

Broadly speaking, we present the data in the following categories: (i) Well type and ownership, (ii) Arsenic levels, (iii) Test kit performance, (iv) Population coverage, (v) Well age and (vi) Well depth.

Much of the data in this chapter is presented in tabular or graphical form. A tabular summary of most of the available data is presented in annex 1. This appendix provides a dense, but detailed overview, and much of the data descriptions given in this section are taken from it. Unless otherwise stated, all data presented refers to wells that were functional at the time of the well screening.

2.2 Data quality

It is obvious that a dataset of the size in question, collected by 1,737 teams of two, employed by eight different NGOs will contain some errors. Some of these errors (such as misspellings of village names) could be -and were- corrected before analysis. Other errors can be noted and quantified, but they cannot be corrected (for example, a database entry for a well with a recorded arsenic level of 0.2 mg/L but a green pump spout. Either the arsenic level or the pump spout colour is incorrect, but it is impossible to determine which one, unless a visit is made to the well in question). Table 2.1 lists the checks that were made on the data, while tables 2.3 and 2.4 present some of the information on data that are either missing from the database, or presumed to be inaccurate.

Table 2.1: Summary of quality control checks on data

Item Checked	Wells included	Number found (percentage)
Family size not recorded	Operational	25,869 (8.2)
No. of users not recorded	Operational	17,184 (5.4)
Year of construction not recorded	Operational	36 (< 0.1)
Well ownership not recorded	Operational	3 (< 0.1)
Well type not recorded	Operational	8 (< 0.1)
Well depth not recorded	Operational	1,464 (0.5)
Well depth exceeds 1000 ft. (305 m)	Operational	232 (0.1)
Mismatch between pump spout colour and arsenic level	Operational	8,486 (2.7)
Arsenic level exceeds test kit maximum (0.5 mg/L)	All	1,399 (0.4)
Arsenic level not equal to zero for non-functional well	Not operational	1,168 (0.4)

From the summary in table 2.1 it is clear that while recording of data about use of the wells was not always very accurately done, the data concerning well construction and arsenic levels are generally of better quality. Table 2.3 shows that there are rather large differences in the attention paid to data entry or field level data recording among the NGOs.

Table 2. 2: Mismatches between recorded arsenic level and pump spout colour

	Arsenic level, mg/L (functioning wells)			
Pump spout colour	**< 0.05**	**0.05**	**> 0.05**	**Total**
Green	85,238 (97.0%)	17,830 (83.1%)	2,029 (1.0%)	**105,097 (33.2%)**
Red	1,044 (1.2%)	3,608 (16.8%)	205,397 (98.9%)	**210,049 (66.3%)**
Blank or undefined	1,632 (1.5%)	17 (0.1%)	156 (0.1%)	**1,805 (0.6%)**
Total	**87,914 (27.7%)**	**21,455 (6.8%)**	**207,582 (65.5%)**	**316,951 (100%)**

Correctly coloured (white cells) Incorrectly coloured (shaded cells)

NB: Percentages are calculated based on column totals except for the last 'TOTAL' row which is computed based on total well numbers.

Table 2.2 lists the measured arsenic levels against reported pump spout colour. Approaching this table from the assumption that the recorded arsenic level is correct, not the spout colour, we can see the following. Overall, 65.5% of the wells tests above the 50 ppb national arsenic standard. The remaining 34.5% of wells have arsenic levels below the national standard.

Of all the 105,097 wells painted green, 2,029 should not have been given that colour. In other words, 1.9% of all green wells were incorrectly coloured. Likewise, of all the wells painted red, 4,652 (or 2.2% of that group) were coloured incorrectly. This is a perfectly acceptable result for misclassifications.

Of the wells which tested below 0.05 mg/L, 97% were correctly coloured, and of the wells testing above 0.05 mg/L 98.9% were correctly coloured. However, of all the wells testing exactly at 0.05 mg/L, only slightly more than 83% were given the correct spout colour. Further investigation shows that 88.5% of those misclassifications occur in the three upazilas covered by ISDCM, which would suggest that the testing teams working in those upazilas systematically miscoloured wells which tested at exactly 0.05 mg/L. Overall this means that of all wells which tested at 0.05 mg/L of arsenic or below, 94.2% have a correctly painted green spout.

In all subsequent analysis the measured arsenic level is assumed to provide the correct information; no further use will be made of the recorded pump spout colour.

Table 2.3 shows the differences among the different upazilas, and among the type of errors most frequently made. When considering every error that can be quantified (table 2.1), overall data reliability comes out at 88.3%.

Counting only those errors relating to arsenic level and depth (since those are the most important pieces of information used in analysis), increases data reliability by nine percentage points, to 97%. In this case Serajdikhan scores highest with 99.99% of data without quantifiable errors, and Homna scores lowest with 90.6%. It should be stressed that although errors can be demonstrated, this does not necessarily mean that the data used for analysis are wrong. A mismatch between arsenic level and pump spout colour means that one of the two is wrong, but it cannot be determined which one. When the arsenic level is used in analysis, there will thus be some uncertainty about its correctness, but not certainty about its incorrectness. Likewise, non-functional wells cannot be tested, so a "non-blank" arsenic level should not be recorded for any wells that are out of order. Here too, two conclusions are possible: the well was marked as "out of order" by mistake, or an arsenic level was recorded by mistake. It cannot now be determined which of the two is incorrect.

Table 2. 3: Summary of data quality analysis

NGO	Upazila	Total wells tested	No demonstrable data problems, all data	Percentage	No demonstrable data problems, excluding family size and # of users	Percentage
BRAC	Barura	26,304	24,887	94.6	25,780	98.0
	Bhanga	20,986	19,683	93.8	20,509	97.7
	Haim Char	3,606	3,364	93.3	3,538	98.1
	Manirampur	34,701	32,186	92.5	33,415	96.1
CDIP	Nabinagar	29,788	27,970	93.9	29,673	99.6
DCH	Serajdikhan	18,623	17,349	93.2	18,622	100.0
EPRC	Kalia	11,116	10,325	92.9	11,028	99.2
Grameen	Muradnagar	31,525	29,295	92.9	31,391	99.6
Shikkha	Shahrasti	16,475	15,811	96.0	16,389	99.5
GUP	Rajoir	12,995	12,091	93.0	12,697	97.7
	Shib Char	29,394	27,877	94.8	29,044	98.8
ISDCM	Bancharampur	19,807	16,341	82.5	18,754	94.7
	Damurhuda	37,945	24,663	65.0	34,941	92.1
	Homna	18,833	13,662	72.5	17,072	90.6
NGOF	Babuganj	4,773	4,272	89.5	4,603	96.4
TOTAL	15	316,961	279,776	88.3	307,456	97.0

Information on data reliability has been presented here at some length, in order to place the following analysis in context, and in an attempt to be completely open about the provenance and quality of the data used. Given the results of the quality analysis, no further data filtering or cleaning was employed prior to analysis.

2.3 Well types, ownership and status

The database records a number of 'administrative' items relating to each well. In the first place, a well is categorized as being either "Institutional" or not. Institutional wells are usually located at schools, mosques, markets etc. Any well not marked as "Institutional" is considered to be a household or family well.

In the second place, "ownership" for each well is recorded. The standard well data form recognizes five ownership categories:

1. Government
2. NGO
3. Community
4. Private
5. Other

Whether this category describes true (and continuing) ownership of the well, or just describes who was responsible for the original construction is open to debate. The "Other" category would contain all wells for which ownership does not fit in any of the other classes (a tiny group, containing only 1,300 wells).

Lastly, a "type" was recorded for each well. Choices for well type were as follows:

1. Shallow
2. Deep
3. Tara
4. Dug
5. Irrigation
6. Other

This is a slightly confusing classification as it mixes well type with well purpose. In addition, no clear guidelines were given on when a well is considered to be "deep" or "shallow". These shortcomings were fixed in the revised version of the national well data format, but for the current analysis the following choices were made: (i) any well not marked as an irrigation well is assumed to be for domestic use, and (ii) the "deep"[1] and "shallow" descriptors are not used; instead the recorded depth of the well will be considered.

Since wells outside the "government" or "private" ownership classes make up only 1.7% of the total number of wells in the database, they have not been included in table 2.4.

[1] Various practices exist. The official definition by the DPHE is that a well is considered to be "deep" if it extends beyond 250 feet (76 m), although this definition is not widely used. The BGS considered a well to be "deep" if it was deeper than 150 m (492 ft).

Table 2. 4: Summary of well status, use and ownership

		Private		Government		Totals	Group totals
		Domestic (% of total)	Irrigation (% of total)	Domestic (% of total)	Irrigation (% of total)		
Functioning	Household	261,613 *(78.9)*	1,129 *(0.3)*	24,881 *(7.5)*	6 *(<0.1)*	287,629 *(86.8)*	311,513 *(94.0)*
	Institutional	10,143 *(3.1)*	8,255 *(2.5)*	5,481 *(1.7)*	5 *(<0.1)*	23,884 *(7.2)*	
Out of order	Household	8,602 *(2.6)*	826 *(0.2)*	2,144 *(0.6)*	14 *(<0.1)*	11,586 *(3.4)*	13,892 *(4.2)*
	Institutional	962 *(0.2)*	394 *(0.1)*	935 *(0.2)*	15 *(<0.1)*	2,306 *(0.7)*	
Totals		281,320 *(84.9)*	10,604 *(3.2)*	33,441 *(10.1)*	40 *(<0.1)*	325,405 (331,440)	
Group totals		291,924 *(88.1)*		33,481 *(10.1)*			

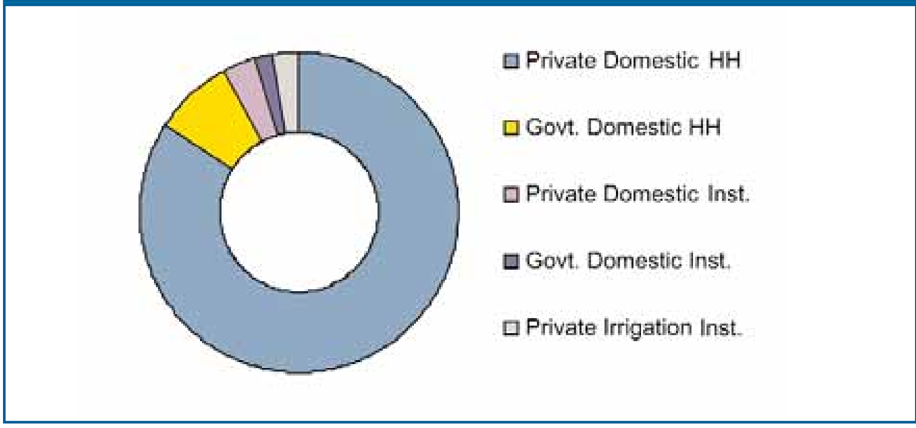
NB: Percentages do not add to 100 because "other" well ownership has been omitted from this table, and percentages were calculated relative to the total number of wells including "other" (331,440 wells total vs. 325,405 reported in the table).

The vast majority of the wells are used for domestic purposes, are privately owned and are in working order. That only a little over 4% of all wells are out of order is nothing short of surprising, but ultimately a testament to the appropriateness of the technology used at local level to install and maintain wells. Proportionally, more government than privately owned wells are out of order (figure 2.2), and the same holds true for institutional and household wells. This is not surprising, as the primary owner and user of a well will be the most motivated to protect his investment and keep the well in working order. Unclear responsibilities, lack of funding and ineffective maintenance systems are all factors that - alone or in combination- can lead to higher numbers of non-functioning wells.

The wells surveyed do not include dedicated irrigation wells installed by projects, government, etc. So the fact that only few wells are marked as used for irrigation is a reflection of the survey methodology, not a finding that few irrigation wells exist. The numbers may also reflect the fact that few irrigation wells are used for domestic purposes.

The main ownership and use categories are shown in figure 2.1. Figure 2.2 shows well operational status compared to overall ownership.

Figure 2. 1: Major well use and ownership breakdown



The only upazilas with a different pattern of well ownership are Babuganj and Kalia (Figure 2.3), where the proportion of government wells is much larger than in any of the other upazilas (close to 37% in both). This is the combined result of low private investment and higher than average government investment in wells in the two upazilas; government wells per 1,000 population are two and three times higher than in the 15 upazila area as a whole. The reason for this could be that it is more expensive to construct wells in Kalia and Babuganj (wells having to be deeper to avoid salinity problems). In Kalia over 38% of all wells are completed in the depth range of 150 - 250 ft (46 - 76 m), against 11% for all other upazilas. In Babuganj, 41% of wells do not exceed 50 feet (15 m) in depth, but 18% are deeper than 500 feet (152 m); this compares to less than1% of deep wells for all other upazilas combined. Higher costs would slow down private well construction, leading to a relative increase in the number of wells constructed by the government.

Figure 2. 2: Well status by ownership and use

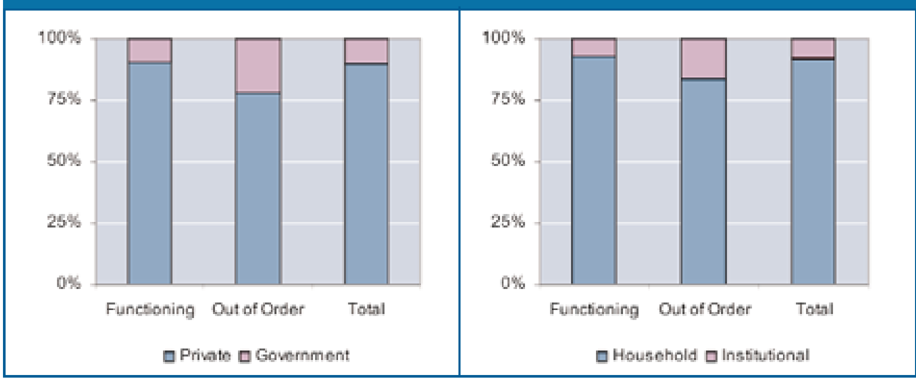
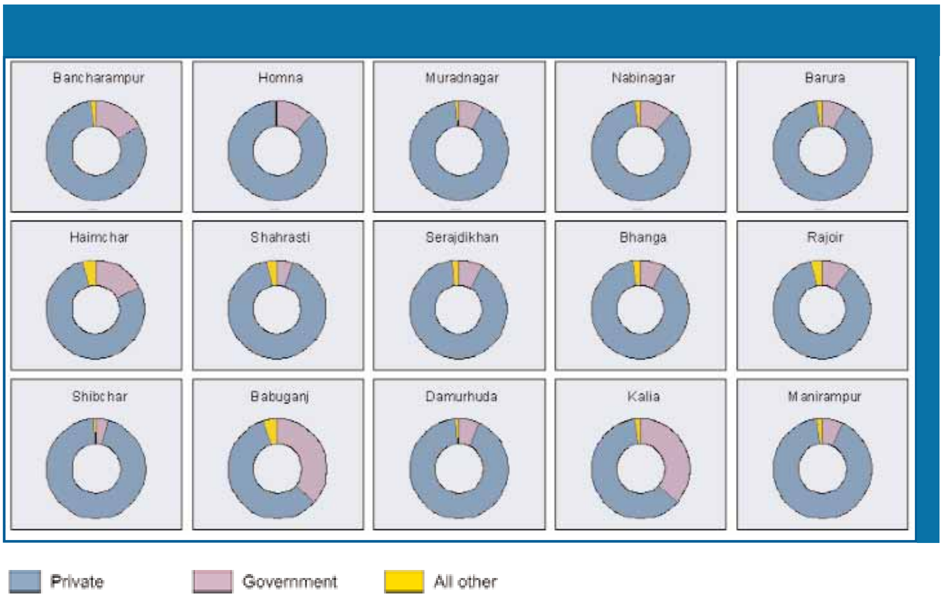


Figure 2.3 includes all wells, not only government and privately owned ones (any well falling outside the "Government" or "Private" classes is listed as "All other" in the picture). It is however very clear how small the proportions are compared to total investment by private sector and government.

Figure 2. 3: Well ownership in 15 upazilas



2.4 Well screening results

Of the 316,951 wells tested, 65.5 % (207,582 wells) exceed the 50 ppb national arsenic standard. In the remaining 109,369 wells, arsenic levels are within acceptable limits. In 29% of the arsenic-safe wells, no arsenic could be detected at all. The remainder (77,619 wells) had anywhere between 10 to 50 ppb of arsenic in their water. Figure 2.3 shows the percentage of wells exceeding the arsenic standard by upazila. The pronounced spatial variability is clearly visible on the map. Table 2.5 summarizes test results, and includes a summary of the DPHE/BGS test results for the 15 upazilas (BGS and DPHE 2001)

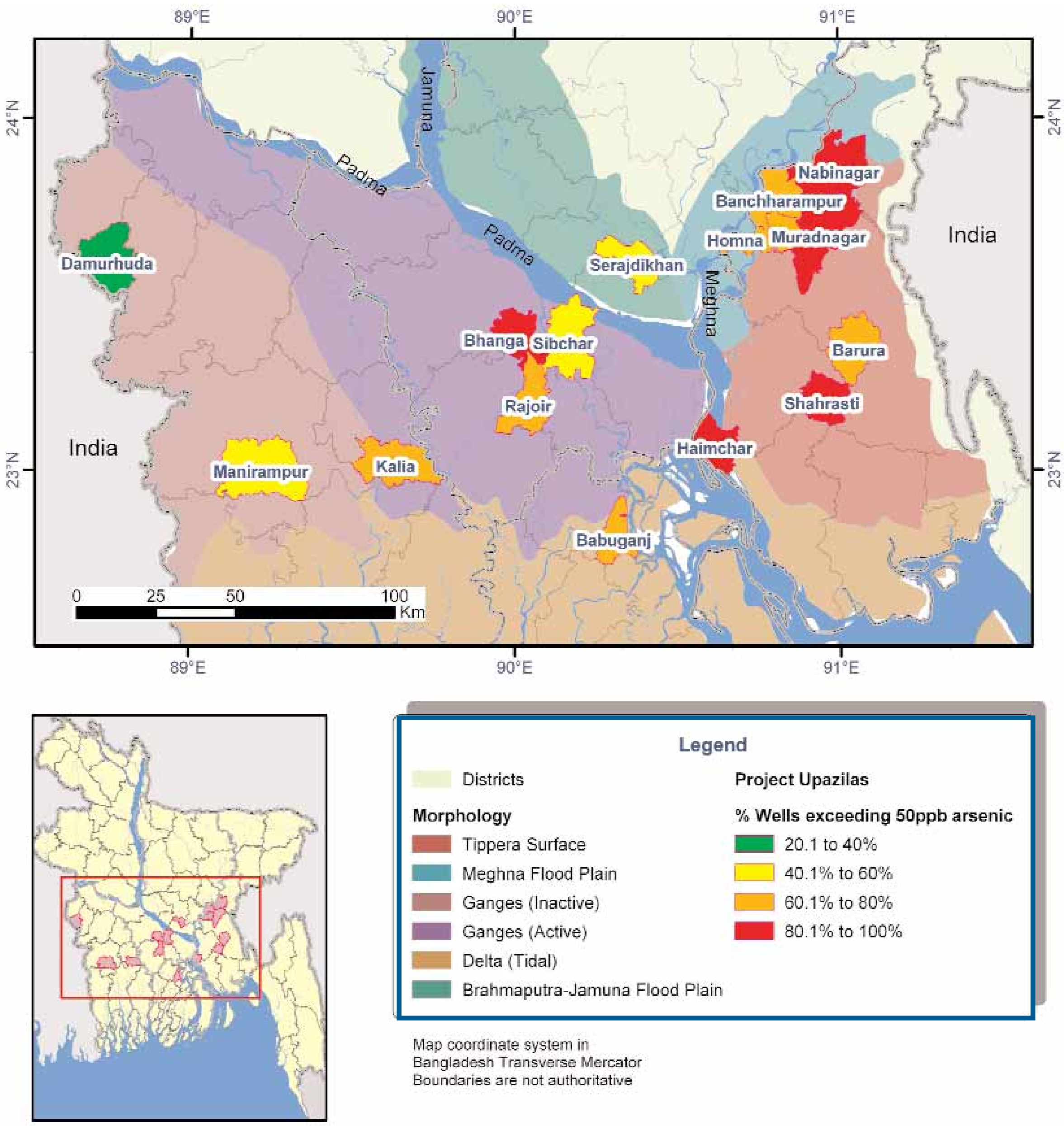
Table 2. 5: Summary of 15 upazila test results

Predominant geological units	GSB codes	Upazila	Wells tested	% of total	% of all wells with As>50 µg/L	% of wells in BGS/DPHE survey with As>50 µg/L
1: Deltaic silt and deltaic sand	dsl and dsd	Damurhuda	37,945	12.0	20.2	62.5
		Kalia	11,116	3.5	73.1	50.0
		Manirampur	34,781	11.0	52.4	66.7
		Bhanga	20,986	6.6	90.1	100.0
		Rajoir	12,995	4.1	74.7	66.7
		Shib Char	29,394	9.3	44.8	87.5
		Subtotal 1	147,217	46.4	51.5	
2: Alluvial silt, and Alluvial silt and clay	asl and asc	Bancharampur	19,807	6.2	73.7	83.3
		Nabinagar	29,788	9.4	86.7	100.0
		Homna	18,833	5.9	62.0	75.0
		Muradnagar	31,525	9.9	93.2	100.0
		Serajdikhan	18,623	5.9	46.7	87.5
		Subtotal 2	118,576	37.7	76.0	
3: Chandina alluvium	ac	Barura	26,304	8.3	71.0	70.0
		Shahrasti	16,475	5.2	98.4	87.5
		Subtotal 3	42,779	13.5	81.6	
4: Estuarine deposits	de	Haim Char	3,606	1.1	85.6	75.0
5: Tidal deltaic deposits	dt	Babuganj	4,773	1.5	76.0	50.0
Grand Totals			316,951	100	65.5	

Please note that the DPHE/BGS results are based on an average of nine tests per upazila, and in itself the differences between the DPHE/UNICEF and DPHE/BGS results is no cause for undue alarm. The lowest proportion of affected wells is found in Damurhuda upazila in the older deltaic deposits of the inactive Ganges delta (20.2%). The highest percentage of affected wells are found in the alluvium of the Chandina delta (Shahrasti, 98.4%) and Meghna floodplain (Muradnagar, 93.2%).

Although the 15 upazilas are all located in what can be named the "arsenic hot zone" there are marked differences in the range of wells affected. Within each of the upazilas - whether heavily or lightly affected - there are pronounced differences again. In Damurhuda, there are communities where 100% of all wells are affected, and even in Shahrasti there are villages without any affected wells. This variability is one of the vexing dimensions to the Bangladesh arsenic crisis, for it impedes rapid assessment, and makes it almost impossible to formulate general advice regarding mitigation.

Figure 2. 4: Percentage of wells exceeding 50ppb arsenic by upazila, with 15 upazila project area marked



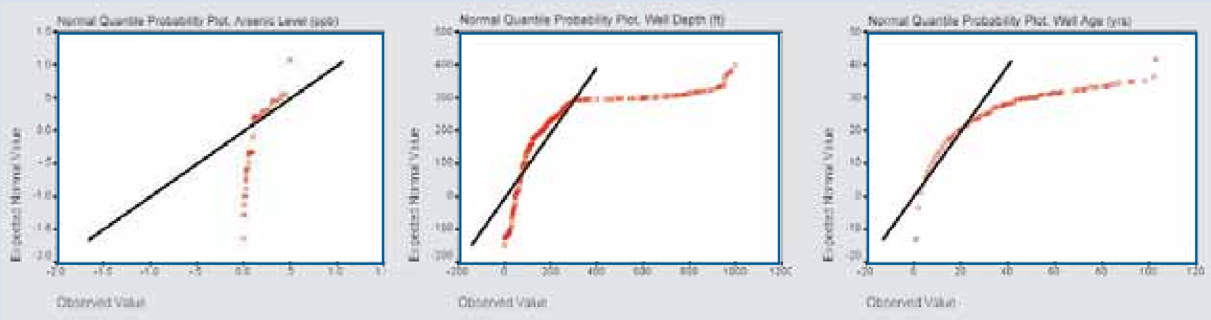
Statistical Analysis of Groundwater Quality Data

Statistical analysis of water resources data is often undertaken to look for relationships between variables (e.g. whether arsenic concentration in water increases with increasing iron concentration), or to quantify and explain differences between two or more data groups (e.g. whether wells older than 25 years have higher or lower arsenic levels than younger wells).

Which methods are appropriate for performing such analyses depends on a number of things, among which are:

1. The distribution of the data (e.g. Normal, log-Normal, etc.).
2. The type of variables being studied.

Many environmental data sets are not Normally distributed; this is to say that the values are not evenly distributed around a mean. The well data presented in this report are no exception; arsenic level, well depth and well age for example are all not-Normally distributed (no attempt was made to determine the type of distribution, but Normal quantile probability plots are shown below for illustration-the closer the data points are to the straight line, the more their distribution resembles the Normal one).



Many statistical tests assume data which are Normally distributed. Seeing that this is not the case with most of the important well data means that nonparametric tests rather than parametric tests will need to be used.

In the second place we need to look at the variables we want to study. There are usually at least two: a response (or dependent) variable, which is the one whose variation is being studied (in graphs normally plotted on the y-axis), and an explanatory (or independent) variable, which is the one which explains why and how the magnitude of the response variable changes (plotted on the x-axis). In our analysis, arsenic concentration will usually be considered the response variable. Variables can be continuous (i.e. they can assume any value between their lower and upper bounds), or they can be discrete (i.e. they only assume particular values). Discrete variables can furthermore be ordinal (there is a ranking to their values), or nominal (there is no ranking possible). Some examples are given in the table below.

Variable types		Examples
Continuous		Well depth
Discrete	Ordinal	Arsenic level*, well age
	Nominal	Well type, well ownership

**The test kits only recognize six levels of arsenic concentration. Laboratory tests would produce results on a continuous scale.*

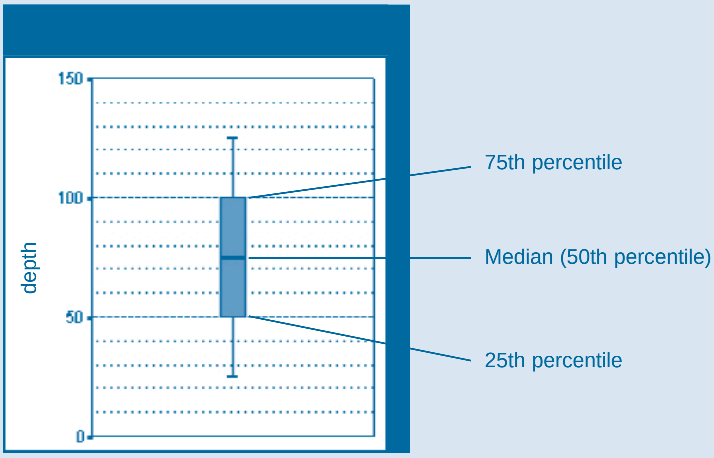
Please note that with ordinal data (such as the arsenic level) a common measure such as the mean value (the average) really has no meaning. Which tests are appropriate depends on the type of variable we want to study. Without going into any further detail, the overview below shows some (not all) of the nonparametric tests available to us.

Available data	Nonparametric test
Two independent data groups (ordinal)	Rank-sum test (Mann-Whitney)
More than two independent data groups	Kruskall-Wallis test or Kendall's taub depending on variable type
Correlation between two continuous variables	Kendall's tau

Source: D.R. Helsel and R.M. Hirsch (1992), Statistical Methods in Water Resources.

Reading Box Plots

Part of the arsenic and depth analysis is presented in the form of so-called "box plots". These are used to summarize the distribution of a dataset, and typically look like the example below:



The example was plotted with a dataset of well depths consisting of the following values: 25, 25, 50, 50, 75, 100, 100, 125, 125. The median value is thus 75, and the red box represents the interquartile range, (it shows a measure of the spread of the data). The whiskers show either the minimum and maximum values, or -most commonly- a maximum of 1.5 times the interquartile range (the height of the box). Values between 1.5 and 3 times the box height are called outliers and in this report are shown as small circles. Occasionally there are extreme values (larger than 3 times the box height) which - when they are shown - show up as small asterisks.

Boxplots thus provide visual summaries of:

1. The centre of the data (the median, or centre line of the box)
2. The variation or spread (the height of the box)
3. The "skewness" (the relative size of the box halves), and
4. Presence or absence of unusual values (outliers and extreme values).

Arsenic Levels Measured by Test Kit 2.4.1

The charts on the following pages show summary information on the distribution of arsenic levels. The largest number of wells occurs in the group exceeding 100 ppb of arsenic, which is also clear from figure 2.6 (which represents relative numbers by upazila). So not only do arsenic levels in 66% of all wells exceed 50 ppb, in 44% of all wells the level exceeds 100 ppb (twice the allowed standard level). The number of wells without any arsenic detected at all (N.D. in the graph) is relatively small at 10% overall.

Construction of Box Plots

Please note that the box plots showing arsenic concentrations, and subsequent ones showing depth and arsenic levels were constructed by counting the wells in each upazila that fall in a particular arsenic contamination (or depth) category. Those box plots are thus made up of 15 data points, with each upazila representing one data point in each individual boxplot.

Figure 2.5: Number of wells in a given arsenic level category (functioning wells)

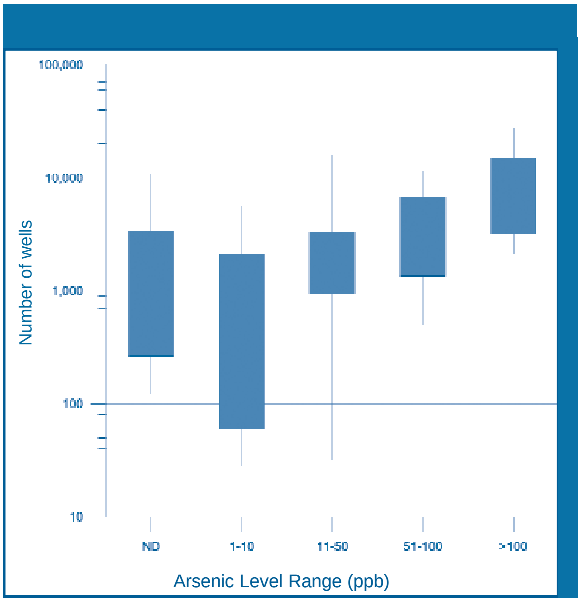
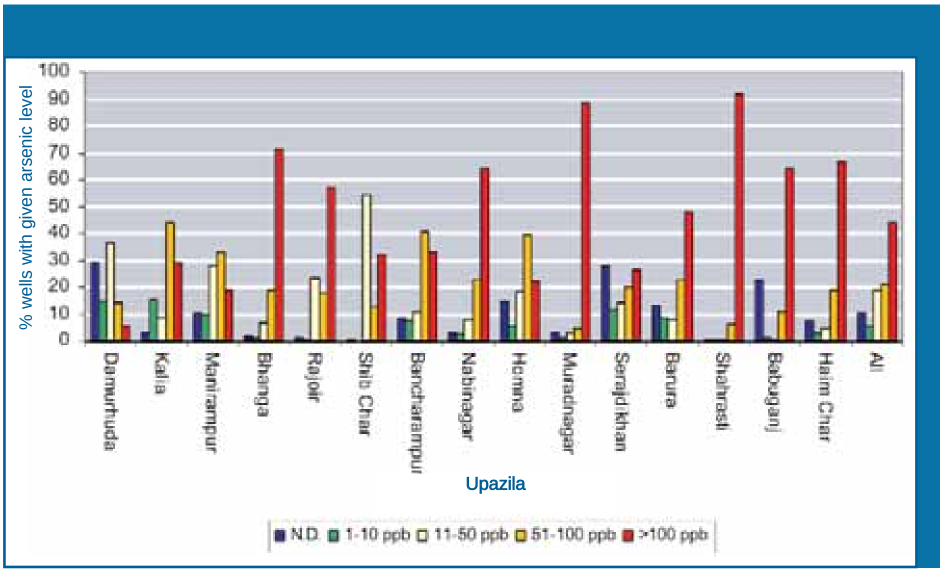
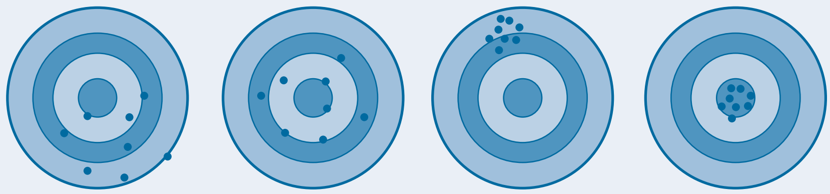


Figure 2.6: The distribution of arsenic levels in the 15 upazilas



Precision and accuracy

In all experimental measurements, there is a degree of uncertainty or error. When reporting data, the degree of uncertainty can be measured by considering the precision and accuracy of the analysis. The precision simply means the reproducibility of the analysis: if the same sample is analyzed multiple times, how much will the results vary? Accuracy, on the other hand, refers to how close the measurement is to the true value.



Analytical precision can be assessed by making repeat measurements and calculating the ratio of the standard deviation to the average. This is called the coefficient of variation, and as a rule of thumb should be less than 10% for laboratory measurements. Precision will depend primarily upon the instrument and method, but also on the operator and quality control procedures.

Precision of the measurements carried out in the 15 upazilas cannot be assessed, since only one single measurements was performed on each sample. The comparison of laboratory and field kit measurements however (section 2.4.3) can be seen as an attempt to assess accuracy.

Source: UNICEF (2004) *UNICEF Handbook on Water Quality*, in press.

Arsenic levels measured in the laboratory 2.4.2

The NGOs carrying out the testing were required to submit three percent of all samples to a laboratory for confirmation testing. In practice not all confirmation testing was carried out. Although all NGOs submitted samples, not all were able to obtain test results from the laboratory for inclusion in the UNICEF database. Nevertheless, a total of 6,295 laboratory test results from 14 upazilas were submitted (there are no laboratory results for Serajdikhan). Those data are summarized in table 2.6 on the next page.

The testing of confirmation samples in the 15 upazilas was done in part by private laboratories (Intronics, Tetrahedron and NGO Forum), and in part by the DPHE laboratories in Jhenaidah and Mymensingh. Arsenic testing in the laboratory is difficult at the best of times, and it is not always possible to accurately judge the performance of the laboratories in Bangladesh; no independent assessments or accreditation exists. Of 17 laboratories which participated in an inter-laboratory study carried out in 2001 (Aggarwal, Dargie et al.) fewer than one-third obtained analytical results within 20% of the expected values. Some of the laboratory data are questionable outright: A few laboratories imply a level of accuracy of measurement which cannot in practice be attained. Examples are measured arsenic concentrations of 1 ppb, or 239.23 ppb. In the first example the absolute level seems to be below the detection limit of most instruments (APHA/AWWA/WEF 1998), while in the second example the number of significant digits exceeds reasonable expectations. At least one laboratory reported performing more than 500 arsenic tests on a single day, which is an unbelievably high number.

Table 2.6: Summary of laboratory test results

Upazila	# of wells tested in Laboratory	% of total wells tested in Laboratory	Average arsenic concentration (µg/L)	Maximum arsenic concentration (µg/L)	% > 50 µg/L
Damurhuda	392	1.0	82	935	45.7
Kalia	365	3.3	74	1,905	45.2
Manirampur	167	0.5	75	273	63.5
Bhanga	167	0.8	162	630	68.3
Rajoir	491	3.8	159	880	73.7
Shib Char	805	2.7	111	914	47.7
Bancharampur	580	2.9	165	1,320	67.4
Nabinagar	502	1.7	224	659	87.3
Homna	616	3.3	152	821	62.2
Muradnagar	994	3.1	42	377	16.8
Barura	167	0.6	150	379	74.3
Shahrasti	600	3.6	248	1,239	80.3
Babuganj	400	8.4	267	1,460	64.5
Haim Char	95	2.6	169	1,136	67.4
Total	**6,341**	**2.0**	**143**		**57.0**

We do not know whether the NGOs made efforts to randomize the taking of confirmation samples throughout their respective upazilas. We can thus not compare the proportion of wells found to exceed the national arsenic standard using a test kit, with the proportion found to exceed the standard using the laboratory. Nevertheless, the laboratory data for Muradnagar seem problematic, seeing that slightly less than 17% of wells (N=993) were found to exceed 50 µg/L of arsenic. Test kit data on the other hand show more than 93% of wells to be contaminated above that level (the DPHE/BGS study found 100% of wells to exceed the standard). There is thus either severe bias in the data, or the data are false.

Arsenic Test Kit Performance 2.4.3

Having test kit- as well as laboratory data allows us to make some observations about the performance of the kits that were used. Specifically, we would like to know how many wells were identified correctly as having arsenic levels above or below the standard level. Wells which have a "true" arsenic level below 50 ppb but are identified by a test kit as exceeding that level are called false positives. Wells which have a "true" arsenic level above 50 ppb, but are identified as being below that standard are false negatives. While false positives lead to wells being taken out of use unnecessarily, false negatives impact community health since they lead to people continuing to use arsenic contaminated water in the mistaken belief that it is safe.

Sensitivity and Specificity

Two important concepts in judging the quality of a test kit are its sensitivity and specificity.

Sensitivity refers to the probability that the test correctly identifies contaminated samples, while specificity is the likelihood that the test correctly identifies non-contaminated samples. A highly sensitive test will have very few false negative results, while a highly specific test will not produce false positives.

		True Value	
		No	Yes
Test result	Yes	False Positive (FP)	True Positive (FP)
	No	True Negative (TN)	False Negative (FN)

Sensitivity = TP/(TP+FN)
Specificity = TN/(FP+TN)
Positive Predictive Value = TP/(TP+FP)
Negative Predictive Value = TN/(FN+TN)

Strictly speaking, sensitivity and selectivity only apply to tests where the results are of a YES/NO format. These terms are sometimes applied to quantitative or semi-quantitative results, by using a reference value to group quantitative results into YES/NO categories. In our case, we can define all test results indicating 50 µg/L arsenic or more as positive ("YES"), and all results below 50 µg/L as negative ("NO"). When we do this, the kit sensitivity and specificity will depend on the actual concentrations being tested, and will be lowest near the reference value. For example, if the actual value of a sample being tested was 50 µg/L and a test indicated 45 µg/L, the test would be counted as a false negative even though the measurement is very accurate. If the actual value was 500 µg/L, and the test kit indicated only 45 µg/L, this would be a much more serious false negative, and could indicate that the kit is not very sensitive to arsenic.

The Positive Predictive Value (PPV) assesses the reliability of a positive test result, and is dependent on the true number of positives. With a high ratio of true positives (high prevalence), the PPV will increase. When the number of True Positives is low (i.e. a low overall arsenic contamination rate), the PPV will be lower, indicating a lower reliability of each positive result. The Negative Predictive Value (NPV) assesses the reliability of a negative test result; it is higher when there is a high prevalence of True Negatives. Or in summary:

Sensitivity: when the well is truly unsafe, how likely is the kit to say Red?
Specificity: when the well is truly safe, how likely is the kit to say Green?
PPV: when the kit says Red, how likely is it to be right?
NPV: when the kit says Green, how likely is it to be right?

(Source: adapted from UNICEF (2004), *UNICEF Handbook on Water Quality*, in press).

A total of 6,341 sample pairs from 14 upazilas were examined, and grouping the test results in four categories gave the following results.

Figure 2.7: Categorization of results of kit and laboratory tests

ITest Kit	0.05	**FP**: 440 6,9 %	**TP**: 3,192 50,3 %
		TN: 2,284 36,0 %	**FN**: 425 6,9 %
		0.05	
		Laboratory ("True" value)	

Overall kit sensitivity is thus 88%, while specificity is 84%. In other words, of every 100 negative tests, we can expect 16 false positives, and with every 100 positive tests we will have 12 false negatives. With an overall "prevalence" of wells exceeding 50 ppb of just over 60%, and the very small difference between the number of false positives and the number of false negatives, the NPV and PPV are almost identical to the sensitivity and specificity (84% and 88% respectively). These results are significantly better than the results reported in 2002 (Rahman, Mukherjee et al. 2002), which were obtained much earlier using an older model Merck kit (which found up to 68% false negatives and up to 35% false positives).

Figure 2.8: Test kit performance and laboratory results

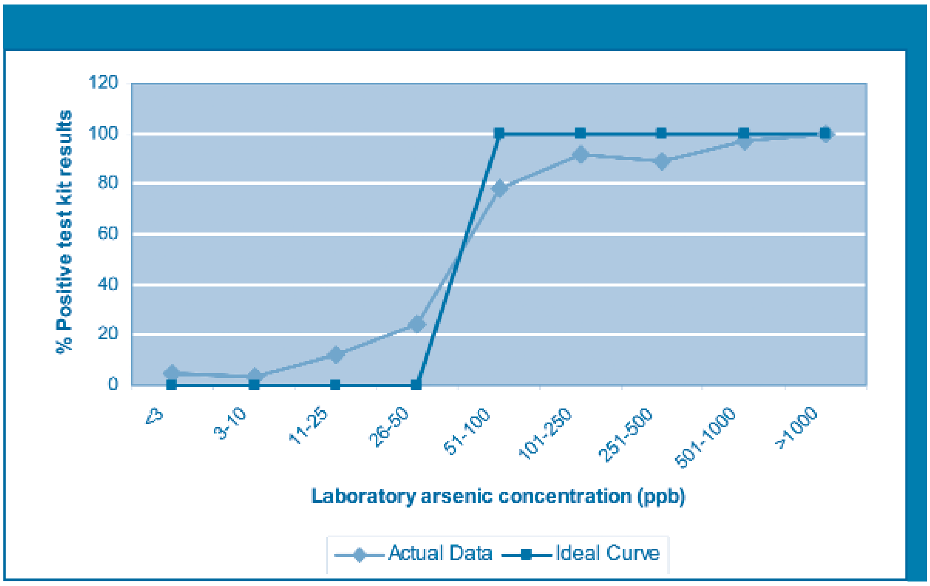
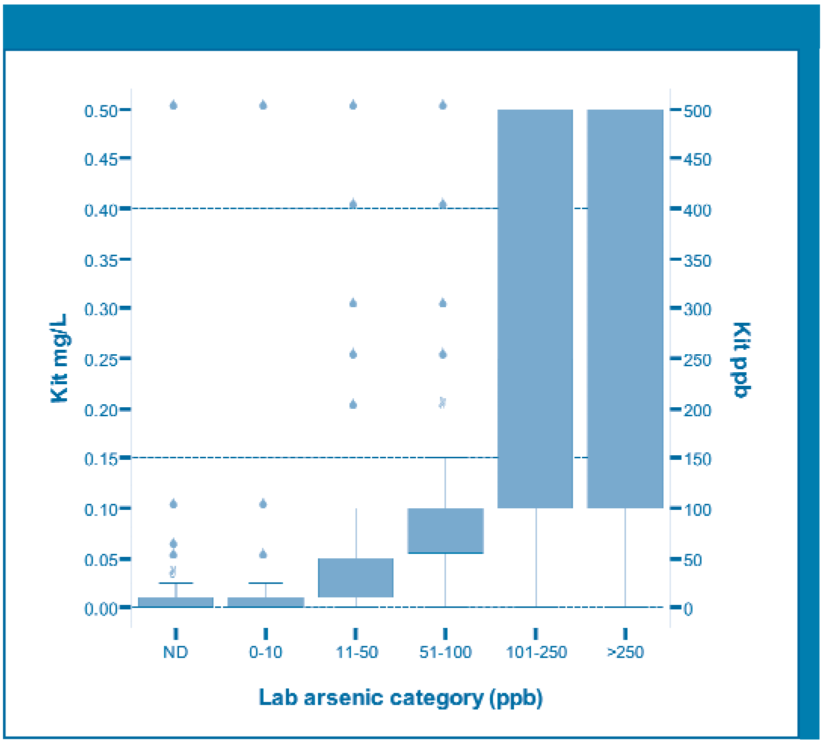


Figure 2.8 represents these results graphically. The curve below 50 ppb reflects test kit specificity, while the curve above 50 ppb shows the sensitivity. We can see here what we would intuitively expect to see: a high proportion of correct classifications at very low (<10 ppb) and very high (>250 ppb) arsenic concentrations, with more mixed results in between those concentrations.

Figure 2.9 shows the range of test kit results for categorized laboratory results. It is clear from the figure that the test kit results cannot be very accurate in absolute terms. For each laboratory test in a particular category, there is a large range of test kit results. However, in terms of correctly categorizing wells they perform adequately.

Figure 2.9: Box plot of kit results vs. categorized laboratory results



Considering the aggregate results, 86.4% of all test kit results identify the correct category for the well (either "Green" below 50 ppb, or "Red" above that). False positives and false negatives are fairly evenly spread, with 6.9% and 6.7% respectively. Concretely, this would mean that of every 1,000 wells tested, 67 would be painted green whereas they should have been painted red. The owners of a further 69 wells would be told their well was unsafe, while actually they are not.

As the graph in figure 2.9 shows, test kit results are not very consistent, and a closer look at the data bears this out. Accurately classified wells range from 78% to 94% by upazila, with misclassifications predominated by false positives in some upazilas, and by false negatives in others. The likelihood of false positives or false negatives predominating depends on overall contamination rate in an area. If there are many true positives, (i.e. a high contamination rate) each test represents a chance to get the result wrong and score a false negative; in this case we would expect false negatives to dominate the incorrect results. This would explain the very small number of false positives found in Shahrasti and Muradnagar for example (0.2% FP in both cases).

The verification data from four upazilas provided by BRAC are a good example of why the available results should be treated with some care. BRAC sampled the same wells in Manirampur, Haim Char, Bhanga and Barura upazilas three times during different months of 2002; once in February, once in April and once in July/August. Arsenic levels were then measured in a laboratory (two different private laboratories were used). The original screening of those wells by test kit had taken place between September and December of 2001. Comparing the test kit results with each of the three lab results in turn shows wide fluctuations in the rates for correct categorization. For example in Manirampur, correct categorization for wells which originally tested >50 ppb by test kit ranges from 41% to 89% (N=117). Correct categorization for 50 green wells in Bhanga ranges from 62% to 92%. The other upazilas give similar ranges (table 2.7). The most likely explanation is that the laboratory data is not reliable. However, it is also possible that there is true variation in arsenic levels over time (the BGS survey found large temporal arsenic variations in the special study areas in Chapai Nawabganj and Lakshmipur, although not around 50 ppb - see BGS and DPHE 2001 pp. 178-179). Making a truly meaningful comparison of test kit and laboratory performance would at a minimum require the use of split samples, rather than samples taking at different (and large) time intervals.

When investigating the performance of test kits at higher arsenic concentrations, some data seem counter intuitive. A reasonable expectation would be that the higher the arsenic level, the higher the percentage of correct well categorizations. By at least one measure, this is true. Of the 2,000 test kit results above 100 ppb, 1,859 were matched by their laboratory confirmation (i.e. the lab result also indicated >100 ppb). In other words, accurate categorization in 93% of the cases. Reversing the burden of proof, and asking the question how many of the samples indicated by the laboratory to exceed 100 ppb were correctly identified by the test kit, the result drops to 66%. In other words, when a test kit identifies a well as exceeding 100 ppb, this is almost always correct (i.e. a high PPV at 100 ppb). But a large proportion of wells that actually exceed 100 ppb are never identified as such by the test kit, indicating a low sensitivity at 100 ppb. So expectations are not matched by reality. Further testing - including more rigorous quality control- would be required to explain this result.

Table 2.7: Test kit and lab result comparisons for a 3 sample series in 4 upazilas

Upazila and test kit result	Number of samples	Range of correct categorizations
Barura <= 50 ppb	50	54%-66%
Barura >50 ppb	117	89%-92%
Bhanga <= 50 ppb	50	62%-92%
Bhanga > 50 ppb	118	64%-93%
Haim Char <= 50 ppb	30	73%-83%
Haim Char > 50 ppb	70	41%-87%
Manirampur <= 50 ppb	50	68%-94%
Manirampur > 50 ppb	117	41%-89%

In summary, the available data support the use of test kits, showing that the vast majority of wells will be classified correctly. Various measures of test kit performance all show results matching or exceeding 84%. It is not necessarily true that higher arsenic levels (>100 ppb) are detected more consistently than lower levels (>50 ppb). The test kit used in the 15 upazilas is still available, but no longer widely employed in Bangladesh. Since all available field test kits use the same method for the detection of arsenic, similar verification tests on other kits could yield comparable results. However, this would need to be checked through trials; the results reported here cannot be applied to other test kits without their specific verification.

2.5 Well users and population coverage

There are two ways to look at well use data. One way is to count the number of users for each well in the database. Another way is to count only the family members of the owner of the well. Comparing these numbers to the census population data for the 15 upazilas will give a rough indication of the proportion of the population relying on water from wells, and the number of people exposed to arsenic levels above the level allowed by the national standard. Results for both approaches are shown in this section.

Selecting all functioning household wells used for domestic purposes (290,457 wells, leaving out institutional and irrigation wells), and making the assumption that each well is only used by the owner and his family, coverage in the 15 upazila area reaches 50%, with on average 8 users per well. The lowest coverage is evident in Babuganj (20%) and Haim Char (24%). Highest coverage is attained in Damurhuda, with 73%.

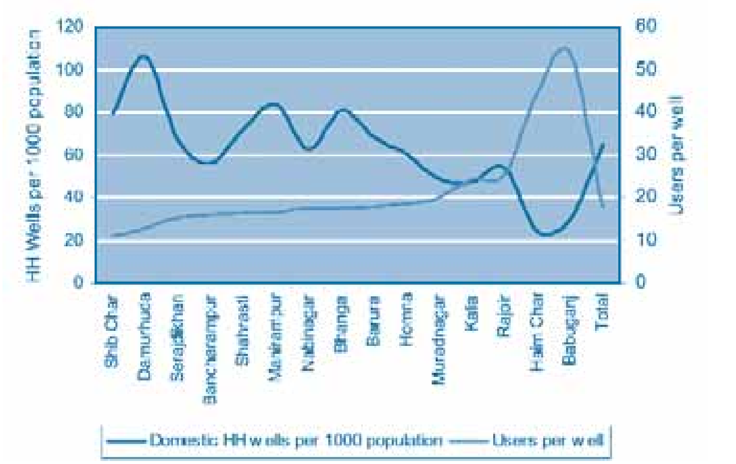
However, including others who make use of the well, by counting the reported number of users, changes the picture significantly. Coverage then exceeds 100% of the population in all but three upazilas, a result which is most probably caused by a combination of imprecise reporting and outdated population figures (the population figures used are projections for 2001, based on the results of the 1999 census). This finding contradicts some of the anecdotal evidence which suggests that wells are not reliably shared with outsiders by their owners, and it needs to be borne in mind that the number of users are reported by the well owner. While the figures should be treated with some caution, the data seem to confirm the oft-mentioned high water supply coverage rates Bangladesh has achieved through shallow well construction.

The graph in figure 2.10 is only meant to be indicative, but it shows some interesting features of domestic well use in Bangladesh. In the first place, the number of users per well is very low, even in an upazila like Babuganj with a relatively small number of wells. While the use of a line-plot is somewhat unconventional for the data shown, it does bring out the pattern in the data most clearly. The top (blue) line shows the well density per 1000 population by upazila. The bottom (pink) line shows (on the right hand scale) the average number of users per well, as computed from the database. There is some increase in users per well where well density decreases. This is most obvious in the southernmost upazila (Babuganj). Here the number of domestic wells per 1000 people is lowest (30), but even then the number of users per well only reaches a little over 50[1]. In other words, with a high density of wells, and low user numbers per well, possibly losing the use of a large proportion of wells due to arsenic contamination need not put any physical limitations on access to water for the whole community. There is sufficient spare capacity to share wells without unduly increasing waiting time at the pump, provided that arsenic-affected and arsenic-safe wells are geographically "mixed" rather than clustered. The fact that reported user numbers seem to go up and down with the density of wells provides further support to the idea that more sharing of wells may be going on than is sometimes assumed.

Average numbers across the 15 upazilas are 64 wells per 1000 population, and 18 users per well.

[1] 250 users per well is often considered the practical maximum if undue waiting is to be avoided. In Bangladesh this would be equivalent to almost 50 families. Government policy however aims at having one well for each married couple.

Figure 2.10: Wells and well users by upazila (domestic household wells)

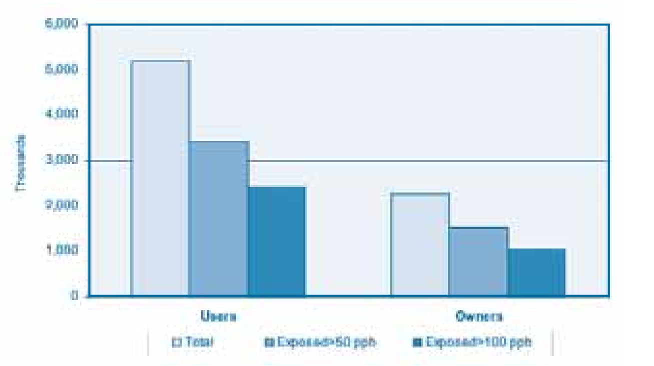


Source: Population census 1991, UNICEF well database

2.6 Exposed Population

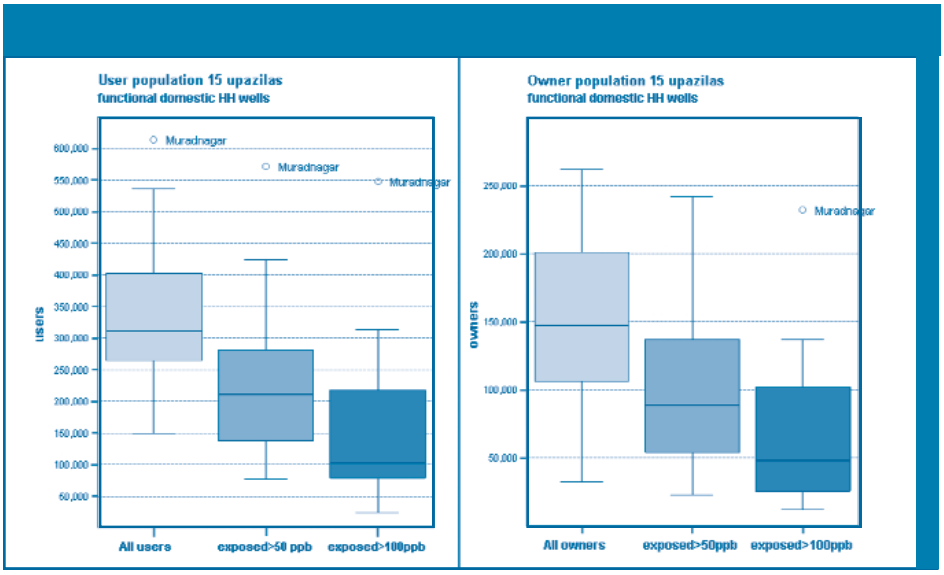
Exploring the number of users and family members of wells affected by arsenic leads to the graph in figure 2.11. This shows a total number of almost three and a half million well users exposed to arsenic levels in excess of 50 ppb, which is 66% of the five million users in the database. Almost two and a half million users -or 50% of the total- are exposed to arsenic levels in excess of 100 ppb. A more conservative count is included in the same graph, enumerating only the families of the well owners. Those numbers are still high, at one and a half million and one million respectively (67% and 46% of the total number of 2.2 million recorded family members).

Figure 2. 11: Total and exposed user and well owner populations



A slightly different way of looking at the exposed population is shown in figure 2.12, recording the distribution of the exposed population across the 15 upazilas. This shows Muradnagar as being the upazila with both the largest user population, and the largest exposed population at any level. This follows from the large population base (624,000 people) coupled with a 93% well contamination rate.

Figure 2.12: Total and exposed user and well owner populations



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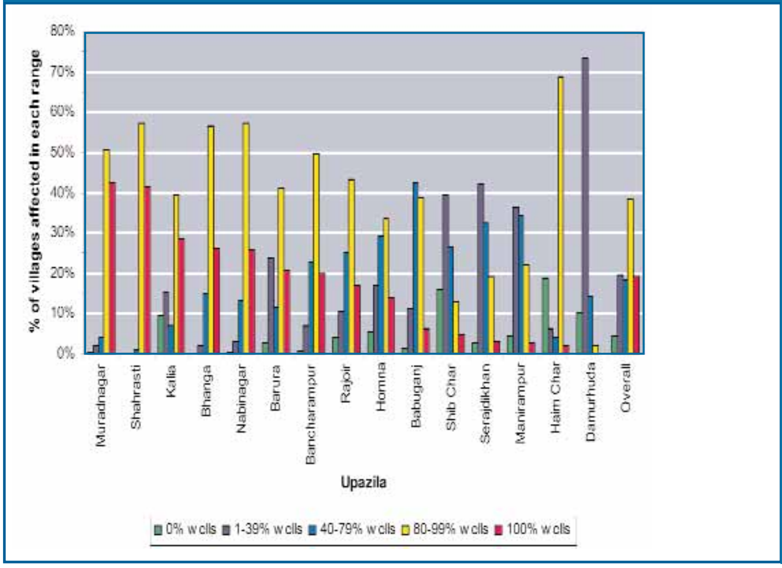
Heavily affected communities and schools 2.6.1

From a mitigation perspective, it is useful to determine how many and which communities are most affected by arsenic contaminated wells. The average number of wells contaminated hides big variations at village level. There are very few villages where not a single well is affected, but on the other end of the scale there are 574 communities where all wells exceed the 50 ppb arsenic standard (figure 2.13).

Figure 2.13: Wells and well users by upazila (domestic household wells)



The graph in figure 2.13 was constructed considering all wells in an upazila, and not only the domestic ones. This is likely to lower the total number of villages in the "highly affected" group, but it does truly identify the most severely affected communities. Those villages which are 100% affected really have no single well available in the community which provides arsenic safe water. Muradnagar and Shahrasti are worst off, because in almost all villages 80% to 100% of wells are affected. On the other end of the scale are upazilas like Haim Char and Damurhuda, which have a large proportion of villages where no wells at all are affected, or a relatively small percentage.

However, just counting affected communities can be potentially misleading. A village with only one well which happens to be red would be included in the list of villages that are 100% affected, but the actual number of people affected may be quite small. Combining the information about the percentage of wells affected with the user population in the communities provides table 2.8.

From a population perspective, the table shows that Muradnagar, Nabinagar, Shahrasti, Barura and Bhanga should be the upazilas where emergency mitigation measures should get priority. Looking at the number of affected villages, the five priority upazilas are the same. A further refinement could be made by looking at absolute arsenic levels (e.g. giving priority to users exposed above 100 ppb), but that would be cumbersome, and ultimately would probably not lead to significant changes in priority. According to the Bangladesh National Arsenic Policy (Local Government Division MLGRD&C 2004), all villages where 80% or more of the wells exceed the arsenic standard should receive emergency mitigation interventions. In the 15 upazilas, there are 1,724 such villages (58% of the total). The CD accompanying this report has a complete listing of all villages and the percentage of affected wells in each.

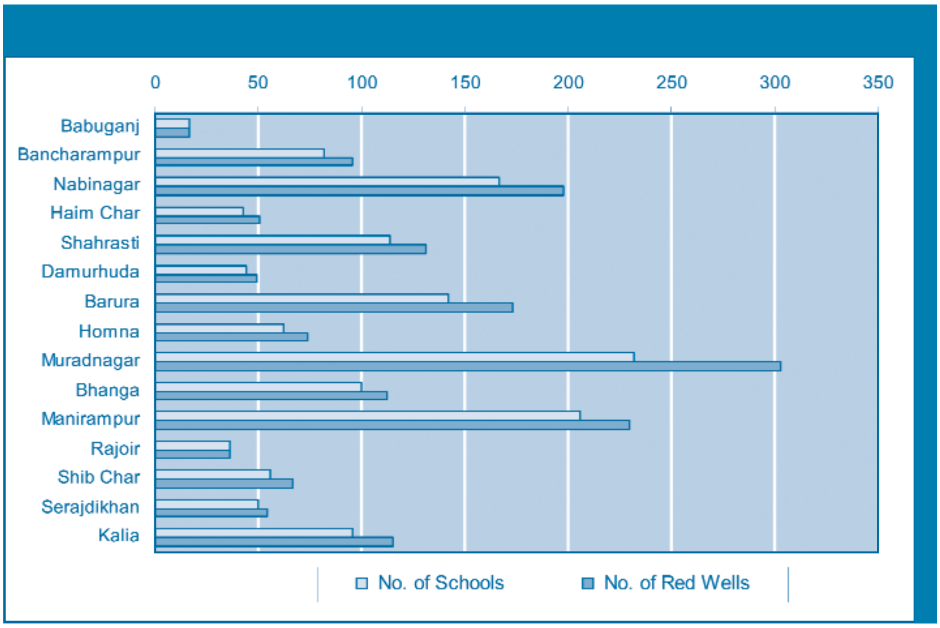
Table 2.8: Number of most severely affected communities and number of well users, by upazila.

Upazila	Total Villages	Villages with 80-99% of wells affected	Villages with 100% of wells affected	Number of people using wells in 100% affected communities	Total number of people using water from red wells
Muradnagar	316	160	135	151,124	570,848
Nabinagar	217	124	56	73,403	423,341
Shahrasti	176	101	73	69,469	245,303
Barura	315	130	65	60,566	307,270
Bhanga	239	135	63	41,705	305,885
Kalia	200	79	57	36,983	163,701
Homna	227	76	32	20,899	191,099
Bancharampur	141	70	28	19,770	211,994
Manirampur	248	55	7	12,044	259,120
Rajoir	194	84	33	7,900	213,372
Serajdikhan	182	35	6	2,918	135,272
Babuganj	80	31	5	2,296	84,946
Shib Char	266	34	13	2,221	139,754
Haim Char	48	33	1	635	102,363
Damurhuda	147	3	0	0	77,584
TOTAL	**2,996**	**1,150**	**574**	**501,933**	**3,431,857**

Besides considering all wells, it is also useful to know how badly affected schools are. Drinking water from a contaminated source at school may be a significant route of exposure, depending of course on time spent there everyday as well as personal behaviour. Existing evidence about arsenic methylation capacity in children is contradictory. Poorer methylation capacity in children was only observed in one study of three (WHO 2004) but there is clearer evidence of the impact of arsenic on the intellectual development of children. A study in Mexico found that chronic malnutrition combined with exposure to arsenic likely influences verbal ability and long term memory (Calderon, Navarro et al. 2001), while a study in Bangladesh concluded that exposure to arsenic in drinking water was associated with reduced intellectual function in children in a dose response manner (Wasserman, Liu et al. 2004). In sum, available evidence suggests it is important to minimize children's exposure to arsenic, and schools should not be overlooked in mitigation efforts.

The database does not include a category for "school wells", so it is not straightforward to determine how many schools are affected. However, an attempt was made to determine which wells are school wells by searching the "address" and "owner" fields in the database for words like "school", "madrasa", "high", "primary", "kinder", etc. The results were manually inspected and edited, resulting in a list of wells which are highly likely to be school wells. Multiple wells at the same compound were counted as belonging to the same school, and schools where all available wells tested above 50 ppb were then listed. The full report with school names and locations is included on the CD accompanying this report; a summary is given in figure 2.14.

Figure 2.14: Number of schools without access to arsenic safe well water by upazila



The total number of schools in the database is 2,017. The total number of schools without arsenic free water is 1,447 (72 % of the total), with 1,706 wells among them. Because of the way the data were extracted from the database, these numbers should not be treated as absolutes. Nabinagar, Muradnagar and Manirampur seem to have the largest number of affected schools, and priority attention may be given there.

Well age 2.7

Figure 2.15 shows the trend in well construction from 1960-2001, the last full year for which data were available. This picture clearly slows well construction getting started in 1970, and strongly accelerating in the 1980s. Very distinct peaks occur in both government and private rates of construction, every five years from 1970. The 1995 peak is less pronounced than the others, but it is there. Although it is on the edge of the graph, the year 2000 seems to represent another peak in construction.

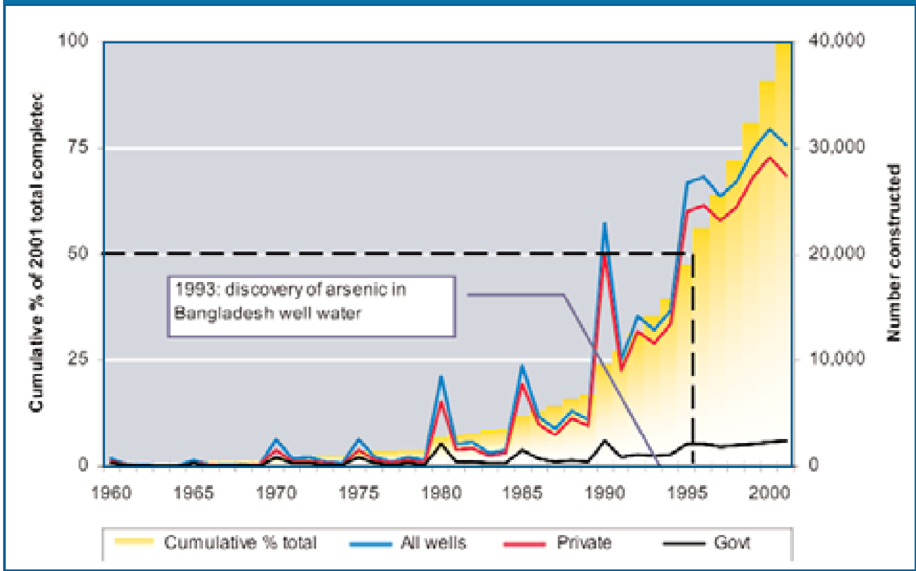
The five year peaks reflect a clear case of "digit preference", which is common in reporting of age and other numeric data, in particular in populations with low levels of education. It is manifested in a preference for reporting numbers which end in "0" or "5". (Shryock and Seigel 1976). An added aspect may be the fact that all peaks precede election years, and politicians seeking (re-) election may be responsible for the availability of additional funds for the improvement of rural infrastructure.

The second striking (and worrying) observation is that 50% of the wells in the 15 upazilas were constructed since 1995, which is two years after the discovery of arsenic. The largest single increases took place in 1998, 1999 and 2000; during each of those years more than 9% of all wells were constructed.

Well construction by the government has increased significantly over the years, more than doubling in the 8 years since 1993. Overall rates of construction remain insignificant however compared to private construction.

It is worth considering whether there is any relationship between well age and arsenic contamination. When considering age groups, we come to two related conclusions. In the first place, the median arsenic levels for wells older than 25 years is significantly higher than the median arsenic level of wells younger than that (table 2.9). Following on from that finding, we also find that older wells have a higher chance of being contaminated above the 50 ppb level than younger wells. This is not surprising; if older wells have higher levels of arsenic, the number of older wells exceeding the standard would also be expected to be larger (figure 2.16).

Figure 2.15: Number of wells constructed per year, and cumulative percent constructed up to 2001



Further investigation of the older wells shows that they do not differ in any way from the younger wells; the majority (80%) is completed in the range of 50 - 150 feet deep (15 - 46 m), with the remainder in the adjacent ranges (15 - 50 ft and 150 - 250 ft). They are distributed throughout the 15 upazila area.

Table 2.9: Significant difference in median arsenic concentrations between young and old wells

Well age (years)	Number of functioning wells (arsenic level <= 500ppb)	Median arsenic concentration, ppb
> 25	13.351	200
< = 25	318.048	100
Mann-Whitney p< 0.001		

The DPHE/BGS study (BGS and DPHE 2001) also found older wells to be more likely to exceed the 50 ppb arsenic limit. Since new wells with high arsenic concentrations also exist, it is unlikely that older wells have always had higher arsenic levels; the increase is more likely to have taken place over time. Water flow in Bangladesh's aquifers is generally very slow (e.g. Rahman and Ravenscroft 2003) and hand pumps extract relatively small amounts of water from the aquifer. In consequence, the "ground water capture zone" around the tubewell would only expand slowly. Water flowing towards the well could become contaminated with arsenic along the way, and as the radius of the capture zone increased this would become ever more likely. Over time then, more and more water with higher arsenic levels would reach the well, explaining the increasing arsenic concentration (see figure 2.17).

This possible explanation remains to be proven. Although it would take a long time to produce useful time-series data, establishing a systematic monitoring system is the only way to reliably investigate the occurrence of any long term trends in arsenic concentrations.

Figure 2.16: Likelihood of well contamination by age

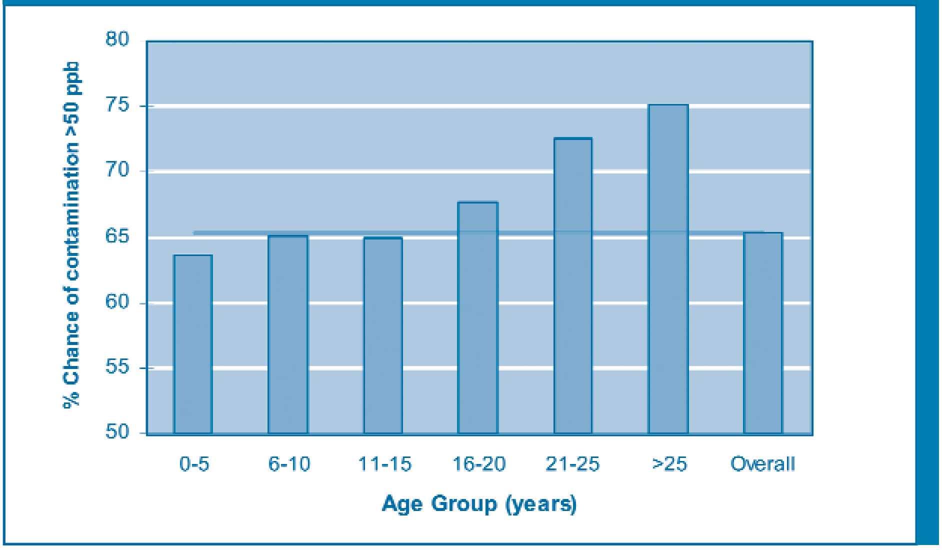
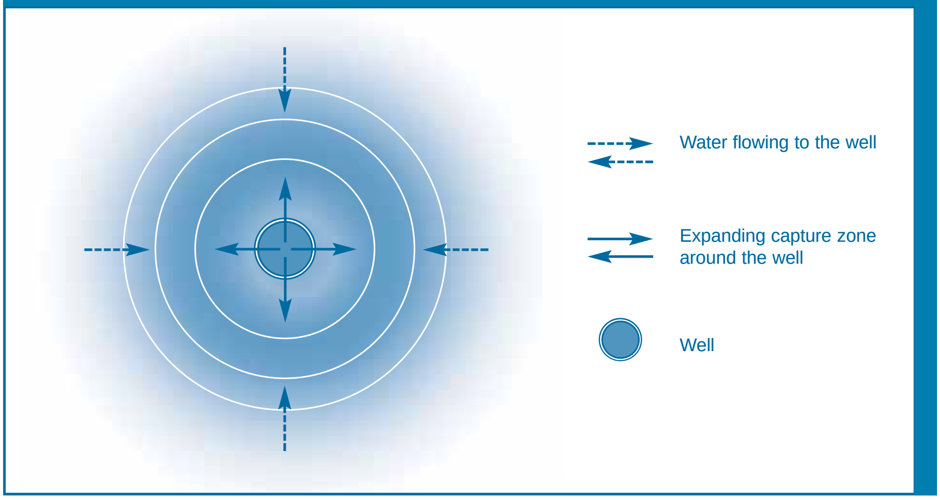


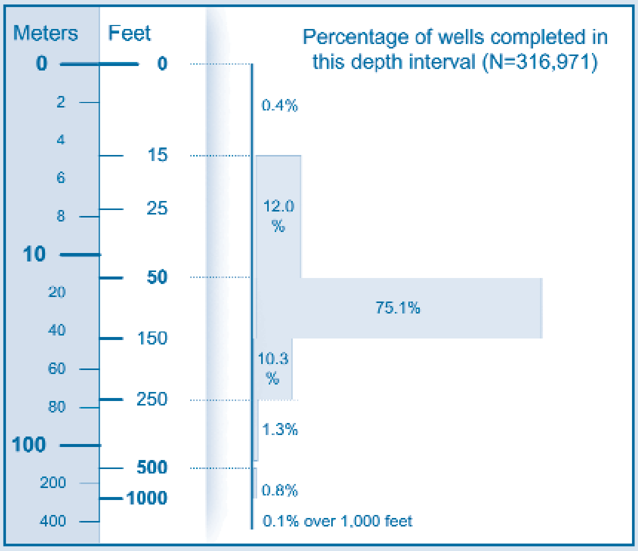
Figure 2.17: Expanding capture zone around a well



2.8 Well Depth

Figure 2.18 shows the distribution of well depths by upazila, arranged in geological groups (geological groupings are shown by colour). It is clear that for most upazilas, the majority of wells are completed in the interval of 50 - 150 feet (15 - 46 meters). Variations within each surface geology group are pronounced. Regional variations are modest in scale for the northeastern and eastern upazilas, but much larger for the others. Serajdikhan is the clear exception to the depth distribution pattern, with a mean well depth of 200 feet (51 m), and to a lesser extent Rajoir, Kalia and Manirampur which also display a much larger variation of well depths.

Feet or meters?



Well depth in the database is recorded in feet. Use of SI units would be more appropriate in a report such as this one, yet the continuous reporting of the primary unit and its SI equivalent would quickly become tedious. For this reason, a conversion scale is given here, to assist the reader with unit conversion. Note the logarithmic "Meters" side of the scale.

This picture is confirmed by figure 2.19 on the next page, which shows the distribution of the number of wells completed per upazila in a particular depth range (note the logarithmic scale). Note the almost perfect inverted 'V' pattern with the peak in the depth range of 50 - 150 feet. This is likely to represent the interval which produces clear water in sufficient quantity, and can easily (and affordably) be reached using local drilling methods.

The existence of larger numbers of deeper wells in Rajoir, Kalia and Manirampur is consistent with other available data. A JICA study in Jessore (JICA 2002) found good water producing layers (in what are called the "first" and "second" aquifer) at depths from 50 - 200 meters (164 - 656 feet). Work done by the USGS in Rajoir but not yet published shows coarse sands at 70 - 130 meters (230 - 427 ft)[1]. Presumably the local well drillers are aware of the good water producing zones, and target them for well construction. Comparative data on Serajdikhan are harder to find. Generally speaking the wells in the East of the country would be expected to be shallower, given the general absence of coarse sands at depths below 100 meters (see e.g. cross sections shown in the BGS/DPHE report mentioned earlier). In other words, wells would be completed to any depth producing an acceptable quantity of water at an acceptable quality, given the absence of a known better aquifer. However, in parts of Serajdikhan a good target must exist at acceptable depth.

In figure 2.19 the upper range of the 251 - 500 ft category is accounted for by Serajdikhan upazila, with a number of wells in that depth range far exceeding the numbers found in the other upazilas. For Haim Char (which makes up the lower range of the category) the situation is reversed, with much fewer wells in that depth range (as can be seen from figure 2.18 (next page) as well; almost all wells in Haim Char are less than 100 feet deep).

[1] Personal communication G.N. Breit, USGS

Figure 2. 18: Well depth distribution by upazila, grouped by surface geology

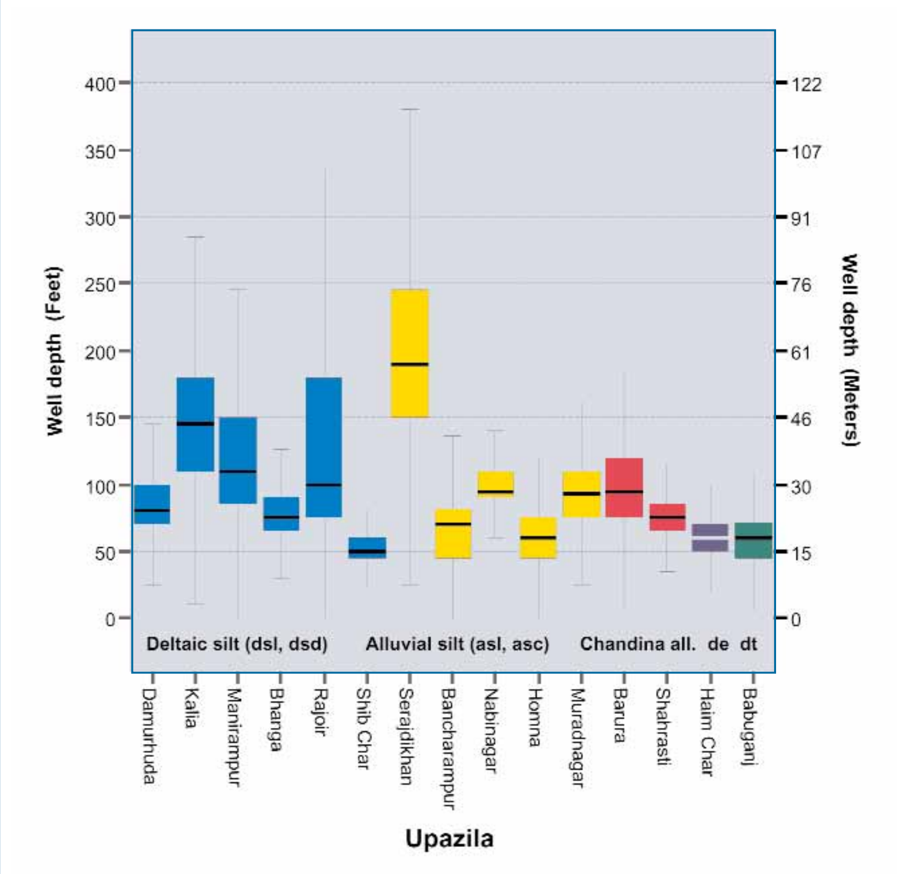
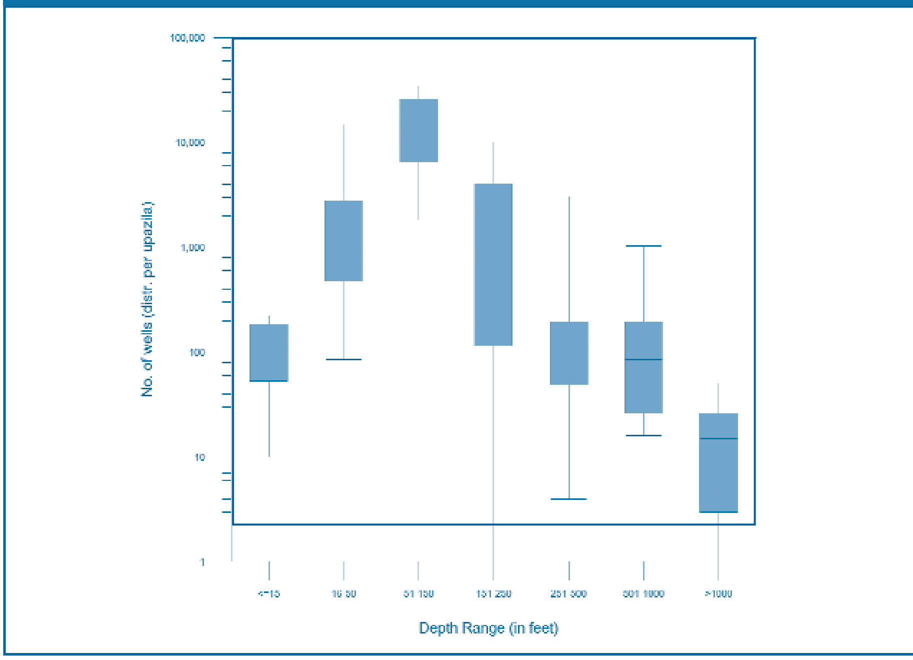


Figure 2. 19: Number of wells completed by depth range, 15 upazilas



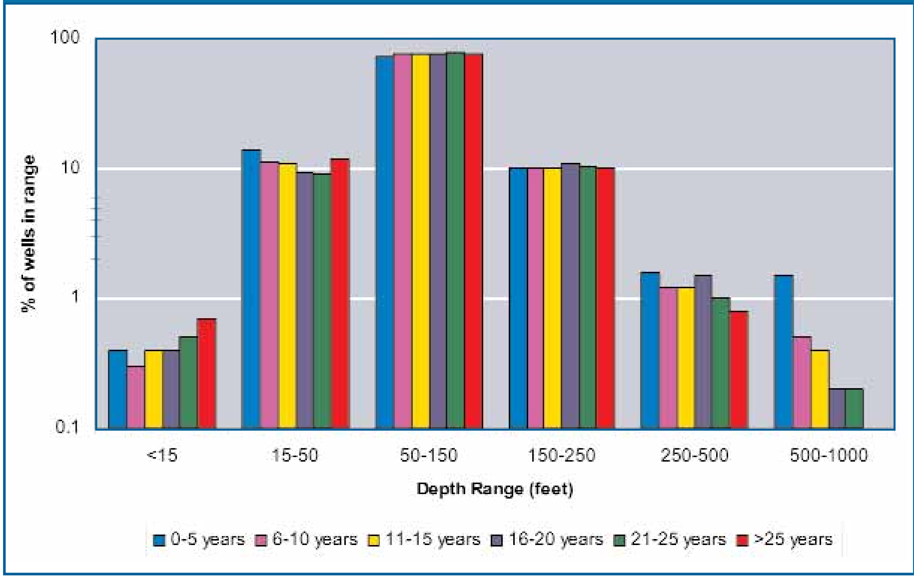
It is not clear how meaningful the category with wells exceeding 1000 feet (305 meters) is. Well depth is self-reported by the owner, and no physical measurements were carried out. It is possible that a relatively large proportion of the wells in this category contains data entry or reporting errors. The total number of wells in this category is very small however (N=259) and since there is no way of knowing how accurate or inaccurate these data are, the category has been retained in the analysis.

Comparing the percentage of wells completed to a particular depth over the years shows that very little has changed. The ranges between 50 feet and 250 feet show consistent well percentages completed in all age groups (Figure 2.20). Outside those ranges a trend is observable towards more recent deep wells (>500 feet deep). This could be a result of increasing awareness, and the knowledge that deep wells have a smaller chance of being arsenic contaminated. If this were the case, it would be an important effect of the awareness raising campaigns; not only are people more aware, they also seem ready to invest to lower their risk of exposure.

In the oldest group (>25 years old), no deep wells exist, but there are comparatively more wells in the range up to 15 feet (which reflects a larger proportion of dug wells). When the DPHE/BGS study found that the depth range of 50 - 150 feet contained a large proportion of highly contaminated wells, and that older wells have higher arsenic levels, the hypothesis was advanced that this was because older wells were likely to be shallower. Figure 20 shows that higher arsenic concentrations in older wells cannot be explained in this way, since there is no change in the proportion of wells in the 50 - 150 ft range over time.

Please note that in the categories <15 feet and >500 feet changes are exaggerated by the logarithmic scale.

Figure 2.20: Trends in well depth construction over time (note logarithmic vertical scale)



2.9 Well depth and arsenic

A first quick look at measured arsenic levels at various depths is presented in figure 2.21. It is a general picture intended only to show two things: In the first place, in the aggregate, there is not one depth where no arsenic is found. Although we shall see later that in defined geographical areas generalizations may be made about arsenic and depth, in general statements to the effect that "deep wells are arsenic free" or "shallow dug wells are low in arsenic" should be treated with caution. The second feature of the graph is the distinct banding of arsenic readings, caused by the measurement scale of the test kit(s) used. As a matter of fact, 0, 10, 25, 50, 100 and 500 ppb are all clearly identifiable bands, representing the test kit scale.

Constructing a similar boxplot to figure 2.19, but only counting the number of wells exceeding 50 ppb of arsenic (figure 2.22) shows that the depth where the most wells are concentrated is also the depth with the most arsenic contaminated wells. There is a drop in the number of wells in the 500 - 1000 feet (152 - 305 m), and to a lesser extent in the 250 - 500 feet (76 - 152 m) range. However, the distribution of wells in the 50 - 150 feet (15 - 46 m) range is virtually identical for all wells and wells exceeding the arsenic standard, which would indicate that the chances of finding arsenic free drinking water at that interval are very slim.

Performing a nonparametric statistical test on data categorized by depth (<50 ft, 51 - 150 ft, 151 - 500 ft and >500 ft) and arsenic concentration (<=50 ppb and >50ppb) shows a significant relationship between depth and arsenic ($p<0.01$, Kruskal-Wallis test excluding dug wells, and wells deeper than 1,000 ft). As figure 2.21 shows however, there can be little power in the correlation, and there will be no predictive value to it.

Figure 2.21: Well depth vs. arsenic concentration

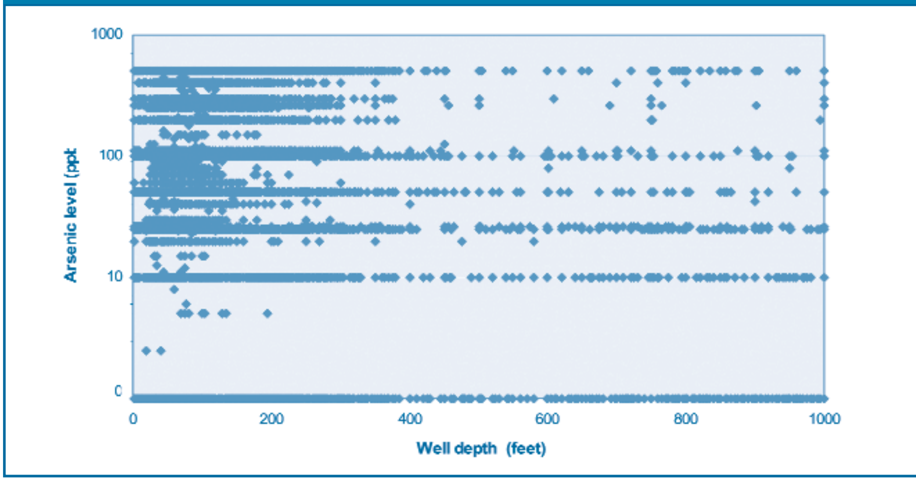
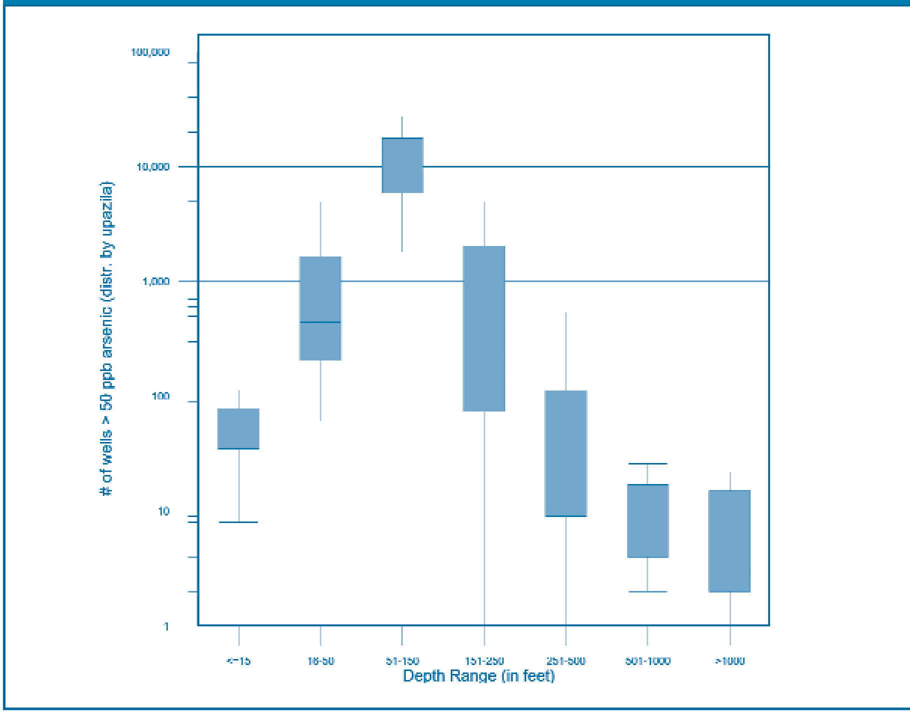


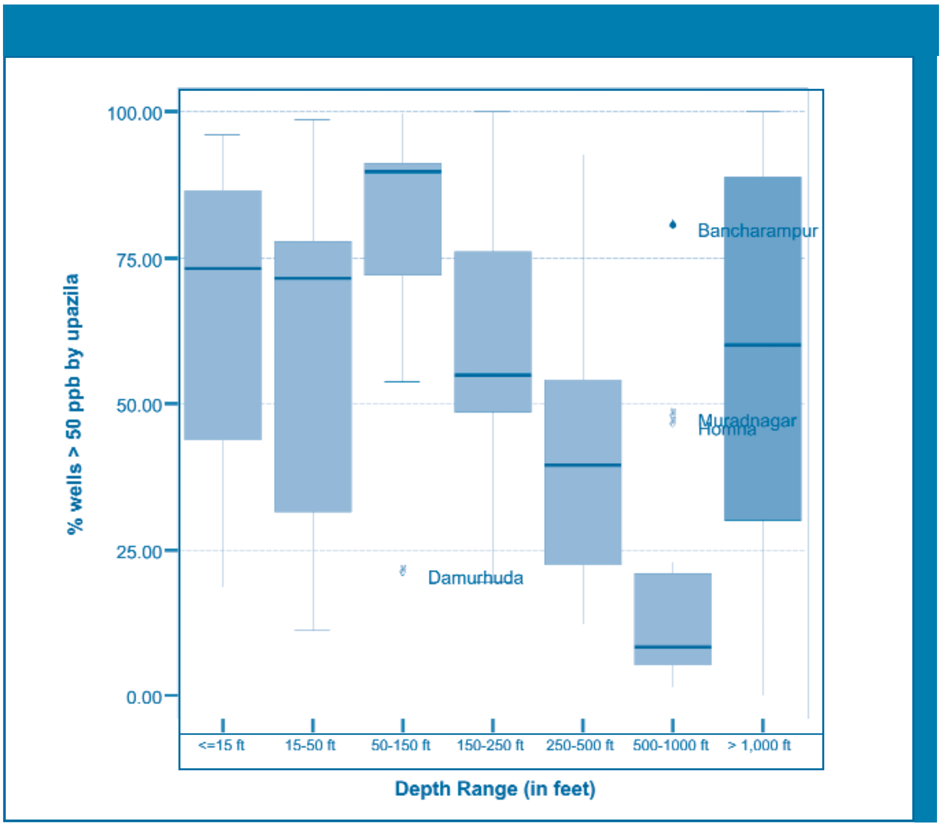
Figure 2.22: Number of wells with arsenic levels above 50 ppb, by depth range



Looking at the percentage of contaminated wells in each depth interval is more informative, and gives the picture shown in figure 2.23. This figure shows clearly that generally speaking, the 50 - 150 feet depth interval is a poor choice for locating arsenic safe water, with the exception of Damurhuda upazila (which has about a 20% contamination rate in that interval). The adjacent intervals (15 - 50 and 150 - 250 feet) are also poor choices. Wells in the interval from 500 - 1000 feet (152 - 305 m) have a high likelihood of finding arsenic-safe water. "Deep wells" are commonly taken to be wells exceeding 500 feet in depth, and so this interval corresponds to the deep wells in the 15 upazilas. Based -among other things-on the findings of other studies (BGS and DPHE 2001; AAN 2004a; APSU 2004) the expectation is that deep wells show a much lower than average arsenic contamination range. Figure 2.21 confirms this, although the upper end of the range still shows 25% of wells exceeding the standard, which is much higher than for example the 1% exceedence reported in the BGS/DPHE study. Notable outliers are Bancharampur, Homna and Muradnagar, where from 46% to 80% of deep wells are contaminated. Those three upazilas are all located in the northeast region, where few if any deep wells were sampled by the BGS. Confirmation of well depths and further measurements on arsenic in deep wells seems warranted based on the 15 upazila data.

Also clear from figure 2.23 is the wide range in the percentage of wells contaminated in most depth intervals. All intervals except the 50 - 150 feet one have their minimum at below 25% contamination. All intervals except the 500 - 1000 feet one have their maximum value close to 100% contamination. With the plots based on a total well count by upazila, the large range of percentages reflects the uniqueness of each upazila. For example, in the interval of 15 - 50 feet depth, the spread in contamination rate of between 11% and 98% means that in some upazilas there is a high likelihood of finding arsenic-safe water in that interval, while in others there is not. The contamination of wells in the category of wells > 1000 feet in depth looks like random noise and should most probably be disregarded.

Figure 2. 23: Percentage of wells exceeding 50 ppb arsenic, by depth range



Dug wells 2.9.1

Within the range of very shallow wells, a separate group deserving some scrutiny is that of the dug wells. From an arsenic viewpoint, dug wells are usually considered to be somewhat safer than drilled shallow wells, although the risk of bacterial contamination is usually higher (a risk assessment of arsenic mitigation options carried out by the Arsenic Policy Support Unit (APSU 2004) found only 3% of dug wells to exceed 50 ppb arsenic, but found thermotolerant coliform bacteria in 94% of the dug wells, indicating a real chance of risk substitution). The mechanisms that produce water with low concentrations of arsenic and other dissolved minerals in dug wells often include the following:

1. The dug wells tend to be open to the atmosphere, and oxidation of well water can cause a lowering of arsenic levels. This may be especially true when iron is also present in the water, and co-precipitation of arsenic and iron occurs;
2. Dug wells tend to be shallow, and may only contain water from relatively shallow, oxygenated aquifers which are much influenced by surface infiltration. These surface waters would be low in arsenic;
3. The air and aerated water in the well may oxidise the soils around the well. Infiltration

of water into wells through this oxidised soil could significantly reduce the concentration of arsenic in well water.

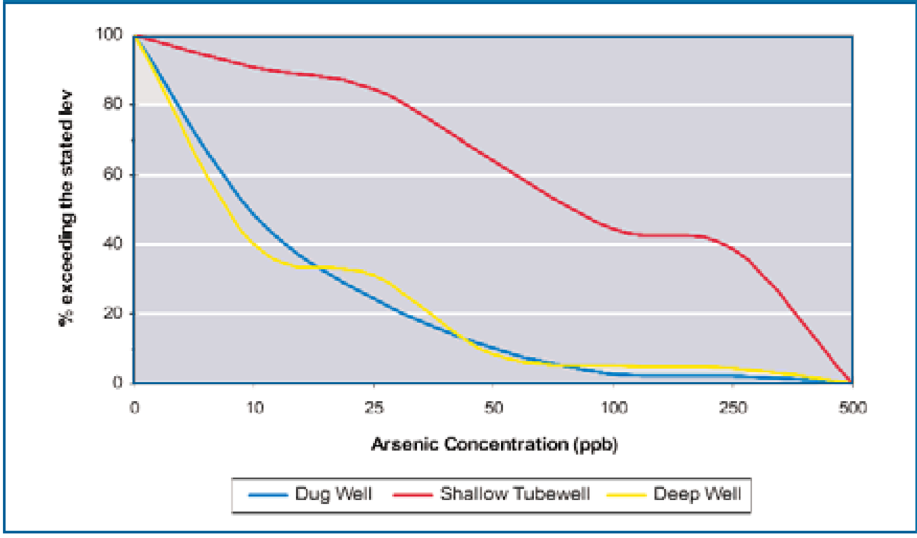
However, as mentioned already, dug wells which exceed the arsenic standard do exist. The Asia Arsenic Network found 46% of a sample of 50 dug wells in one upazila to be contaminated above 50 ppb (AAN 2004b). Figure 2.23 shows that in half the upazilas, of the wells up to 50 feet at least 75% exceed the arsenic standard. Dug wells would generally fall into this depth range, and it would be good to know whether they show the same contamination trend as shallow drilled wells. Filtering out the dug wells with a depth up to 60 feet (18 m) from the database shows the following picture.

There are a total of 783 dug wells in 13 upazilas, of which 11% (85 wells) exceed the arsenic standard. Of the affected dug wells, the majority (66 wells) are located in Bancharampur upazila (which also has by far the largest number of dug wells overall; 498 wells, or 64% of the total). As a group, dug wells are much older than shallow boreholes. The mean age is almost 42 years. In spite of their old age, the median arsenic level is actually an order of magnitude lower than that of all wells (10 ppb for dug wells, vs. 100 ppb for all wells) and lower still than that of all wells older than 25 years (which are at 200 ppb). So while not always safe, the contamination rate for dug wells seems to be generally much below that of other wells in the same depth interval. With careful source selection and careful construction dug wells would seem to offer a low arsenic-risk alternative to shallow wells. Figure 2.24 on the next page shows a comparison of arsenic contamination levels for dug wells, shallow tubewells and deep wells (>500 ft). Both dug wells and deep wells offer a substantially lower risk of showing arsenic contamination above the standard.

2.10 Well ownership and arsenic

As shown earlier on in this chapter, the majority of wells in all upazilas are privately owned. It is occasionally suggested that the contamination rate of government constructed wells should be lower than those constructed by the private sector. This suggestion is based on the fact that the local knowledge of DPHE District Executive Engineer or upazila based Sub-Assistant Engineer will allow the well drillers to avoid arsenic affected areas.

Figure 2.24: comparison of proportion of arsenic affected deep wells, dug wells and shallow tubewells



In first instance, the evidence does not seem to support that assumption (Table 2.10). On the contrary; government constructed wells are actually more often contaminated than the average, and community-owned wells are even more often unsafe. However, 23% of all government wells are older than 20 years, while only 12% of all other wells are that old. Since we saw earlier that older wells tend to have higher arsenic concentrations, it is likely that well age is a confounding variable.

Considering only wells which are five years old or less, the picture changes. In this age bracket, 60% of the government wells exceed 50 ppb, versus 64% of all other wells. The most recent government wells are indeed less often contaminated than all others. However, almost 6% of all government wells are deep wells, while overall the proportion of deep wells is less than 1%. Filtering out the deep wells, and only considering shallow tubewells less than five years old changes things again. In this case, 69% of government wells exceed 50 ppb, vs. 64% of all other wells.

Table 2.10: Differences in contamination rate for different well ownership and well type

	Percentage of wells exceeding 50 ppb arsenic		
Well ownership	**Shallow and deep wells, all ages**	**Shallow and deep wells, <=5 years of age**	**Shallow tube wells, <=5 years of age**
Government	70%	60%	69%
Community	75%	70%	72%
All other	65%	64%	64%

Figure 2.25 on the next page summarizes the data on arsenic and well depth intervals for each upazila, grouped by surface geology. From left to right in the graph are increasing well depth, while within each element increasing chances of contamination are listed from bottom to top.

The graph was created in the expectation that regional differences in contamination trends would show up, given the changes that have taken place over time in the delta which forms Bangladesh. The positions of the major rivers (Jamuna, Padma and Meghna) have shifted, and sea level fluctuations have resulted in changing areas of sea water influence reflected in the composition of the sediments.

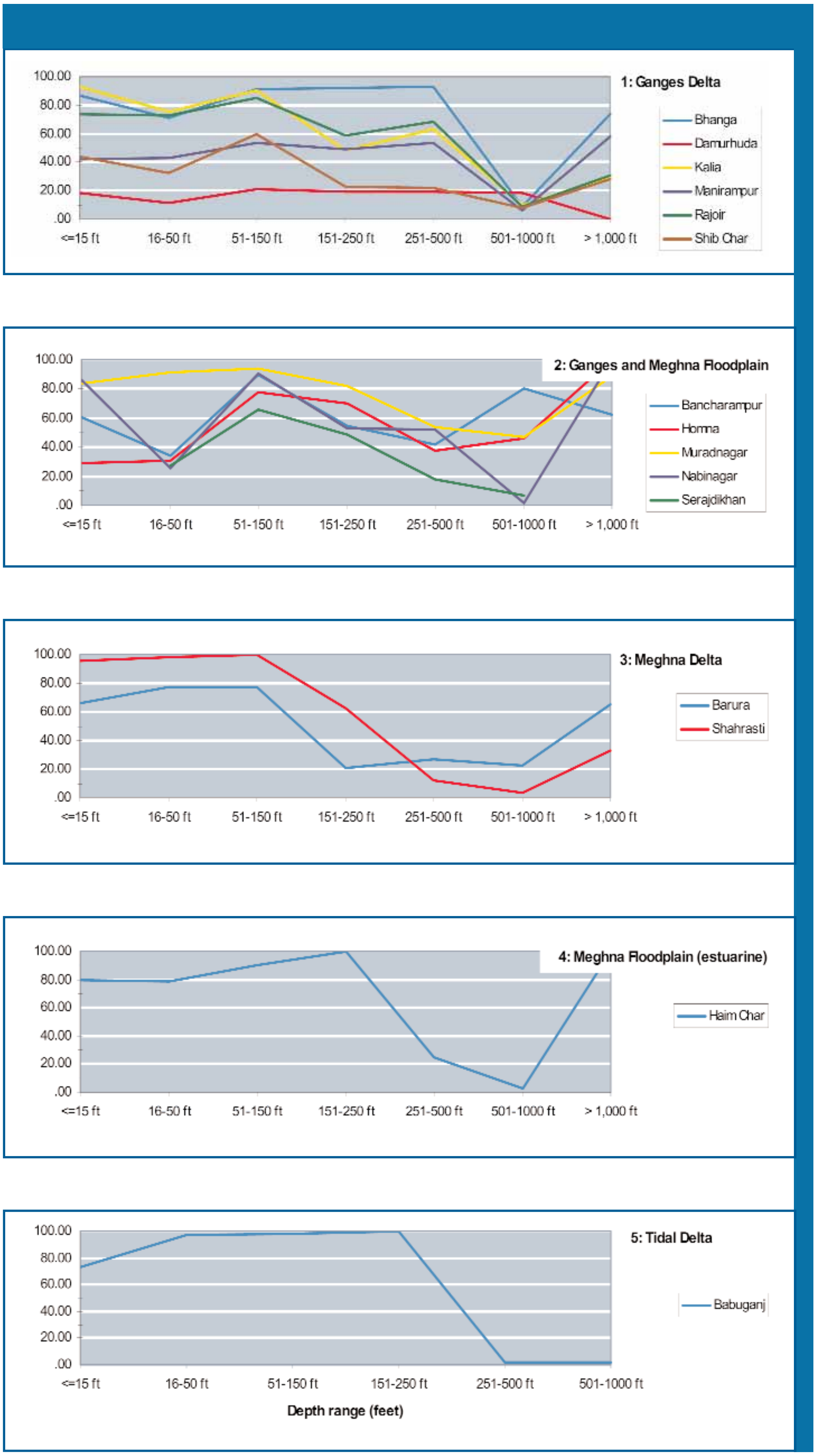
The northeast upazilas in the second group (Bancharampur, Homna, Muradnagar, Nabinagar and Serajdikhan) are relatively distant from the present coastline, and in general the ground water is fresh, even at great depths (although there are some reports of brackish water being found). In the five upazilas in this area, the chances of finding arsenic safe water in wells more than 50 feet deep are pretty small, except for Nabinagar and Serajdikhan in the 500 - 1000 feet depth range.

In contrast to the northeast floodplain area, most of the other areas show a pattern of high arsenic except in the 250 - 1000 foot ranges, and in some cases the 150 - 250 feet range as well (Shib Char and Barura).

Damurhuda in the West is unique in that it shows uniformly low proportions of arsenic affected wells through all depth ranges. Either arsenic never dissolved in the water in the first place, or it has become (re-)fixed in the sediment over time.

All in all, the well arsenic data show a varied picture. Even on the upazila-level scale, there is a lot of variation in the data (looking at aggregated upazila data implies a smoothing of the data set, but in spite of this differences are very pronounced). Practically, this means that there is unlikely to be a "one size fits all" solution to the arsenic problem. Every (new) well still needs to be tested, and approaches to alternative water supplies and (for example) decisions about the continued use of shallow wells will need to be made based on a review of local data, and a judgment by responsible authorities or individuals.

Figure 2.25: Well depths and arsenic variation per upazila



Left hand scale (y): Percentage of wells exceeding 50 ppb arsenic concentration, by depth interval

Patient Data

3

3.1 Arsenic exposure, metabolism and measurement

Inorganic arsenic compounds are classified as carcinogenic to humans (IARC 1987), but assessing toxicity of arsenic is complicated; among other reasons because there are many confounding factors in determining toxicity (Gebel 2000). Arsenic exists in many forms, which greatly differ in toxicity (WHO 1996). It has however been established that the inorganic forms of arsenic are more toxic than the organic forms. In acute exposure AsIII is slightly more toxic than AsV, but because the low levels of arsenate ingested in drinking water are reduced to arsenite internally, the two species should be considered equally toxic (WHO 2001) . Both are readily absorbed from the intestinal tract (as evidenced from the fact that in controlled intake studies the majority of ingested arsenic is excreted in urine and only a small percentage in stool).

After absorption, two types of metabolic reaction take place: oxidation / reduction reactions, converting arsenite to arsenate and back, and methylation[1], which changes trivalent arsenic first to monomethyl arsonic acid (MMA) and then to dimethyl arsinic acid or DMA, using the enzyme S-adenosyl methionine (SAM). In humans, both arsenite and arsenate are extensively methylated, with DMA being the main metabolite excreted through urine (UNICEF 2001).

In the methylation process, the primary methyl is serine, which is an amino acid obtained in the hydrolysis of protein. Thus, protein intake is important for the methylation of arsenic in the human body.

Inorganic arsenic is rapidly cleared from the blood, and so blood arsenic is not a useful indicator for the sort of chronic arsenic exposure taking place through the consumption of contaminated water. However, arsenic accumulates in tissue over time, especially tissues rich in keratin, such as hair, skin and nails. For this reason, hair, nails (and skin) are used as bio-indicators of exposure, albeit crude ones. Arsenic in tissue signals exposure at

[1] Methylation is the process whereby a hydrogen atom in a molecule is replaced with the methyl (CH3) group.

some point in the past, but no indication of length or level of exposure can be obtained this way. Neither can a judgment be made about how recent the exposure was, or if it continues at present. Studies indicate that arsenic can be excreted in human milk, although the levels are low. Since arsenic is rapidly metabolised and excreted in urine, urinary arsenic levels are well suited as indicators of recent exposure. Total arsenic, inorganic arsenic and the sum of arsenic metabolites (inorganic arsenic plus MMA and DMA) in urine have all been used as biomarkers of recent exposure (WHO 2001).

3.2 Health effects of chronic arsenic exposure

Ingesting arsenic contaminated water over a long period of time causes a medical condition known as arsenicosis or arsenism (the term "arsenicosis" will be used in this report). The manifestations of arsenicosis include many non-specific clinical symptoms and a number of specific skin conditions. The more common non-specific symptoms (expressed in more than 10% of all cases) include numbness, dizziness, palpitations, fatigue, sleep disorders, anorexia and abdominal pain (Lianfang and Shenling 2003). Specific clinical signs include three types of skin changes:

1. **Keratosis**: a hardening of the skin into light yellow to brown nodules, often on the palms of the hand or the soles of the feet;
2. **Melanosis**: a pigmentation change taking the form of dark spots on both sides of the trunk, gradually spreading to the extremities; and
3. **Depigmentation**: colourless spots the size of millet grain, up to densely clustered rain-drop sized spots, mostly on the trunk.

Besides visible skin changes, arsenic has the potential to cause or contribute to several other adverse health outcomes, ranging from diabetes, hypertension and respiratory effects to adverse reproductive outcomes such as miscarriage and still birth.

Arsenic is causally related to an increased risk of cancer in the skin, lungs, bladder and kidneys, and the development of cancer remains the health endpoint of concern for chronic arsenic exposure.

There is marked variation in susceptibility to arsenic induced toxic effects between (human) population groups and individuals. Possible factors which influence susceptibility are age at onset of arsenic exposure, sex, duration of exposure, concentration of arsenic, nutritional status and genetic differences. In addition, occupation or behaviour may play a role; smokers exposed to arsenic are at an even higher risk of developing lung cancer than they would be as an effect of smoking alone, and exposure to (UV) sunlight in addition to arsenic further increases skin cancer risk.

Usually, the latency period for the development of skin symptoms (esp. keratosis) is considered to be 10 years, and for the development of skin cancer and internal cancers it is considered to be 20 - 30 years. However, shorter latency periods occur, and the latency period for other health effects (especially reproductive ones) may be shorter too. Much remains to be learnt about the susceptibility to, and progression of arsenicosis.

There is no effective medical treatment for arsenicosis. Switching to an arsenic-safe water supply is always important, and in the early stages of the disease may lead to a -sometimes rapid- reversal of skin symptoms. However, even with an apparent complete reversal of symptoms, the risk of developing cancer may remain higher than normal in exposed individuals. Use of ointments to soften cracked skin can provide symptomatic relief and may prevent infection. Anti-oxidant vitamins (C, E) are sometimes provided to patients because there are some indications that they may lead to higher levels of arsenic methylation.

Patient identification in Bangladesh 3.3

In Bangladesh, the population exposed to arsenic in water above 0.05 µg/L is large (28-35 million according to estimates by BGS and DPHE). All arsenic mitigation programs in Bangladesh include a patient identification component, following a protocol for the recognition of likely cases. Protocols in use have changed over time, although some standardization is likely to occur following the approval of the proposed WHO protocol by the Ministry of Health in Bangladesh. This protocol (figure 3.1) was endorsed by a WHO regional expert meeting in November of 2003. A test of the protocol in Bangladesh demonstrated that over 90% of the cases diagnosed as positive by a general physician were also diagnosed as such by the expert (N=183). In general (and also in the approved protocol), the following aspects are considered in identifying arsenicosis patients:

1. Pigmentation and keratosis;
2. History of chronic exposure to arsenic in water;
3. Biomarkers for exposure to arsenic (arsenic in hair, nails or urine).

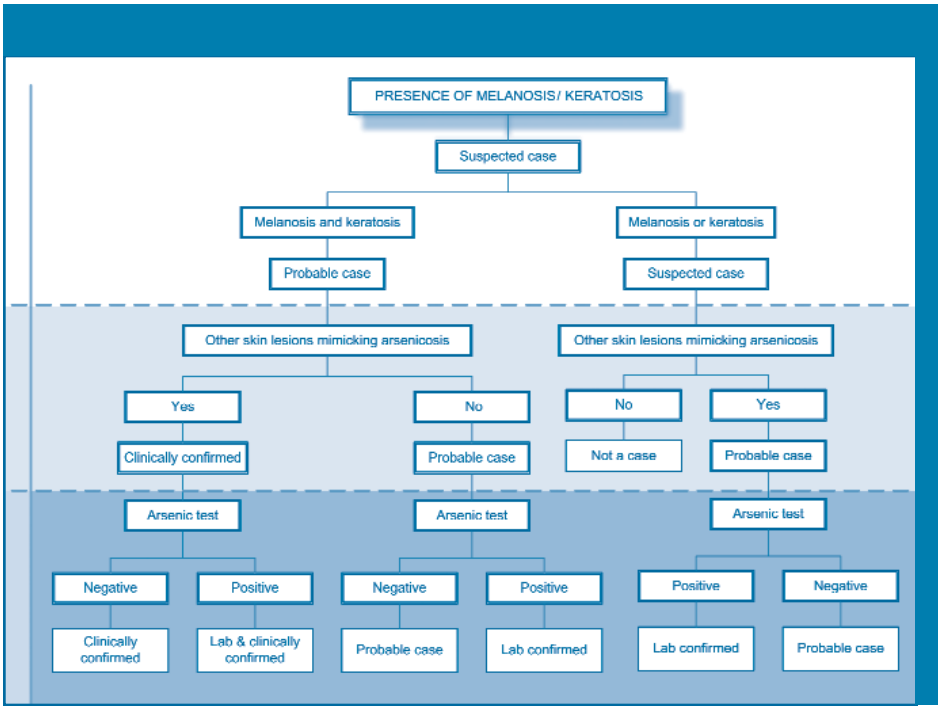
Melanosis and keratosis are considered diagnostic of chronic arsenic toxicity, and in the WHO protocol, people identified based on those dermatological criteria are considered "suspected cases". Dermatological symptoms together with a history of chronic exposure for more than six months identify a "probable case", while probable cases with positive biomarkers for exposure become confirmed cases.

In the 15 upazila area, patient identification was mostly carried out either by doctors from Dhaka Community Hospital (DCH) carrying out house-to-house searches, or by doctors from the DGHS assisted by DCH doctors, organizing union-level health camps. Only in one upazila was patient identification carried out by DGHS staff alone. Reports submitted to UNICEF by DCH and DGHS were used to supplement the findings of the data analysis (DCH 2002a; DCHb 2002; Dey 2002)

In all cases, potential patients were informed of the purpose of the screening, and were examined by a doctor after having given their consent. Personal bio-data and behavioural data were recorded for all patients, as well as location, water use patterns, etc. Biological samples (blood, urine, hair, nails) were taken from a number of patients, and analyzed at site or in the laboratory.

Suspected patients were provided with skin ointment (to help soften skin affected by keratosis) and anti-oxidant vitamins (a recent study by the Bangladesh Arsenic Control Society seems to confirm that this is a good thing. Rabbani, Ali et al. 2003 report that the use of vitamins and minerals increases arsenic elimination from the body). In some of the upazilas, NGOs continued to provide patient care (e.g. DCH in Serajdikhan and BRAC in Bhanga), while in others patients were referred to the upazila health complex for monitoring and follow-up care.

Figure 3.1: Algorithm for definition of non-cancerous arsenical dermal lesions



Source: WHO (2004).

Available fifteen upazila patient data 3.4

The patient data available for the fifteen upazilas are of very mixed quality. Most comprehensive is the information collected by DCH for UNICEF. This includes individual records on all the identified patients with information on location, age, sex and other details, as well as some of the blood test and laboratory results. Not available however, are the data of a case control study reportedly carried out by DCH in one or more of the upazilas. This is a pity, since case controls would have made it possible to make (hopefully meaningful) comparisons between patients and non-patients, and perhaps to come to some conclusions about factors contributing to the development of arsenicosis. As it is, no comparison with the general population is possible, since all records relate to patients only. If general population health data can be obtained at some point in the future, a comparative analysis would be useful. Individual records from the eight upazilas screened by the DGHS are not available, not complete, or not unambiguous. For Shahrasti upazila, only a total number of patients is known; no other data are available at all.

For this reason, the analysis of data will be presented in stages. An upazila-wise summary of all available patient data will follow in the next section. A more detailed analysis of only the data collected by DCH will follow the overview. The next chapter will examine well and patient data for three unions in even greater detail.

A further point to keep in mind is that patient data represent a moment in time. Anyone developing symptoms of arsenicosis after the initial patient survey will not be included in the figures. This means that over time, the data set will become more and more outdated. In theory, arsenicosis is a reportable disease, meaning that figures on patient numbers will start showing up in the national health information system. Augmenting available survey data with such nationally reported figures would ensure availability of a more up-to-date dataset.

3.5 Summary fifteen upazila patient data

A total of 2,682 patients were identified in the 15 upazilas, as summarized in table 3.1. In the health camps, the first identification was done by village health workers, with confirmation by doctors. Of 2,553 patients identified by health workers in seven upazilas, 651 were confirmed by doctors. This represents a rate of almost 75% of false positive identifications by health workers. A similar finding of high rates of false positive identifications in the original 5-upazila project implemented by DPHE/UNICEF prompted the switch to using trained doctors for patient identifications.

In every upazila for which a breakdown by sex is available, the number of male patients exceeds the number of female patients. Overall, there are 3 male patients for every two female ones. This is also true for the upazilas without individual sex disaggregation; the DGHS reported 51.1% male, and 48.9% female patients. This apparent discrepancy is likely a reflection of the fact that access to health care is more restricted for women than for men, so fewer women end up being diagnosed. A real difference in prevalence rates could be caused by behavioural influences which are known to increase susceptibility to arsenicosis, such as smoking.

Table 3.1: Total number of patients by upazila and arsenicosis incidence per 1000 exposed

Upazila	Investigator	Male patients	Female patients	Total	Exposed Population (> 50 ppb)	Arsenicosis prevalence per 1000 in population exposed > 50 ppb	Average arsenic concentration in wells>0.05 mg/L (Lab data)
Bhanga	DCH	287	201	488	305,885	1.60	0.23
Haim Char	DCH	24	8	32	102,363	0.31	0.24
Manirampur	DCH	36	14	50	259,120	0.19	0.11
Muradnagar	DCH	238	202	440	570,848	0.77	0.21
Nabinagar	DCH	124	88	212	423,341	0.50	0.25
Serajdikhan	DCH	61	43	104	135,272	0.77	NA
Shib Char	DCH	193	88	281	139,754	2.01	0.20
Babuganj	DGHS + DCH			115	84,946	1.35	0.40
Bancharampur	DGHS + DCH			69	211,994	0.33	0.23
Barura	DGHS + DCH			51	307,270	0.17	0.20
Damurhuda	DGHS + DCH			200	77,589	2.58	0.14
Homna	DGHS + DCH			77	191,099	0.40	0.23
Kalia	DGHS + DCH			42	163,701	0.26	0.15
Rajoir	DGHS + DCH			97	213,372	0.45	0.20
Shahrasti	DGHS			424	245,303	1.73	0.31
Grand Total				**2,682**	**3,431,857**	**0.78**	**0.24**

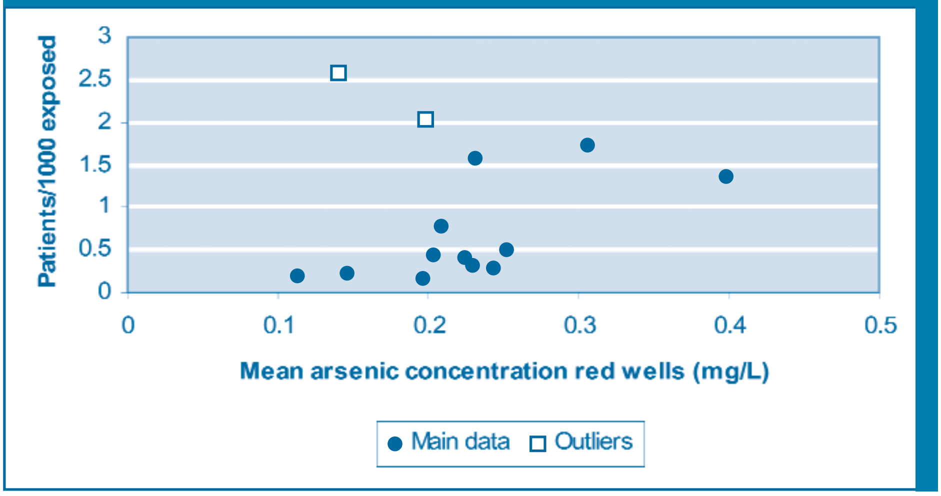
Correlation of arsenic exposure and patient numbers 3.5.1

That factors contributing to the development of arsenicosis are many and varied was mentioned earlier. Table 3.1 brings together some of the information we can use to investigate any relationships. The prevalence figures shown in the table were derived assuming that all patients are users of well water with arsenic levels in excess of 50 ppb, and adding up the recorded user numbers for all functioning household wells not used for irrigation which are contaminated above that level. Prevalence is generally low, ranging from 0.17 to 2.58 per thousand, with the average across the area at 0.78 per thousand. The highest prevalence figures occur in the upazilas with the lowest percentage of wells contaminated above the standard (Damurhuda with 20% affected wells and Shib Char with 45%).

Of course the proportion of contaminated wells is less important than the absolute level of exposure. All else being equal, we would expect to see some relationship between the level of arsenic exposure in the population and the number of individuals developing symptoms of arsenicosis. With average arsenic concentrations in Damurhuda and Shib Char being (well) below the average for the 15 upazilas, it becomes ever harder to explain the high disease prevalence levels in those upazilas.

We used the laboratory data described in the previous chapter, and determined the mean arsenic concentration of all measured wells exceeding 0.05 mg/L. Considering this to be representative of the level of arsenic exposure in the population using red wells, we looked for any correlation between exposure level and prevalence of arsenicosis in the exposed population. The expectation would be that with increasing levels of arsenic exposure, we would see an increase in prevalence of arsenicosis (this expectation implies the use of one-tailed tests for significance). Although there is a small positive relationship, the coefficients of correlation are quite small, and not statistically significant (p=0.16 for Spearman's Rho). When we remove Damurhuda and Shib Char upazilas from consideration as being outliers which cannot be easily explained, the observed correlation between exposure level and disease prevalence increases to a highly significant level (Rho=0.73, p=0.004). Figure 3.2 shows a scatterplot of the data used in the analysis.

Figure 3.2: Mean arsenic concentration and arsenicosis prevalence



Taking the duration of exposure into account by considering the mean well age does not affect the outcome at all, since the average age of all wells is 8 - 9 years in all upazilas.

A last interesting observation is that in the censored data set prevalence seems to increase suddenly at an average arsenic level of 0.2 mg/L. Further work in Shib Char and Damurhuda will have to show whether removing these areas from the analysis was in fact justified.

Patient characteristics: age, income, education and occupation 3.5.2

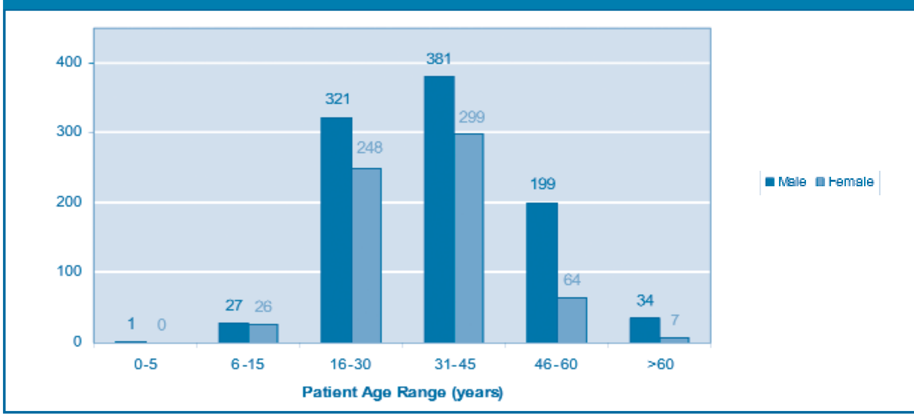
Some of the main characteristics of the patients are summarized in table 3.2. The mean age for men is significantly higher than that for women. Besides being younger, the women are also much less educated than the men. Please note that reported income is family income, and so the conclusion that women earn higher incomes is not necessarily correct. They just report higher family incomes.

Table 3.2: Age, household income, education and occupation for patients in seven upazilas

Characteristic	Males	Females	All patients
Mean age in years	37.1	33.7	35.7
Mean monthly family income in Taka	3333.-	3820.-	3528.-
Education (N=1607)			
None	238 (24.7%)	250 (38.8%)	488 (30.4%)
Primary	357 (37.1%)	251 (39.0%)	608 (37.8%)
Secondary	244 (25.3%)	107 (16.6%)	351 (21.8%)
Beyond secondary	76 (7.9%)	23 (3.6%)	99 (6.2%)
Degree	48 (5.0%)	12 (1.9%)	60 (3.7%)
Other	0	1 (0.2%)	1 (0.1%)
Occupation (N=1607)			
Farmer	426 (44.2%)	19 (3.0%)	445 (27.7%)
Business	219 (22.7%)	12 (1.9%)	231 (14.4%)
Service	73 (7.6%)	12 (1.9%)	85 (5.3%)
Other	245 (25.4%)	601 (93.3%)	846 (52.6%)
Total Numbers	963 (59.9%)	644 (40.1%)	1,607 (100%)

Age range and sex of all patients is shown in figure 3.3 below. The youngest patient is a 5 year old boy, but the majority of patients is in the 16 - 60 age range. Note that men dominate all age ranges from young adult to old age.

Figure 3.3: Age range and sex of arsenicosis patients



3.5.3 Exposure to arsenic and development of arsenicosis

In section 3.5.1, we looked at upazila-wide well arsenic concentrations and arsenicosis prevalence. A more precise and detailed approach would entail pairing identified patients with their individual water source(s) and investigating duration and level of exposure to arsenic. The available data do not allow us to get to that level of detail, in part because no dose information is available in them. However, in the remainder of this section some of the features of the patient dataset will be summarized.

Table 3.3: Summary patient data

	N	Minimum	Maximum	Mean	Percentage
Well Characteristics					
Age of well (years)	1607	1	50	11.3	
Depth of well (feet)	1607	25	800	91	
Well tested for arsenic	1607				78.3%
Well arsenic level>50 ppb	1607				78.1%
Water Use and Arsenicosis Symptoms					
Years of well water use	1607	2	70	23	
Duration of arsenicosis symptoms (years)	1607	0	20	3.6	
Years of water use before onset of symptoms	1607	0	10	4.3	
Smoking					
Smoker					32.4% (93% men)
Years of smoking		0	45	6.1	
Arsenic in Urine and Nails					
Urinary arsenic concentration (µg/L)		5.9	4588	89.5	
Nail arsenic concentration (mg/kg)	104	523	13297	4011.2	

Table 3.3 shows that arsenicosis patients have wells which are on average about two years older than the overall mean well age, and the proportion exceeding the 50 ppb threshold is much larger than the average (78% vs. 66%). Not every well had been tested yet at the time of the survey. According to the patient identification protocol, a patient can only be a "suspected" case (not probable or confirmed) until his or her water source has been shown to contain arsenic at a concentration exceeding the standard.

On average, patients had been showing symptoms for almost four years before being identified, and the present well water had been used for more than four years before symptoms became evident. It is also clear however that well water use was common long before the present well started to be used, and this confuses the investigation of any link between present well use and arsenicosis symptoms.

Arsenic in nails and urine will be considered in a later section.

Looking at (likely) duration of exposure and the number of years symptoms have been evident gives the boxplot of figure 3.4. The data plotted were restricted to only those patients using ground water for drinking (shallow tubewell, deep tubewell or hand dug well) which had been shown to exceed the 50 ppb limit.

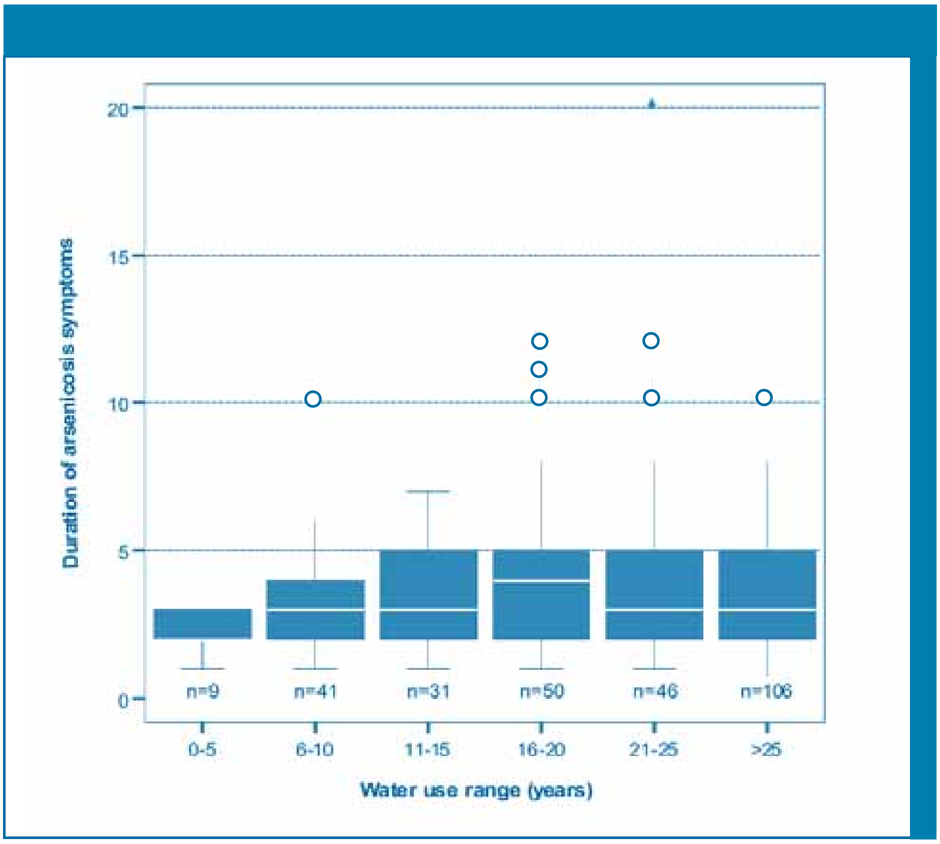
However, even by narrowing the data considered in this way, no clear relationship between time of exposure and onset of symptoms is obvious. The distribution of the duration of arsenicosis symptoms is practically similar for each period of well water use. In fact, the majority of patients have not been experiencing their symptoms very long, even if they have been using well water for a long period of time. This may be a result of the data collection method, rather than a reflection of reality (although severe keratosis would probably not go unnoticed, it is possible that diffuse melanosis is simply not noticed by patients), but this is conjecture. There also appears to be a group of patients that have in fact noticed symptoms almost immediately after starting to use well water. Looking for statistical evidence of a correlation between duration of well water use and duration of symptoms shows a weak positive relationship without significance ($r=0.026$, $p=0.331$).

Exploring some of the variables a bit further shows that looking for a direct relationship between well water use and arsenicosis is probably not very meaningful in this case.

Of the 1,607[1] patients, 1,254 (78%) report using surface water for drinking, while 46 have a well with arsenic below the standard level. For cooking the situation is reversed; 90% of patients use ground water in the preparation of food. This is very different from what would

[1] DCH reports 1637 patients in its patient identification report. However, 30 listed patients with vague or questionable diagnosis were not considered in the analysis, leaving 1607.

Figure 3.4: Distribution of duration of arsenicosis symptoms by duration of well water use (N=283)



be expected, and from findings reported by others (e.g. Caldwell et al, (2003) report 25% surface water use for cooking and 5% for drinking). It is hard to decide what to make of these data; all respondents have arsenicosis, all report having and using a well and the majority of wells are arsenic contaminated (78%) or have not yet been tested (22%). It is possible that the practice of drinking surface water only started recently, following the testing of the wells. Mistakes in data entry also belong to the possibilities (it is possible that the water use categories for drinking and cooking were switched during entry).

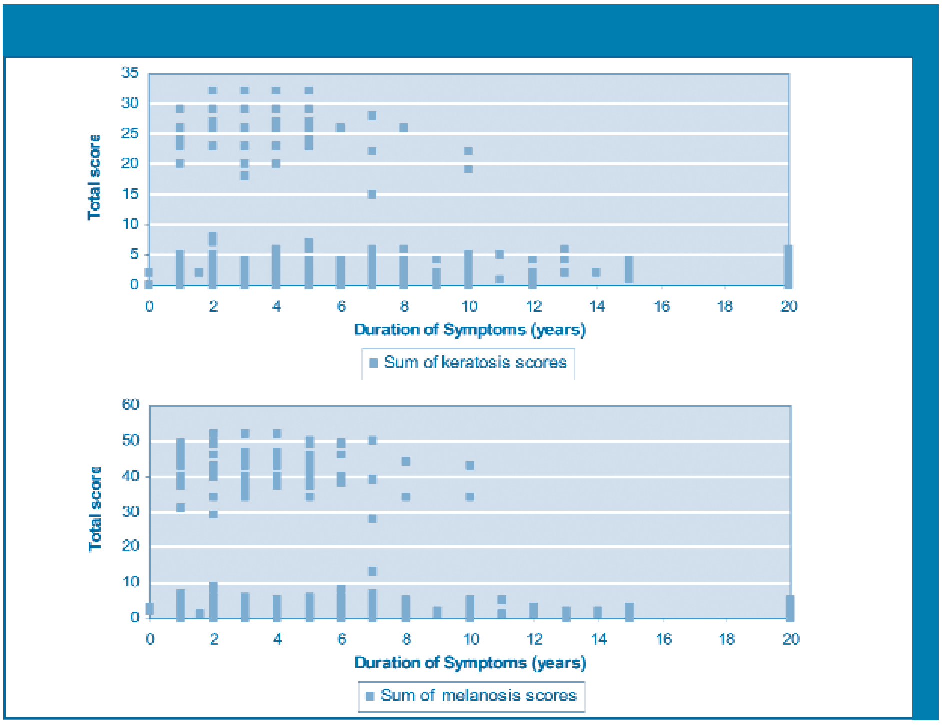
In addition, it appears that a majority of patients must have been using one or more other wells before starting to use their household well referred to in the data set. A total of 1,147 patients (71%) reported using well water for more years than they have owned a well. And 177 users (11%) said their symptoms showed before they owned a well themselves. There are also eight patients who say they have had symptoms even from before they started using well water. In other words, considering current exposure (by looking at well contamination level of the wells owned by families) is not sufficient. A significant portion of the patients in the seven upazilas had been using wells for a long time before coming to own a well themselves.

It is those wells as well as the current ones that would have contributed to the development of arsenicosis. This would also explain why it is possible that someone who is currently using a green well could still be diagnosed with arsenicosis.

Since individual severity scores are given for all symptoms, the data were examined for a relationship between period of illness and severity of symptoms. Each individual symptom (keratosis on the left hand for example) is scored in the database on a scale from 0 (not present) to 4 (severe). To look at relationships, all individual scores for each patient were first added up. This gave total keratosis scores between 0 and 32, and melanosis scores between 0 and 52. On average, patients had had symptoms for 3.6 years. Nine percent of patients had had symptoms for more than seven years, with 20 years being the longest period. The majority of the diagnoses were made on the basis of a patient presenting with melanosis only (29%) or melanosis with keratosis (68%). The remainder of the diagnoses (3%) were based on patients with keratosis only.

The totaled scores were plotted against the duration of symptoms (Fig. 3.5 a and b). The expectation would be that symptoms would be more severe for those patients who have shown symptoms longest.

Figure 3.5: Severity of keratosis and melanosis by duration of symptoms



As a matter of fact, the opposite is apparent from the data; patients who have had symptoms longest have the lowest total severity scores, with a marked absence of any high scores after ten years. The gaps in the middle of the plots indicate that most patients have either predominantly low scores, or predominantly high scores for all symptoms, but no combination of high and low scores. Examining the data in three dimensions (not shown) reveals that low melanosis scores are clustered with low keratosis scares, and high scores with high scores. Melanosis and keratosis scores are significantly correlated ($p<0.001$) which matches the fact that the majority of patients present with both keratosis and melanosis.

A possible explanation for the lowering of scores with time is that those who have had symptoms longest at some point stopped drinking well water, and are slowly improving. The author is not familiar with any studies reporting diminishing dermatological symptoms with increasing period of exposure. A further observation is that 98% of all data are concentrated in the first ten years; only 2% of patients (32 in number) have had symptoms for more than 10 years. This is a very small number to base any firm conclusions on, and further work is warranted. Obviously one of the questions which would need to be looked at is whether the drop in numbers after a long period of exposure could be explained by a high mortality rate.

3.5.4 Hair and nail samples

All patients had their urine tested for total arsenic. While such spot measurements are not always very useful (it would be better to perform measurements on a full 24 hours of urine production, although this is logistically difficult), in cases of chronic exposure the arsenic levels measured this way may be fairly representative of the "true" arsenic level in urine. Normal "background" arsenic levels are <10 µg/L in Europe, and <50 µg/L in Japan. DCH uses a normal level of 40 µg/L. Results of the tests are shown in table 3.4.

Table 3.4: Summary of urinary arsenic test results.

Urinary Arsenic, µg/L	No. of patients	Percentage
<10	7	0.4
11-40	722	44.9
41-100	489	30.4
>100	388	24.1
TOTALS	1,606	100

According to the results in this table, 55% of patients have elevated arsenic levels in urine. However, only 22% of all patients report using well water for drinking. This proportion is exactly the same in both the group with normal and the group with elevated urinary arsenic levels. Other exposure routes (e.g. eating of fish) must have contributed to the arsenic in urine unless the water use data contain errors.

Fingernail or toenail clippings were taken from 104 of the patients, and were analysed for arsenic. Results showed that virtually all patients have elevated arsenic level in their nails ranging from 0.5 mg/kg (normal) to 13 mg/kg.

There is no meaningful correlation between urinary arsenic level or nail arsenic level and melanosis or keratosis severity scores. There is no correlation between nail arsenic levels and duration of exposure, and there is no significant difference in nail arsenic levels between groups exposed <=5 years or >5 years (p=0.86).

Additional health-related data 3.5.5

Using the available height and weight data, the Body Mass Index (BMI) for all patients > 18 years of age was calculated[1]. Results are shown in table 3.5.

Table 3.5: Body Mass Index for arsenicosis patients

BMI	No. of patients	Percentage
<18.5 (underweight)	508	34.7
18.6-24.9 (normal)	905	61.9
25-29.9 (overweight)	45	3.1
> 30 (obese)	5	0.3
TOTALS	1,463	100

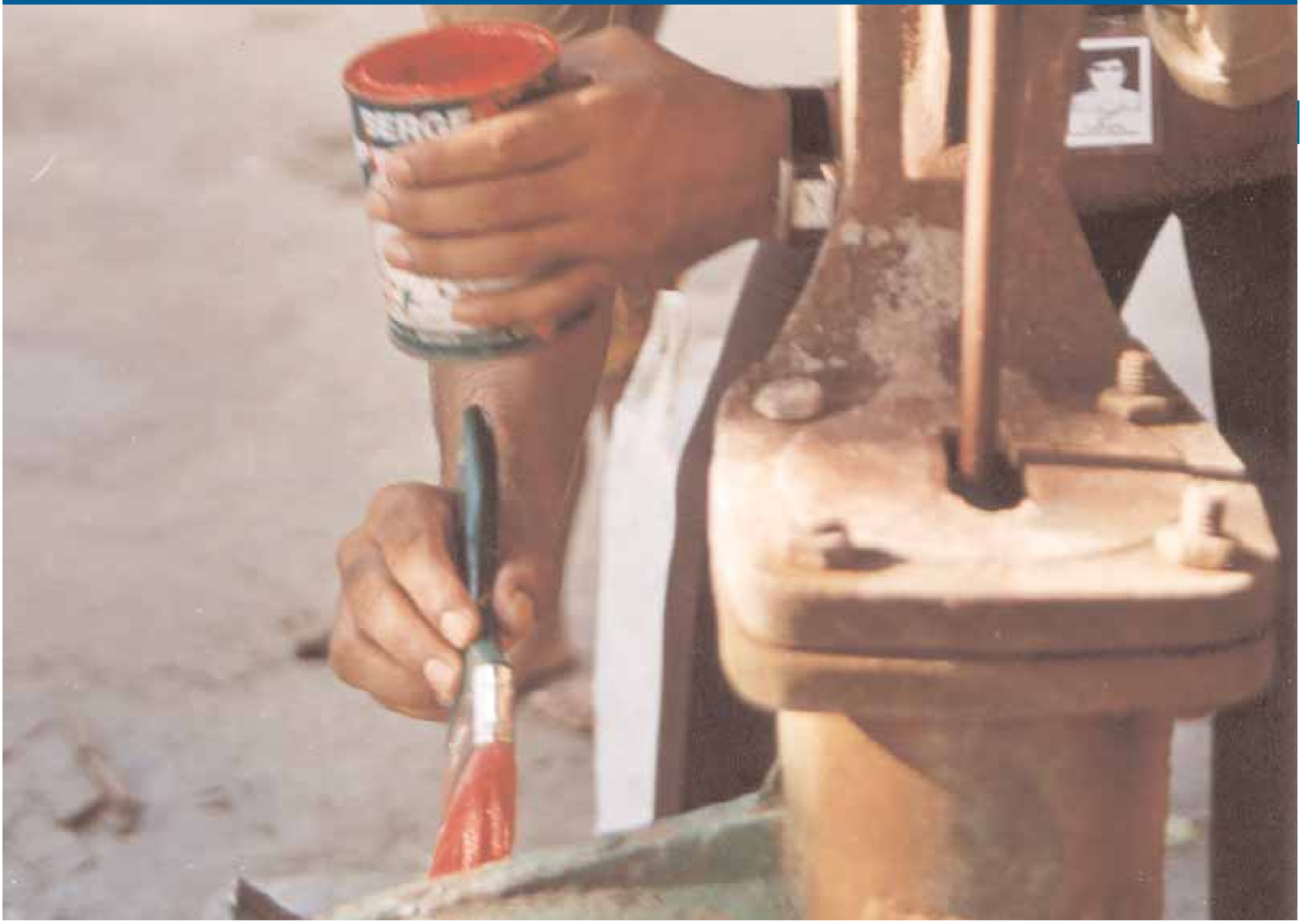
This shows rather a large group of patients classified as underweight. It is tempting to ascribe this to the effects of arsenicosis, but in the absence of comparative data on the population as a whole (i.e. not only patients) it would not be safe to make this assumption. If low BMI figures are normal for the population, one could suppose that nutritional status

[1] The BMI is a reliable indicator of body fat for adults. It is computed by dividing body weight in kilos by the square of height in meters, giving units of kg/m^2.

could be a contributing factor to the development of arsenicosis. If the high proportion of underweight adults is unique to the group of arsenicosis patients, the question would still need to be answered whether the patients have arsenicosis because they are underweight, or whether they are underweight as a result of having arsenicosis. A prevalence comparison study carried out in Bangladesh (Milton, Hasan et al. 2004) was not able to resolve causality. It concluded that poor nutritional status may increase an individual's susceptibility to chronic arsenic toxicity, or alternatively, that arsenicosis may contribute to poor nutritional status.

The dataset also contains information labeled as "complications from arsenicosis". However, many of the conditions listed could be complications from arsenicosis, but they also occur by themselves (e.g. conjunctivitis, bronchitis). And in any case, for 67% of cases complications are either not recorded, or recorded as "none".

Slightly less than one percent of patients reports experiencing social pressure as a result of their condition, and just over one percent report experiencing occupational pressure. It is not known whether in general the patients' environment is aware of their condition (the questions were asked during the patient survey. It is likely that for a large number of patients the survey was the point where they found out about their condition themselves).



Three Union Well Detail

4

4.1 Introduction

In addition to the general data overview presented in the previous chapters, three unions were selected for more detailed treatment. The reason for doing this is to find out whether there are any patterns or relationships at the local level that remain hidden at the aggregate level. The sort of "average" picture that emerges from looking at upazila-level data may obscure trends that occur at the union or village level.

As it happens, UNICEF had GPS surveys carried out in three of the 15 upazilas (reported in EGIS 2002), after the completion of well testing and patient identification. These surveys consisted of recording latitude and longitude for each well in Bhanga, Muradnagar and Serajdikhan[1]. Because of the availability of this additional information, it was decided to select one union from each of the three upazilas for further study.

The selected upazilas present a moderate geographic spread from East to central Bangladesh, and include two heavily affected upazilas (Bhanga and Muradnagar) and one moderately affected one (Serajdikhan). One union in each upazila was selected on criteria of:

Proportion of wells affected. The desire was for a balance between heavily affected and less affected. Unions with a very small number of unaffected wells were avoided however, since it is almost impossible to uncover any patterns.

Arsenic level in wells. Rather than just selecting on exceedence of the 50 ppb standard, exceedences for 100 ppb and 250 ppb were also determined, and unions with high arsenic levels in the water (rather than just a high number of affected wells) were selected.

Number of arsenicosis patients. The distribution of arsenic patients was determined, and unions with a relatively high number of patients were given preference.

[1] Within the 15 upazila area, a separate 3-upazila project was implemented, funded by the United Nations Foundation (UNF), with the objective of "Building Community Based Arsenic Mitigation Response Capacity in Bhanga, Muradnagar and Serajdikhan". It is this separate project which enabled additional work (such as the GPS survey) to be carried out.

The three unions selected after a review of those factors are listed in table 4.1. Their locations are shown in figure 4.1.

Table 4.1: Selected unions for further study

Upazila	Union	# of wells	No. of wells exceeding arsenic at the level				Patients
			>50	>100	>250	=500	
Bhanga	Bhanga	3,905	3,664 *(93.8%)*	3,140 *(80.4%)*	3,140 *(80.4%)*	3,132 *(80.2%)*	121
Muradnagar	Jahapur	1,959	1,709 *(87.2%)*	1,652 *(84.3%)*	1,437 *(73.3%)*	546 *(27.9%)*	38
Serajdikhan	Rasunia	1,404	557 *(39.7%)*	417 *(29.7%)*	417 *(29.7%)*	417 *(29.7%)*	56

4.2 Data set description

During the GPS surveys, mismatches between field findings and database records were noted, and rectified where possible. The types of error that occurred most frequently included: spelling mistakes in village and union names, tubewells listed in the database but not found in the field (and vice versa), mismatches between recorded and observed pump spout colour, none-unique numbering of wells in one village, and duplicate copies of the same well in the database. Many (but not all) of these inaccuracies could be fixed, leading to a higher level of accuracy for the three upazila data than for the 15 upazila data as a whole.

Prior to further analysis, the data were censored to exclude the following:

- Wells exceeding 0.5 mg/L arsenic (this is the highest possible reading for the test kits used;
- Wells for which spout colour and arsenic level do not match;
- Wells exceeding 1,000 feet (305 m) in depth.

This restriction increases the level of confidence with which we can approach the data. A summary of the censored well data is given in table 4.2. For comparison purposes, the full dataset was similarly censored for preparation of the "All data" column. This led to a total of 1,643 wells being excluded from analysis.

Figure 4.1: Location of the three selected unions

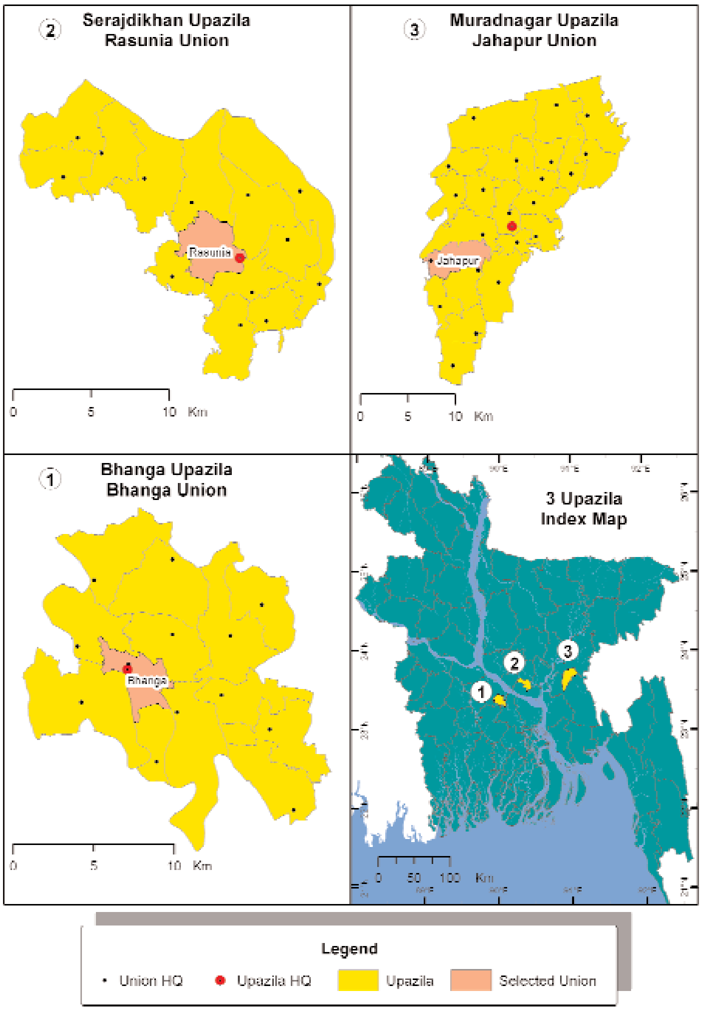


Table 4.2: Characteristics of wells in the three unions as compared to all data

No.	Item		Bhanga	Jahapur	Rasunia	3 Unions	All data
1	No. of villages		29	18	12	59	3,101
2	No. of wells		3,865	1,919	1,404	7,188	315,308
3	% Red wells		94.5	87	39.7	81.8	65.4
4	% Green wells		5.5	13	60.3	18.2	34.6
5	Average arsenic level (mg/L)		0.42	0.33	0.16	0.35	0.21
6	Median arsenic level (mg/L)		0.50	0.40	0.025	0.50	0.1
7	Average age (years)		10.6	8.4	8.9	9.7	9.1
8	Average depth (feet)		90	82	229	115	101.7
9	% wells <=15 feet deep		0.3	0.2	0	0.2	0.4
10	% wells 15-50 ft deep		1.3	5.1	0.2	2.1	12.0
11	% wells 50-150 ft deep		94.6	94.1	6.2	77.2	75.1
12	% wells 150-250 ft deep		2.5	0.6	61.5	13.5	10.3
13	% wells 250-500 ft deep		0.8	0.1	31.6	6.6	1.4
14	wells > 500 ft deep	No.	21	0	8	29	2,510
		%	0.5	0	0.6	0.4	0.8
15	Wells > 500 ft deep, and >50 ppb As	No	1	0	0	1	163
		%	0	0	0	0	0.05
		% in group	4.7	0	0	0	6.5

1. Do the well data provide any practical insights into the relationship between well depth and arsenic levels?
2. Do the patient data support any meaningful insights or conclusions about exposure to arsenic and health outcomes?

The following sections will consider these questions in turn.

4.3 Well depth and arsenic

A first look at plots of well depth against arsenic levels gives the pictures of figure 4.2. In Bhanga union, the picture up to 400 feet (122 m) well depth is mixed. There are contaminated and uncontaminated wells in that range. However, deeper than 400 feet only one of the wells is contaminated, (but there are only 21 wells deeper than 400 feet).

In Jahapur, it appears there is no depth at which contamination does not occur. Some of the highest arsenic levels occur in the few wells which extend beyond 150 feet (46 m). There are only two wells deeper than 250 feet (76 m), and of those one contains 500 ppb in arsenic.

Rasunia union sees all contamination cease below 400 feet (122 m), just like Bhanga (since only 10 wells are deeper than 400 feet, it is impossible to generalize about any arsenic safe depth interval). Above 400 feet, little can be said about what constitutes an arsenic safe interval.

To compare the upazila-wide situation with that in the individual unions, depth ranges and percentage arsenic contamination are plotted in figure 4.3 (similar to figure 2.25).

In Bhanga, there is very little difference in the depth-arsenic relationship at union and upazila level. Chances of finding arsenic safe water at any depth less than 500 feet are very slim. This is not to say that all 12 or 13 unions in Bhanga necessarily display this same pattern; it is possible that there are other unions with better chances at finding arsenic-safe water. However, the data we are considering here certainly does not show it.

Figure 4.2: Depth vs. arsenic levels for 3 selected unions (note different depth scale for Jahapur)

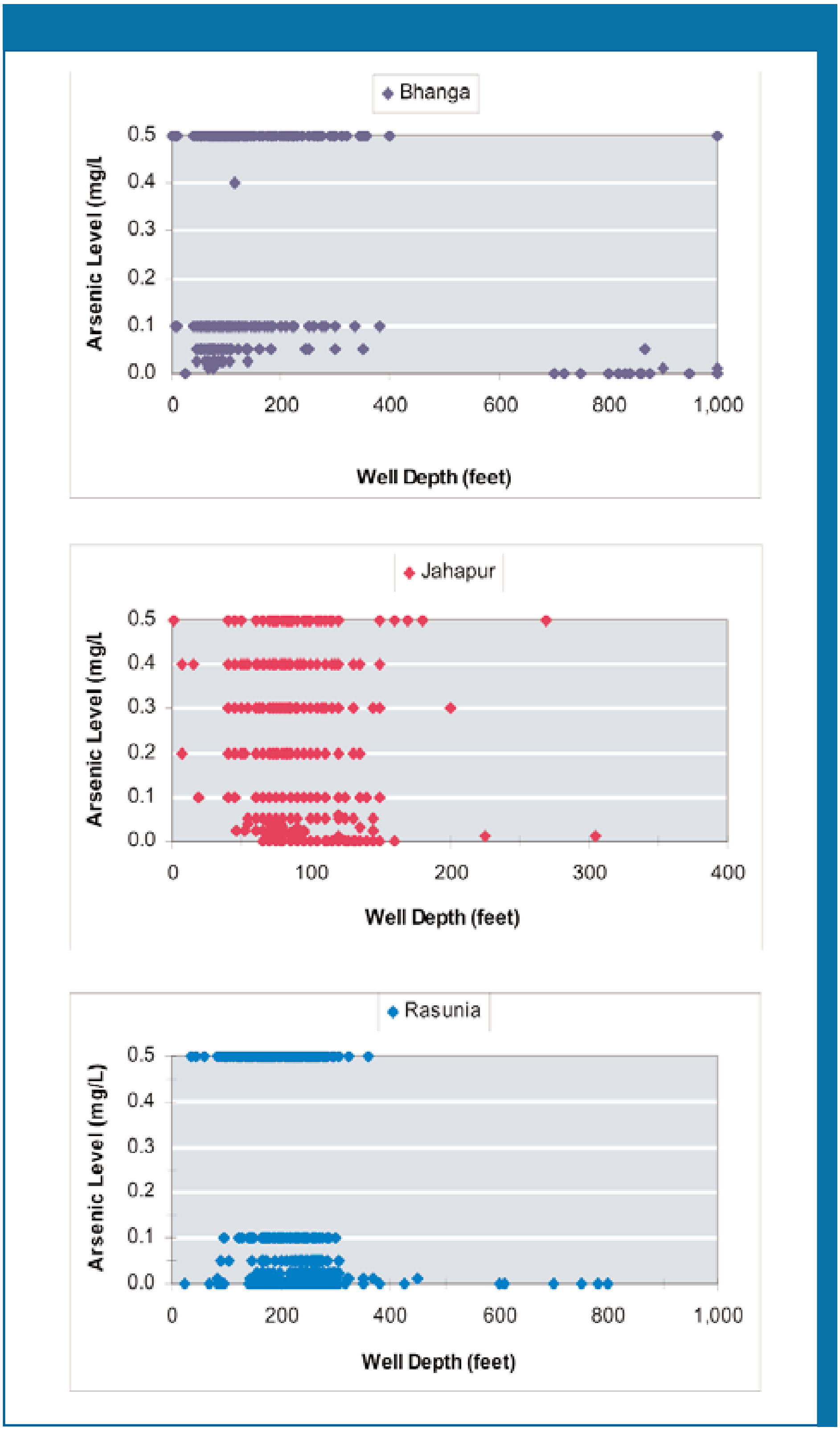
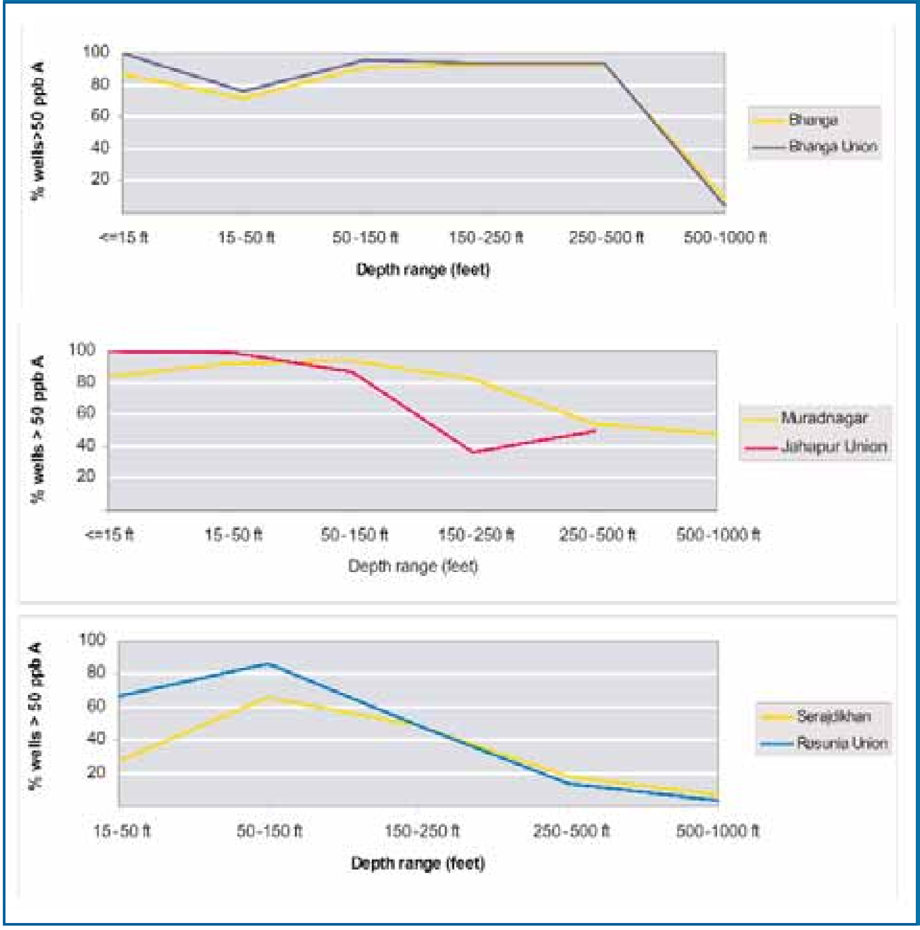


Figure 4.3: Likelihood of finding arsenic at depth intervals for union and upazila



In Jahapur Union, it looks as if the data at union level show some promise. Although the chances of finding arsenic safe water at depths up to 50 feet are actually lower than for the upazila as a whole, from 50 to 250 feet the likelihood of finding arsenic decreases by up to 40 percentage points, before becoming even again in the 250 - 500 feet range. However, the seemingly dramatic drop is caused by the fact that there are only 11 wells in the 150 - 250 feet depth interval (and only two wells in the next interval).

Rasunia Union is also less safe at shallower depths, although this could be a data artifact with just two wells in the 15 - 50 feet depth interval. At those depths with the largest proportion of wells, overall likelihood of contamination appears to follow the upazila data fairly well.

Apparently depth profiling at village level has been successful in identifying arsenic safe depths in villages in Araihazar upazila (van Geen, Zheng et al. 2003). Union level analysis in the current situation case does not offer significant advantages over analysis at upazila level.

Figure 4.4: Well arsenic distribution in Bhanga Union, Bhanga Upazila

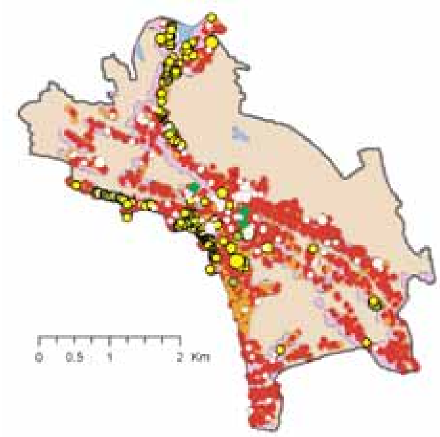


Figure 4.5: Well Arsenic Distribution in Jahapur Union, Muradnagar Upazila

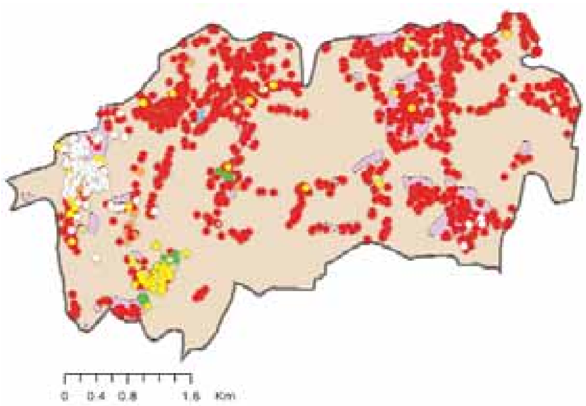
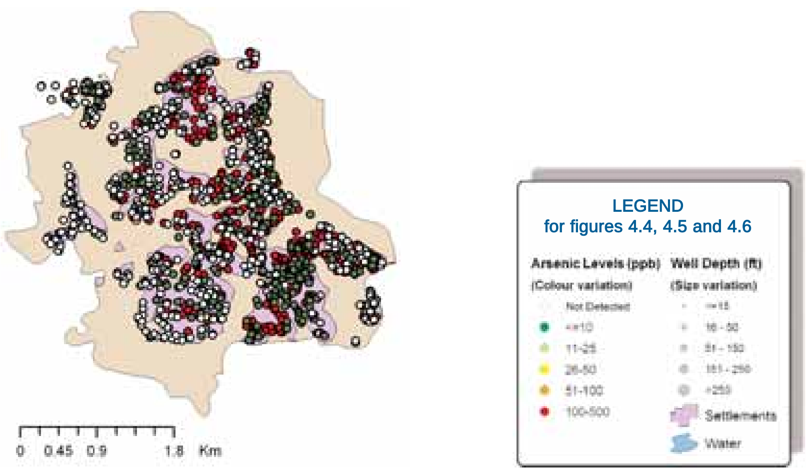


Figure 4.6: Well Arsenic Distribution in Rasunia Union, Serajdikhan Upazila



Considering spatial patterns of contamination and depth produces the maps shown in figures 4.4-4.6. In those figures, each well is represented by a dot, with well arsenic concentration denoted by dot colour, and well depth denoted by dot size.

Although arsenic-unsafe wells occur anywhere in Bhanga union, almost all arsenic-safe wells are clustered on the north, middle and west sides of the area. The whole western edge of the union generally has lower arsenic levels, even when they are above 50 ppb (orange and red colours). Since the yellow dots indicate wells where the test kit indicated 50 ppb arsenic, the margin of error in especially the northern part is very small. Most "no detect" wells (white dots) are clustered in the middle, and they appear to be of predominantly shallow depths.

In Jahapur union, the clustering of wells is even more pronounced. The majority of arsenic safe wells occur on the west side of the union. Unlike the situation in Bhanga, almost no wells exceeding the 50 ppb standard occur in the settlements where most wells are arsenic safe. Visually, it appears that the wells with a low but detectable arsenic level on the western edge are all deeper than the wells showing no arsenic detection. However, this is only a perception caused by the way the wells are displayed. In reality the "non-detect" wells are on average slightly deeper than the wells with arsenic levels close to the 50 ppb level.

In Rasunia union in Serajdikhan, the overall contamination rate is clearly much lower than in the other two unions, but even here a concentration of red wells is observable. The pattern is different from that in Jahapur and Bhanga however. Although one community seems to be completely free of arsenic contaminated wells, even in those settlements where contamination above 50 ppb occurs, arsenic safe wells can usually be found close by. We hardly see this occurring in the other two unions.

In general, looking at well depth alone gives little support for making decisions about continued well construction. Considering spatial distribution of contamination in the three unions however, gives some indications as to which areas to avoid (especialy in Bhanga and Jahapur), and which areas are more likely to lead to drilling of wells with low arsenic levels. There is no obvious explanation for these local patterns.

Visual inspection of the data presented in figure 4.2 shows the complete absence of any meaningful dependent relationship between well depth and arsenic level, and no correlation was attempted. Statistical investigations of well age and arsenic level show a (weak but significant) positive correlation. A significant difference in arsenic levels between wells less than 20 years of age and older ones exists in only one of the three unions (Rasunia). For the record, a summary of the findings of some of the tests is provided in table 4.3.

Table 4.3: Summary of some statistical findings

	Bhanga	Jahapur	Rasunia
Correlation			
Correlation of well age and arsenic (Kendall's tau)	0.052 ($p<0.01$)	0.023 ($p=0.09$)	0.26 ($p<0.01$)
Differences between groups			
Arsenic levels in wells <=20 years old, vs. wells >20 years old (Mann Whitney)	Median value 0.5 mg/L in both groups. No significant difference at 95% confidence interval ($p=0.23$)	Median value 0.4 mg/L in both groups. No significant difference at 95% confidence ($p=0.20$)	Median value 0.01 mg/L in youngest wells, and 0.5 mg/L in older ones. Significant difference at 99% confidence interval ($p<0.01$)
Arsenic levels in wells <=15 feet, 16-150 feet and >150 feet, excluding dug wells (Kruskal-Wallis)	Median value 0.1 mg/L in shallowest wells, 0.5 mg/L in all others. Difference is significant at 99% confidence. $\chi^2=67.82$, $p<0.01$	Median value 0.005 in deepest wells, 0.4 mg/L in all others. Difference not significant at 95% confidence (but is at 94%). $\chi^2=5.50$, $p=0.06$	No wells <=15 feet, but a significant difference at 99% confidence in arsenic level between the two other groups (median levels at 0.5 and 0.1 mg/L). $\chi^2=80.1$, $p<0.01$

Village level patient data 4.4

Any relevant generalizations about the consumption of arsenic contaminated water and health outcomes have so far eluded all investigators. The previous chapter concluded already that analysis of the seven upazila data does not reveal hitherto undiscovered patterns. The factors influencing the development of arsenicosis are probably too numerous, or too complicated to lend themselves to easy analysis. Not having access to health and population data beyond that of the arsenicosis patients themselves certainly does not help.

So it would be too much to expect that a further investigation of the same data at union level would lead to the sort of revelation we still hope for (but which may never come). It might have been revealing to investigate the water use habits of individual patients, but the available data do not allow the linking of any one patient with any one water source. However, it is possible to isolate water sources used in each village where patients exist, and to investigate whether these are in any way different from all water sources. In particular, differences in arsenic level, well depth and well age should be noted. The comparison will be presented in this section. Please note however that the method is very crude and lacks power; any apparent pattern or relationship would need to be further investigated taking into account specific water sources used by the identified patients.

Filtering out the required data showed up some flaws in the various data sets which are worth mentioning:

There is no gazetteer database of village or union names, and names of places tend to be spelled differently by different people. Thus the same names occur in different ways within and between databases (e.g. Shaifulla Kandi village in the patient database, vs. Sayfullakandi village in the well database). Almost inevitably, village names show up in one database without a clear equivalent in another (four villages with patients could not be located in the well database and had to be discarded from the analysis).

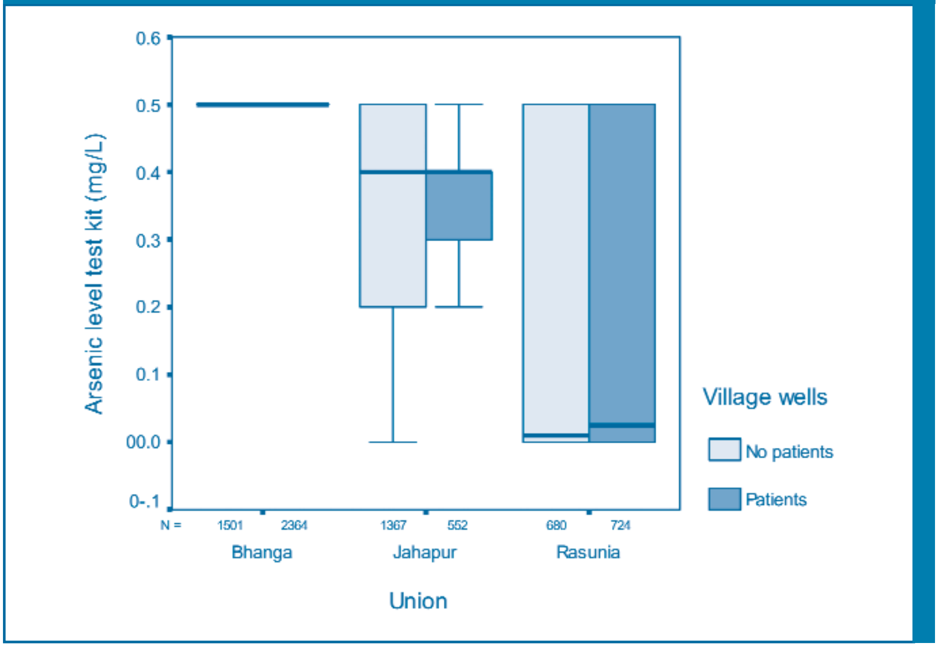
In addition, the patient database for Serajdikhan lists 41 patients in Rasunia union, while the GIS dataset shows 56 patients for the same area. All villages in the patient database which could actually be located in the well database were counted in the group of villages with patients. All others were placed in the "no patients" village group. Table 4.4 summarizes the results.

Table 4.4: Summary of villages with and without patients

Union	# of patients	# of villages with patients matched between well and patient database	# of villages without patients	Total Villages
Bhanga	121	17	12	29
Jahapur	38	4	14	18
Rasunia	41	4	8	12
TOTALS	200	25	34	59

Looking at the distribution of arsenic levels in the three unions (figure 4.7), we see that for villages with and without patients the differences among unions are pronounced, while the difference within unions appears much smaller. Please note however that for reasons of clarity, outliers and extreme values are not shown in the figures. In Bhanga union, the vast majority of wells tests at 500 ppb. Since this is the limit of the test kit, the likely reality is that the actual arsenic concentrations exceed even this very high level. In Jahapur the median values for arsenic levels may be the same, but the interquartile range for the group of villages with patients is much smaller, indicating a much smaller proportion of wells with lower arsenic concentrations. The data for both groups of Jahapur villages are negatively skewed . For Rasunia, both groups of data exhibit large positive skew, with essentially half the data in the upper quartile. Together with a low median arsenic concentration we thus see only a small proportion of the wells exceeding the 50 ppb level.

Figure 4.7: Arsenic level distribution in the three unions



To look for differences, we divided the data in each group of villages further, with one group containing all wells with arsenic levels up to 50 ppb, and one group containing all wells with arsenic levels above 50 ppb. In all unions, the percentage of wells exceeding the arsenic standard is higher in villages with patients than in villages without patients.

Testing for differences between groups shows that in all unions the difference is significant at the 95% confidence interval. In Bhanga and Jahapur it is significant at the 99% confidence interval[1] (table 4.5). Given the overall proportion of affected wells we are talking about (certainly in Bhanga and Jahapur), this finding does not provide decisive new information that can be used to target priority mitigation areas. Both unions should be considered high priority mitigation zones on the basis of the percentage of affected wells alone.

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Table 4.5: Summary arsenic contamination status for wells in villages with and without patients

Union	Arsenic Level	# of wells in villages without patients	# of wells in villages with patients	Test statistics
Bhanga	<=50 ppb	130 *(8.7%)*	84 *(4.0%)*	$\chi^2 = 45.8$ $p<0.01$
	> 50 ppb	1,371 *(91.3%)*	2,280 *(96.0%)*	
	Total Bhanga	**1,501**	**2,364**	
Jahapur	<=50 ppb	240 *(17.6%)*	9 *(1.6%)*	$\chi^2 = 88.3$ $p<0.01$
	> 50 ppb	1,127 *(82.4%)*	543 *(98.4%)*	
	Total Jahapur	**1,367**	**552**	
Rasunia	<=50 ppb	433 *(63.7%)*	414 *(57.2%)*	$\chi^2 = 6.2$ $p=0.013$
	> 50 ppb	247 *(36.3%)*	310 *(42.8%)*	
	Total Rasunia	**680**	**724**	

Differences in the distribution of well depths are also present (figure 4.8), but less pronounced, and also in different directions. Median well depth in villages with patients is larger in all three unions, but the range and interquartile ranges vary; smaller for Bhanga and Jahapur, but larger for Rasunia. Data distribution and median value are significantly different between groups in Bhanga (2 > 11) and Rasunia (2 > 35), but not in Jahapur (2 < 3). That patients would come from communities with more deep wells is unexpected, but as stated before, a more detailed investigation would be required to determine whether this is in any way a meaningful finding.

[1] Using the nonparametric Kruskal-Wallis test for ordered categorical responses

Well ages (figure 4.9) appear more different than similar, although the distribution is not the same between groups for all three unions. In Rasunia union, there is no significant difference between groups, either in median value or in overall distribution of the data (in other words, the wells in both groups come from the same population).

Figure 4.8: Well depth distribution in the three unions

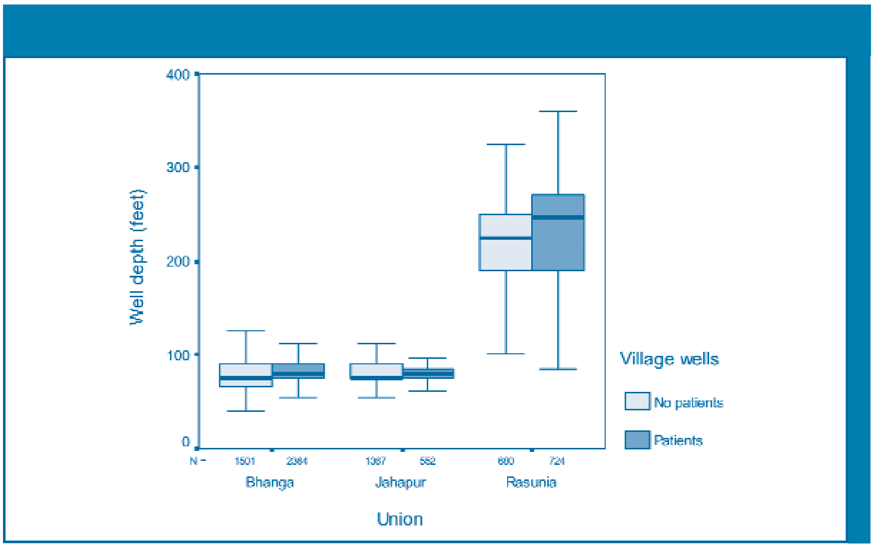
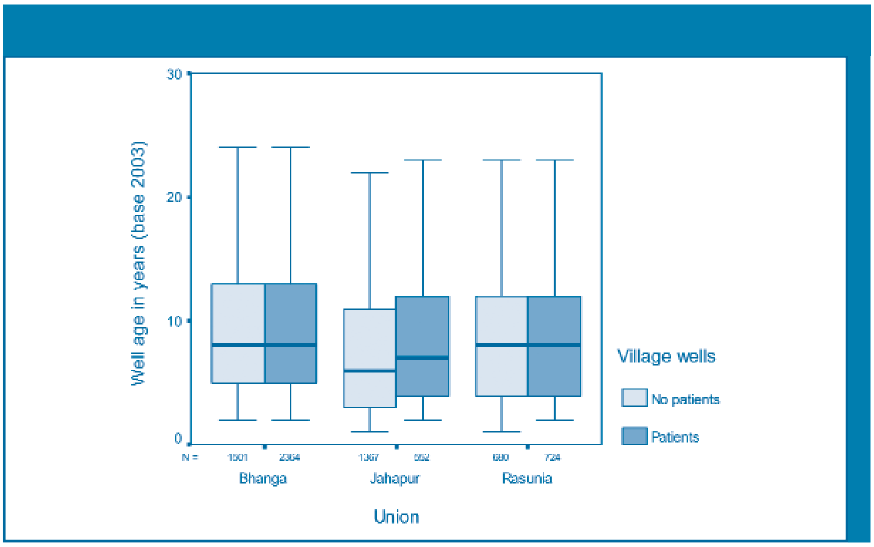


Figure 4.9: Well age distribution in the three unions

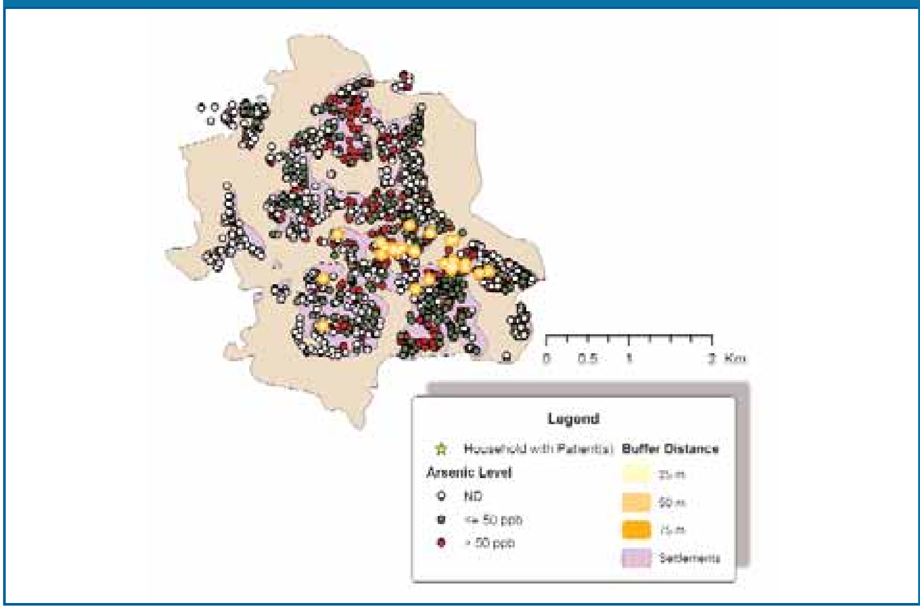


In Bhanga and Jahapur differences between median values and/or overall data distribution are significant, caused by and large by a larger proportion of older wells in the villages with patients, and a larger proportion of younger wells in the villages without patients. The differences are small however, and little practical significance can be attributed to these findings.

All in all, the only observation we appear to be able to make is that most patients are found in villages where more wells are affected with higher arsenic levels. Intuitively this makes sense, and reinforces the idea that mitigation should be focused on those communities which meet the criteria of many wells affected, and high levels of arsenic. However, the data are not so unambiguous that they can be blindly relied upon; Bhanga union for one provides an example where any obviously visible differences between villages with or without patients are non-existent.

In Serajdikhan upazila, the location of compounds where arsenicosis patients are present was determined by GPS. Although we still do not have information on individual water sources used by the patients, combining well and patient information in one map allows some further observations. Figure 4.10 shows the location of all patients, as well as the location and arsenic concentration of all wells. We can see that most patients are found in the area with the highest density of "red" wells. No patients are located in the settlement without affected wells on the west side, although there are two patients in the community with a low density of affected wells on the south-west side. There also appear to be two isolated patients on the lower east side, which are not part of a larger settlement, and which are not even in the close vicinity of a well. Their physical location suggests they may represent a particularly marginalized group which could be at elevated risk of arsenicosis.

Figure 4.10: Patient locations in Rasunia Union



The patient locations are "buffered" by three concentric rings, increasing in radius from 25 to 75 meters. Table 4.6 summarizes how close each patient is to a red or green well.

Table 4.6: Wells closest to patients

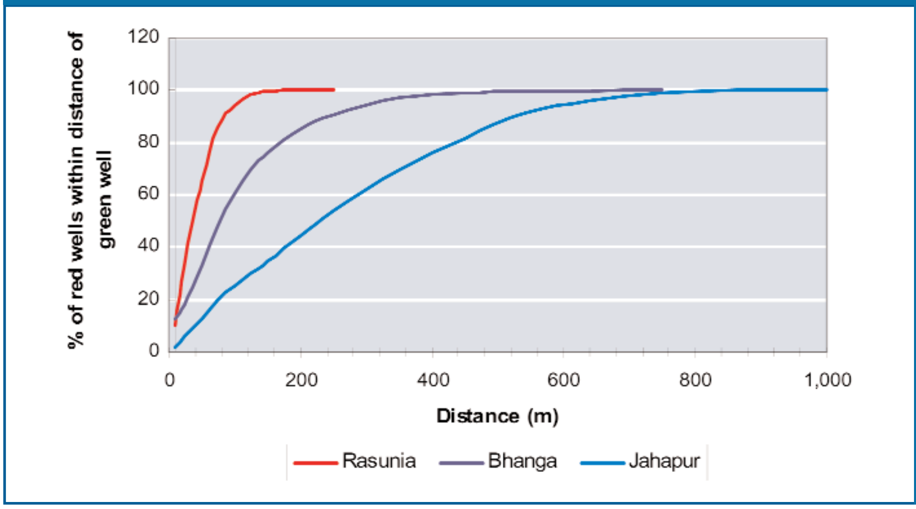
	Patients with access to a well within...		
	...25 m	... 50 m	... 75 m
Red well	73%	86%	96%
Green well	30%	68%	96%

We can see from this table that 43% of patients are closer to a red well than a green well. Expanding the radius to 50 meters from the location of the patient, only 18% of patients are closer to a red well than a green well. Assuming that obtaining access is not an issue, all but two patients would have access to a green well within 75 meters of their location.

Access to arsenic safe water 4.5

Applying the same buffering mechanism to the arsenic safe wells in each union allows us to determine at what distance users of arsenic affected wells could find uncontaminated water. The plot in figure 4.11 shows the percentage of red wells within access of a green well for different distances. Unsurprisingly, it is not difficult for red well users in Rasunia to find a green well close by: 95% of red wells are within 100 meters of a green well. This is explained by the low proportion of red wells, and their spatial distribution.

Figure 4.11: Distance to nearest green well from a red well in 3 Unions



The situation in Bhanga and Jahapur union is not as favourable. The proportion of arsenic safe wells in both those unions is much lower than in Rasunia, so it is not so surprising that access to green wells is harder to find. In Bhanga 15% of red wells is more than 200 meters away from an arsenic safe well. In Jahapur almost half the owners of red wells (46%) will have to walk further than 250 meters for arsenic safe water. The actual percentages are listed in table 4.7. This would suggest that well sharing (if socially feasible) would be more of a constraint in some areas than is sometimes supposed (see e.g. van Geen, Ahsan et al. 2002 who report on well switching in Araihazar upazila).

Table 4.7: Access to arsenic safe water by users of red wells

	Red well users with access to a green well within a distance of …			
	… 25 m	… 50 m	… 75 m	… 100 m
Rasunia	34%	65%	86%	94%
Bhanga	7%	20%	32%	43%
Jahapur	5%	11%	17%	23%

It is clear that there is not one approach that can apply to all situations. In Rasunia, finding ways to encourage people to share arsenic safe water could result in a significant lowering of the overall exposure of the population of the union. In Bhanga, and certainly Jahapur, potential gains are much lower. Contamination rate alone does not determine this; the pattern of contamination is important too. After all, Bhanga has a higher contamination rate than Jahapur (93% vs. 87%), but in almost each of the four buffering intervals, the percentage of red wells within range of an arsenic safe well is twice as large.


এইগুলো আর্সেনিক দূষণে
আক্রান্ত রোগের লক্ষণ
করে
পরামর্শ নিন

Social Survey Data

5

5.1 Introduction - goals, surveys, challenges & findings

One of the four components of the UNICEF arsenic mitigation program was the implementation of a Behaviour Change Communication (BCC) campaign to inform community members about the occurrence and effects of arsenic, to explain the mitigation programme, and to suggest ways to reduce or avoid arsenic exposure. Surveys to assess the effectiveness of this campaign were conducted as part of the 15 upazila arsenic mitigation project.

The surveys aimed to measure the knowledge levels, attitudes and behavioural patterns of respondents living in arsenic-affected areas. The first survey, referred to hereafter as the baseline survey, or baseline, was conducted between July and September of 2001. The subsequent survey, referred to as the follow-up survey, or follow-up, took place in March-May, 2002. In the period between surveys, UNICEF (and others) carried out dissemination programs to make people aware of the problems associated with arsenic contamination. This chapter presents an analysis of the data collected during those surveys. The primary objective of this analysis is to determine whether these dissemination programs increased the level of arsenic-related awareness and knowledge. We would also like to find out whether varying levels of knowledge and attitude among the respondents appear to explain the variance in their stated willingness to take action or to spend money to prevent arsenic-related problems.

Section 5.2 below presents socio-economic and demographic statistics for the respondents from the baseline and follow-up surveys. Descriptive statistics are compared across districts and between baseline and follow-up surveys within each district. Section 5.3 tries to assess whether responses to survey questions change in the aggregate between baseline and follow-up surveys. Section 5.4 tries to identify variables or attributes that are significant in explaining the variations in knowledge, attitude and behaviour of the respondents. We also ular measure. Section 5.5 traces the characteristics of the group that had undertaken testing before the baseline survey occurred. We also try to see whether those who switched from a contaminated water source are any different from the rest of the sample.

5.1.1 Data

The surveys covered the full 15 upazila area (15 upazilas in 10 administrative districts). This report uses 4,453 observations (2,909 observations from the baseline and 1,544 observations from the follow-up survey). The division by district and by the NGO collecting the data is the same as reported in the introduction of this report; the same NGOs which were responsible for the screening and communication were also responsible for carrying out the baseline and follow-up surveys.

One of the NGOs conducting the survey slightly altered its format. In some cases, the degree of difference between the questions precluded us from using responses from the altered survey. In other cases, there was either no difference or the difference was minor, allowing us to use those responses along with the other survey responses. This occurred in four districts: Chandpur, Comilla, Jessore, and Faridpur. All of the responses from Jessore and Faridpur were from this NGO. For Chandpur and Comilla there are responses from the altered and the standard surveys. In the tables and figures below that compare baseline and follow up groups, we have simply combined the responses from the two surveys. In additional statistical (specifically regression) analyses whose goal is to compare the baseline and follow up groups while controlling for the groups' characteristics, we also include a variable to control for the possibility that the survey alteration itself induces different responses. The details of the differences between the surveys are documented in annex 5.

5.1.2 Methodology

In Section 5.3 and its subsections, we focus upon the percentage of respondents who answer correctly any given knowledge or attitude question. It is considered positive if the percentage responding correctly increases between baseline and follow-up surveys. To see whether the increase is higher or lower for respondents with low education and income, we constructed two subsets of the data: those with monthly income less than or equal to Tk 4000 (~US$69) and no schooling or only non-formal education; and those with monthly income greater than Tk. 4000 and having primary education or higher. We have 1,147 observations in the former ("income=0, education=0") and 1,293 in the latter ("income=1, education=1") group. This income dividing line is simply convenient for creating roughly equally sized subsets of the households that we most clearly expect may differ in bahaviour. We do not make a special comparison between the higher-income lower-education and lower-income higher-education sets of households because we have a less clear prior expectation that they will differ. Overall, 65% of income was "lower" by this definition while overall 32% of education was "lower".

To assess the impact of dissemination (i.e. investigate whether and to some extent why knowledge levels or attitudes vary between the baseline and follow-up surveys), we have created a dummy variable 'id' (with the value zero for baseline and one for follow-up) for inclusion in the regression analysis. If the coefficient of the 'id' variable is significant, then we will conclude that dissemination programs could have had a significant effect on the knowledge levels and attitudes. If the coefficient is both significant and positive, then dissemination may have increased the level of knowledge or a given attitude. When this effect of the dissemination is explored in regressions (as opposed to tables alone), we can statistically control for effects of variations in education and income across groups, since variations in knowledge and attitudes may be explained by those characteristics, in particular by differences in those characteristics between baseline and follow-up groups.

We are also interested to learn whether knowledge and attitudes vary across districts. For this purpose, we have created dummy variables for the districts. District dummy variables have been created for Brahmanbaria, Chandpur, Chuadanga, Comilla, Madaripur, Munshiganj, Narail, Jessore and Faridpur (in regressions, their coefficients can be interpreted as differences with respect to the district of Barisal). When a district dummy appears significant, we will conclude that the variation in the variable being analyzed can be explained by whatever unobserved differences exist between that district and Barisal.

Limitations 5.1.3

It is worth noting that because the upazilas were chosen because of their high arsenic prevalence (rather than randomly selected), the awareness may not be representative of all of Bangladesh. Since we are primarily interested in an assessment of arsenic-affected areas (rather than a country-wide assessment) this does not matter much.

The primary difficulty with inferring the effectiveness of dissemination from the data is that, in each location, different groups were sampled before the dissemination and after. Therefore, we do not know whether, for each location, differences between the group sampled before dissemination and the group sampled after dissemination, rather than the dissemination itself, were responsible for documented changes in knowledge, attitudes, and behaviour over time. Based on characteristics of respondents that we do observe, we see that the follow-up group is more educated and has slightly higher income and wealth. One would expect that follow-up respondents, those with higher education and slightly higher income, would have more knowledge even without dissemination. Thus to make more accurate inferences about how dissemination affected responses, we need to control for such observed characteristics in the baseline and follow-up groups' characteristics.

While in our regressions (unlike in the tables, which present differences without controls) we can try to control statistically for the observed differences in income and education, such that we can better estimate the actual effect of dissemination upon the responses, any unobserved differences between the baseline and follow-up groups remain an issue. For instance, the follow-up group may consist of individuals who have broader sets of social connections. They may be better informed even if not exposed to dissemination. We simply can not control for differences in characteristics that we do not observe at all. Only by interviewing the same individuals over time could this challenge be eliminated.

Another challenge is to control for changes that may have occurred through the country, for instance a change in the intensity of the national television campaign about arsenic. This survey did not include a control group, one not exposed to the dissemination efforts which could have indicated the background level of change over time in the country, allowing a comparison of that level of changes in responses with the one observed here. Thus, it is hard to say how much of the difference between the baseline and follow-up responses is due to dissemination and how much reflects changes occurring everywhere.

The surveys do not provide information on the level of arsenic in the tubewells that the respondents use. The absence of this information means that we cannot know whether the level of arsenic contamination is associated with willingness to take preventive action. Also, we have no data on the distances that respondents currently walk to obtain water or are likely to walk if they were to collect water from a prospective safe source of water. Such information could help to explain respondent willingness to take preventive action, although one final note is that these questionnaires contained few questions examining the actions actually taken by respondents that are of particular interest, such as continuing to use a contaminated water source or shifting to another source to lower health risks.

Summary 5.1.4

With these qualifications stated, in order to frame what is possible, below we present evidence that the dissemination campaign did increase knowledge and change attitudes. This is the case even controlling for observed characteristics, including district dummies. We find that characteristics also matter for responses, although it is worth noting that this appears to be less the case after the campaign. Finally, comparing characteristics of those with well tests before and after the campaign appears to explain what otherwise might appear to be a negative effect of dissemination on switching to a new water source.

Basic characteristics of the respondents 5.2

For all tables in this section and the next, numbers in the parentheses represent the total number of responses in that particular category or group. Percentages are computed relative to all respondents for a particular question. Please note however that (as with all surveys) the total number of respondents differ per question. In consequence, percentages cannot be computed from the total number of respondents in a particular group (e.g. there may be a total of 526 respondents with high education and high income in the follow-up survey, but not all of them answered all questions). As is evident in Table 5.1, the total number of respondents in the baseline survey are significantly different from those in the follow-up. There are more females, fewer children, and the average age of the youngest child is almost two years younger in the follow-up survey. And perhaps more importantly in terms of the outcomes of interest here, the follow-up group is also more literate, in terms of both schooling and the ability to read. Among the baseline respondents, 38% never attended school at all, compared to 12% from among the follow-up who have not. While the respondents in the follow-up survey are slightly wealthier than those in the baseline survey, the discrepancies appear to be much greater for education than for income. In summary, the respondents from the two groups are significantly different in terms of gender, marital status, number and age of children, education, income and wealth. We need to keep these differences in mind in analyzing the differences in the stated responses of the two groups.

Table 5.1: Basic characteristics of the respondents

Statistics	Baseline (2,909)	Follow-Up (1,544)
% of Female	29.1%	38.6%
% Married	18.9%	64.5%
Average age (years)	43.5	38.1
Average number of children	3.6	3.1
Average age of the youngest child (years)	9.9	7.9
% Never attended school	37.9%	11.6%
% Who cannot read at all	35.3%	17.6%
% of Farmer	25.0%	20.5%
% Who own a radio	44.1%	65.7%
% Who own a television	24.2%	34.4%
% Who own agricultural land	77.2%	80.7%
% Who have electricity	32.0%	50.1%
% With monthly income of less than Tk. 4,000	66.1%	62.8%
% of People who never listen to the radio	22.0%	15.7%
% of People who never watch TV	39.9%	23.5%

Table 5.2 shows how these indicators vary both across the districts and also within each district between baseline and follow-up surveys. For the districts, the same pattern holds over time as held for the complete baseline and follow-up surveys compared over time, i.e. the follow-up respondents within each district for which we have follow-up data are significantly different from their district counterparts in the baseline survey. The lack of education in the baseline survey, for instance, is most pronounced in Chuadanga, Narail, and Faridpur, but this difference disappears in the follow-up survey. Respondents from Chuadanga and Narail also seem to have less income compared to respondents in other districts, although this difference drops significantly for respondents from Narail in the follow-up survey. We would like to find out whether this inter-district variation in education and income could help to explain the inter-district variation in responses.

Figure 5.1: Distribution of monthly income

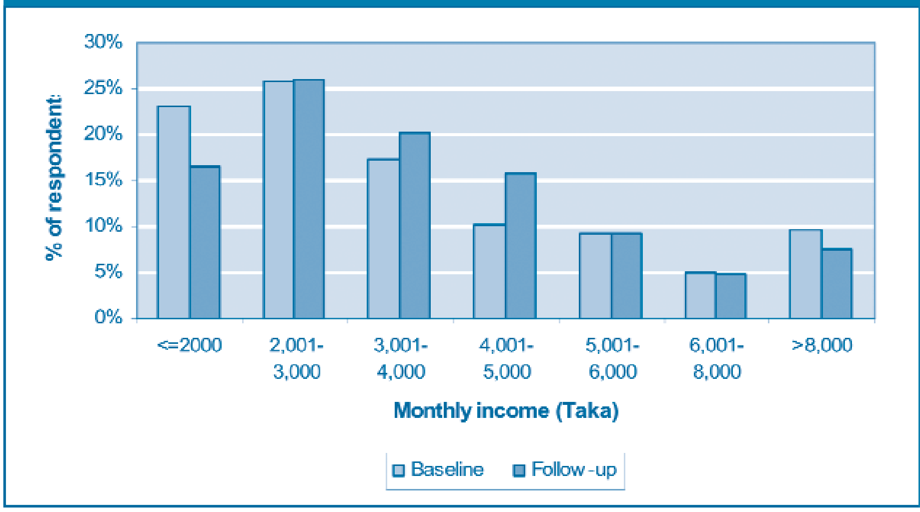


Figure 5.2: Percentage of people who never attended school

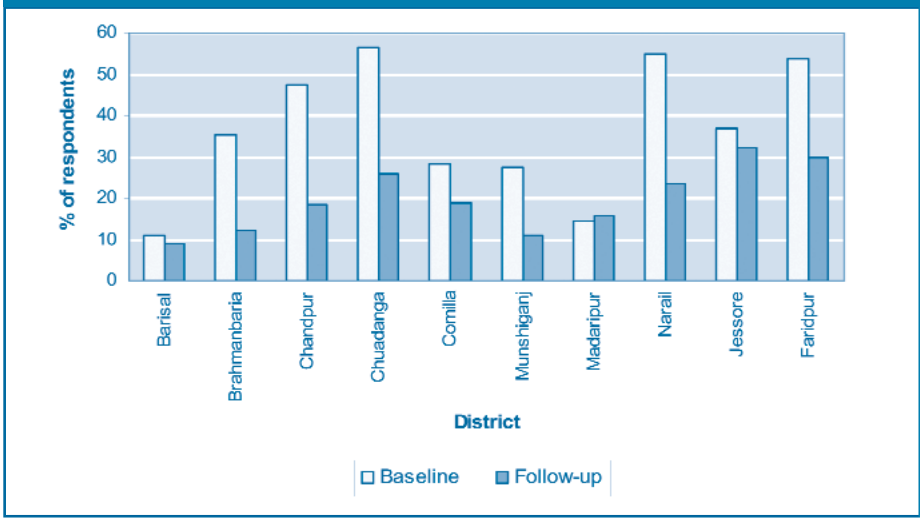


Table 5. 2: Basic characteristics of respondents across the districts

Indicators		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madari.	Narail	Jessore	Farid.
Number of Observations	B	100	206	549	101	648	102	200	102	468	433
	F	100	205	200	100	300	109	200	130	100	100
% of Female	B	24.0	27.7	14.0	49.5	13.9	42.2	24.0	97.1	3.0	10.9
	F	20.5	20.5	25.0	27.0	27.0	40.4	31.2	91.5	8.0	19.0
% Married	B	93.0	89.3	78.0	93.1	81.8	85.3	91.5	86.3	96.2	93.3
	F	88.0	86.3	88.5	86.0	90.3	78.0	82.5	97.7	88.0	95.0
Average Age	B	45.2	42.3	45.1	36.4	45.7	39.7	40.6	33.4	44.7	43.3
	F	39.8	39.8	42.0	34.2	40.6	35.9	39.2	35.9	45.9	49.4
Avg. Number of Children	B	4.0	3.9	4.0	3.1	4.1	3.3	3.2	3.8	NA	NA
	F	3.0	3.0	2.5	2.2	3.3	3.6	3.3	3.6	NA	NA
Average Age of the Youngest Child	B	10.2	10.1	10.7	10.3	10.2	11.4	9.5	7.1	NA	NA
	F	7.8	7.3	9.3	5.2	7.9	8.0	7.7	8.0	NA	NA
% Never Attended School	B	11.0	35.4	47.4	56.4	28.1	27.5	14.5	54.9	37.0	53.6
	F	9.0	12.2	18.5	26.0	19.0	11.0	15.5	23.4	32.0	30.0
% Who Can Not Read At All	B	5.0	35.9	24.0	62.4	47.7	32.4	21.0	54.9	NA	NA
	F	0.0	13.2	14.0	26.0	18.0	12.8	22.5	30.0	NA	NA
% of Farmer	B	35.0	29.1	16.0	37.6	32.7	27.5	22.0	NA	NA	34.4
	F	25.0	18.1	15.0	37.0	22.0	19.3	24.5	NA	NA	32.0
% that Own a Radio	B	41.0	51.5	18.0	31.7	44.2	41.2	64.0	33.3	NA	NA
	F	64.0	87.8	22.0	66.0	81.0	67.0	63.5	43.9	NA	NA
% that Own a television	B	23.0	26.7	7.0	15.8	16.6	45.1	16.6	16.7	NA	NA
	F	20.0	36.1	19.0	17.0	36.0	67.9	43.0	23.9	NA	NA
% that Own Agricultural Land	B	85.0	75.7	73.2	51.5	84.1	40.2	78.5	55.9	87.8	78.5
	F	99.0	86.8	78.0	91.0	84.7	70.6	86.5	75.4	50.0	71.0
% that Have Electricity	B	59.0	42.7	18.8	24.8	39.0	55.9	48.1	20.6	33.1	16.9
	F	60.0	57.6	43.5	62.0	53.3	59.6	57.5	33.1	19.0	45.0
% With Monthly Income of Less than Tk. 4000	B	76.0	72.8	71.6	92.1	53.9	72.6	46.5	92.2	69.4	58.9
	F	58.0	62.9	61.0	97.0	57.7	62.4	59.5	77.7	58.0	46.0
% of People Who Never Listen to Radio	B										
	F	29.0	25.7	21.0	53.5	19.1	30.4	13.5	46.1	17.9	18.5
% of People Who Never Watch TV	B	0.0	9.3	15.0	6.0	12.0	13.8	20.5	36.2	14.0	36.0
	F	46.0	51.9	48.6	62.4	31.3	20.6	27.0	59.8	33.1	42.7

Note: B=Baseline-, F=Follow-up Survey

5.3 Changes between baseline and follow-up surveys

Here we look at seven knowledge questions to see whether the percentage responding correctly increases between surveys. An increase in correct response is considered an indication that dissemination could have improved levels of these types of knowledge. Then we see whether there are similar changes in attitudes. Finally, we would like to examine whether changes carry over to respondents' actual or potential practices, e.g. to willingness to spend a particular amount for prevention of an arsenic-related problem.

Separate tables showing the breakdown in answers by district are included in annex 3. Where relevant, we will refer to these tables in the text.

The expected or "right" answer is provided in brackets with each question.

Knowledge questions 5.3.1

Whether one can find arsenic in water (yes): Here we are trying to ascertain whether a respondent is aware that arsenic can be detected in water. If respondents believe that arsenic cannot be detected, then they will have little incentive to test for arsenic and perhaps also less belief that measures can be to taken to avoid drinking water with arsenic. Table 5.3 shows that between the baseline and follow-up, the percentage giving a correct answer increases from 59% to 90%. However, this increase is more pronounced for low-income, low education group - from 42% to 89% (a two-fold increase) compared to a 30 percent increase for the high-income, high education group.

Table 5. 3: Can one find arsenic in water?

1= Yes, 0= No + Don't Know	Baseline	Follow-up
% Correct	59.1 (1452)	89.6 (1379)
% Correct when income=0 & education=0	42.0 (294)	88.6 (179)
% Correct when income =1 & education=1	69.2 (500)	89.9 (472)

Whether arsenic can be removed from water (yes): Here, the correct answer is that arsenic can be removed from water. Surprisingly, the percentage giving the correct answer remains nearly constant, although there was a significant decrease for respondents in the low-income, low-education group. We need to ascertain whether 'can be removed' is indeed the intended correct answer (referring to arsenic filters, e.g., which we might not necessarily expect people to know about) before drawing any conclusion in this regard.

Table 5.4: Can arsenic be removed from water

1= Yes, 0= No + Don't Know	Baseline	Follow-up
% Correct	43.8 (1071)	41.3 (634)
% Correct when income=0 & education=0	30.3 (212)	19.9 (40)
% Correct when income =1 & education=1	56.4 (407)	51.0 (266)

Looking at district variation, in Barisal, Brahmanbaria, Chuadanga, Comilla, and Madaripur the percentage of correct responses decreases. For the other districts it increases between baseline and follow-up. This inconsistency is intriguing and raises the issue of how the question is interpreted or, put another way, what the correct response is depending on interpretation.

Whether symptoms will go away if respondent stops using arsenic water (yes): Here we ask if one thinks symptoms caused by use of arsenic contaminated water would go away if one stops drinking arsenic-contaminated water. Medically speaking, there is no certainty that symptoms will disappear; what actually happens may depend on the stage and severity of symptoms. However, symptoms may disappear, certainly in the early stages of disease. This is a message we would like people to be aware of and act on; for this reason "yes" is counted as the correct response. In Table 5.5, we see a significant increase in the percentage of correct responses between baseline and follow-up. The increase is about 50 percent greater for low-income, low education than for high-income, high-education.

Table 5.5: Whether symptoms will go away

1= Yes, 0= No + Don't Know	Baseline	Follow-up
% Correct	32.2 *(210)*	63.8*(726)*
% Correct when income=0 & education=0	23.9 *(31)*	59.2*(119)*
% Correct when income =1 & education=1	36.7*(72)*	61.9*(216)*

Looking at responses by district, the only surprise is in Munshiganj, which, interestingly, experienced a marked decline between the baseline and follow-up surveys.

Can people die if they continue to drink arsenic water? (yes): Here, we wish to find out whether respondents believed that people could die from continued use of arsenic-contaminated water. We notice, in Table 5.6, an increase in the percentage of correct answers; however we don't see any significant difference along the education and income level.

Table 5.6: Can people die from drinking water with arsenic?

1= Yes, 0= No + Don't Know	Baseline	Follow-up
% Correct	69.5(446)	93.0 (952)
% Correct when income=0 & education=0	65.9(85)	89.7(166)
% Correct when income =1 & education=1	74.7(145)	95.7(292)

Whether respondent knew of any organization carrying out arsenic testing? (aware): This question asks whether the respondent is aware of any government or non-government organizations testing tubewells for arsenic. By the time the follow-up survey took place, a very high percentage of people were aware of arsenic testing (increased by about 50%). Increases in awareness are more significant for the low-income, low education group.

Table 5.7: Awareness of arsenic testing program

1= Aware, 0= Not Aware	Baseline	Follow-up
% aware	*63.3(1555)*	*96.8(1484)*
% aware when income=0 & education=0	*45.1(315)*	*95.0(191)*
% aware when income =1 & education=1	*78.8(570)*	*97.3(509)*

The correct response rates for this question were similar in the follow-up survey, although there was significant variation in the response rates in the baseline survey (from 50% correct responses in Chandpur, to 89% in Madaripur).

What does the red spout mean? (presence of arsenic): The spouts of tubewells that contain arsenic are painted 'red' and the safe tubewells are painted 'green'. This question asks whether respondents know the meaning of the 'red' marking. We see a significant increase over time in the percentage of correct answers, with a much greater increase in

Table 5.8: Meaning of a red pump spout

1= Red means arsenic, 0= No + Don't Know	Baseline	Follow-up
% Knows red denotes presence of arsenic	*44.2(858)*	*87.5(1082)*
% Knows red is arsenic when income=0 & education =0	*23.2(136)*	*86.4(127)*
% Knows red is arsenic when income =1 & education=1	*67.0(386)*	*87.1(366)*

the low-education, low-income group.

In certain districts, notably Narail and Chuadanga, very few respondents answered this question in the baseline survey (5 and 3, respectively), making analysis difficult. The response pattern for the district of Munshiganj was puzzling, as only one respondent out of 109 answered the question correctly in the follow-up survey. The districts unaffected by the low initial response rate, other than Munshiganj, experienced a similar increase in correct response rate.

Can someone spread arsenicosis? (no): In this question, respondents are asked if arsenicosis is contagious. The correct answer is 'no'. We see that the percentage answering correctly increases from 31% in baseline to 77% in the follow-up survey. The increase is more pronounced (more than two-fold) for the low-income, low-education group.

Table 5.9: Can someone spread arsenicosis?

1= No, 0= Yes + Don't Know	Baseline	Follow-up
% Correct	*31.4 (769)*	*77.1(1182)*
% Correct when income=0 & education =0	*33.3(101)*	*79.1(159)*
% Correct when income =1 & education=1	*48.5(348)*	*77.6(406)*

5.3.2 Attitude questions

Should a person suffering from arsenicosis be allowed to share same water source? (yes): Here, we try to learn attitudes towards sharing water source with a person who is suffering from arsenicosis. The 'correct' attitude is 'yes'. The percentage saying 'yes' increases from 37% in the baseline to 88% in the follow-up survey. The increase in the 'yes' response among the low-income, low-education group is slightly higher.

Table 5.10: Should water be shared with someone with arsenicosis?

1= Yes, 0= No + Don't Know	Baseline	Follow-up
% Yes	*37.5(247)*	*88.3(1004)*
% Yes when income=0 & education =0	*24.4(32)*	*81.2(164)*

We see increases in correct responses in each district, although in Narail district at 59% the proportion of people saying "yes" is significantly smaller than in any of the other districts. In five of the districts, the increase in correct responses is 60 percentage points or more.

Should a child be allowed to play with an arsenic-affected child? (yes): This question asks whether respondents would allow their children to play with a child suffering from arsenicosis. Again, we expect the respondents to say 'yes' to this attitude question. Here, we see a significant increase in the percentage saying 'yes' between baseline and follow-up surveys. The increase is again more pronounced for low-income, low education group.

Table 5.11: Should a child be allowed to play with a child with arsenicosis?

1= Yes, 0 = No + Don't Know	Baseline	Follow-up
% Yes	*35.5(234)*	*90.8(1029)*
% Yes when income=0 & education =0	*22.1(29)*	*47.7(95)*
% Yes when income =1 & education=1	*84.4(168)*	*93.1(322)*

Should an arsenic-affected person leave the village? (no): In this attitude question, we ask the respondents whether they would prefer that an arsenic-affected person leave the village. We expect respondents to say 'no' to this question, i.e. that is the 'correct' answer. The percentage saying 'no' increases from 65% to 93% between baseline and follow-up surveys. The increase is essentially the same for each group.

Table 5.12: Should an arsenic affected person leave the village?

1= No, 0 = Yes + Don't Know	Baseline	Follow-up
% No	*65.2(428)*	*92.9(1054)*
% No when income=0 & education =0	*60.5(78)*	*91.0(181)*
% No when income =1 & education=1	*64.3(128)*	*93.7(326)*

Overall, the increase is not as high as we observed in case of other knowledge and attitude questions due to the relatively high correct baseline response rate.

Will you allow your child to marry an arsenic-affected person? (yes): In this final attitude question, respondents are asked whether they would allow their children to marry a person with arsenicosis. We see a significant increase in the percentage saying 'yes' with a pronounced increase for the low-income, low education group. Overall, the percent responding correctly is much lower than in other knowledge/attitude questions.

Table 5.13: Would you allow your child to marry an arsenicosis patient?

1= Yes, 0 = No + Don't Know	Baseline	Follow-up
% Yes	*5.3(130)*	*27.1(415)*
% Yes when income=0 & education =0	*1.6(11)*	*27.5(55)*
% Yes when income =1 & education=1	*7.9(57)*	*27.7(145)*

Fewer people in low-income, low-education district Narail will allow their child to marry an arsenic-affected person. The most substantial increase was found in Chuadanga, the only district where respondents answered correctly more than half the time.

5.3.3 Practice and actions questions

Did you ever take water from an arsenic contaminated source? The percentage of people who ever took arsenic contaminated water increases between baseline and follow-up surveys. However, the difference between income and education groups is small, and correct response rates were similar in the follow-up survey. An important perspective on these responses, though, is that very few respondents in the baseline survey answered, so it is difficult to come to clear conclusions concerning the change in this type of behaviour.

Table 5.14: Did you ever take arsenic contaminated water?

1= Yes, 0 = No + Don't Know	Baseline	Follow-up
% Yes	40.7 *(35)*	78.1*(588)*
% Yes when income=0 & education =0	22.2 *(2)*	77.1 *(101)*
% Yes when income =1 & education=1	44.2 *(16)*	73.0 *(157)*

Do you still take water from that source? We see the percent of people using the same water source increases between baseline and follow-up surveys. However, we again have few respondents responding to this question in the baseline survey - a very small number given the large number of people who responded to knowledge questions in the baseline. Overall, the increase is greater for the low-income, low-education group.

Table 5.15: Do you still use contaminated water?

1= Yes, 0 = No + Don't Know	Baseline	Follow-up
% Yes	48.6*(17)*	*58.8(347)*
% Yes when income=0 & education =0	0.0*(0)*	*68.3(69)*
% Yes when income =1 & education=1	53.3*(8)*	*59.9(94)*

The fact that by the time the follow-up survey was carried out all wells had been tested may explain the observed increase in respondents answering “yes” to both practice and action questions. Having a tested well means that more people must have been able to answer this question correctly.

Willingness to pay questions 5.3.4

For each question we see an increase in the percent 'yes' between baseline and follow-up. It was significant for every category except 'testing the tubewell'; this may be explained by the fact that by the time the follow-up survey was carried out, almost all of the tubewells were already tested for arsenic. In addition, due to discrepancies between surveys, a subset of the respondents was asked if they were willing to perform labour in exchange for these services, in addition to being asked about willingness to spend. This could affect the results below.

Table 5.16: Willingness to pay

1= Yes, for testing the tubewell	Baseline	Follow-up
% Yes	90.2*(2458)*	*89.9(1468)*
% Yes when income=0 & education =0	84.6 (700)	84.3 (198)
% Yes when income =1 & education=1	95.3(723)	93.2(484)
1= Yes, for maintaining the tubewell	**Baseline**	**Follow-up**
% Yes	82.2*(652)*	*95.2(1073)*
% Yes when income=0 & education =0	69.8(129)	92.8(195)
% Yes when income =1 & education=1	93.0 (722)	97.8(313)
1= Yes, for installation of a new tubewell	**Baseline**	**Follow-up**
% Yes	92.4*(2456)*	*95.4(1533)*
% Yes when income=0 & education =0	88.7(699)	95.5 (199)
% Yes when income =1 & education=1	96.7(722)	97.5 (523)
1= Yes, for maintaining the new tubewell	**Baseline**	**Follow-up**
% Yes	93.2*(2457)*	*95.3(1530)*
% Yes when income=0 & education =0	93.0 (699)	94.0 (199)
% Yes when income =1 & education=1	95.4 (723)	97.5(524)

The response rate between districts is remarkably similar. In some cases, respondents in Narail were less willing to spend money on these measures. The lower level of income and wealth of the respondents from Narail is perhaps responsible for this difference.

Amounts respondents are willing to spend: Table 5.17 shows less willingness to spend in the follow-up for 'testing the tubewell' but more for all other categories. Notice the high

Table 5.17: Amounts respondents are willing to spend (Bangladesh Taka)

	Baseline		Follow-up	
For testing the tubewell	**Mean**	**SD**	**Mean**	**SD**
Amount	34.4	47.0	34.8	65.5
Amount when income=0 & education =0	25.5	28.6	20.0	39.8
Amount when income =1 & education=1	40.5	50.3	48.2	82.8
For maintaining the tubewell				
Amount	102.2	277.6	116.9	266.6
Amount when income=0 & education =0	74.9	160.8	69.7	98.2
Amount when income =1 & education=1	128.6	359.3	169.3	351.6
For installation of a new tubewell				
Amount	129.9	529.8	591.2	996.5
Amount when income=0 & education =0	34.0	148.4	522.5	636.3
Amount when income =1 & education=1	196.6	658.0	907.5	1237.5
For maintaining the new tubewell				
Amount	38.0	297.9	45.2	151.7
Amount when income=0 & education =0	15.0	129.7	27.7	33.8
Amount when income =1 & education=1	65.3	462.4	68.8	248.6

standard deviations for every mean. Also, in every category, the respondents with low income and low education are willing to spend less than those with high education and high income, with some pronounced differences. This is consistent with our expectation; willingness to spend should be influenced by levels of income and possibly education. For districts we see similar trends, e.g. less follow-up willingness to spend for 'testing the tubewell' and more for other categories.

A recent study examining willingness to pay for piped water supplies in arsenic affected areas of Bangladesh (Ahmad, Goldar et al. 2003) showed an estimated mean willingness to pay for a house connection of Tk. 1,787, and Tk. 960 for a public standpost. Estimated amounts for monthly maintenance are Tk. 87 for a house connection, and Tk. 51 for the public tap. Those figures are not too far removed from our findings, especially in the high-income, high-education group. In either case, the amounts people are willing to spend for maintenance are likely to be sufficient to cover true operating costs

Regression

Multiple regression is widely used in the social sciences in attempting to answer the general question: "What is the best predictor of…". Multiple linear regression is an expansion of simple linear regression, but instead of one, it uses two or more independent variables to explain changes in a single dependent variable. In our case, we use education, income, marital status, etc. to try to explain variations in responses to various knowledge and attitude questions.

So called dummy variables are used to add values of an ordinal or nominal variable to the regression equation. Dummy variables take on the value 0 or 1. A value of 1 simply means that something is true (such as age<25, survey type = 'baseline' or District='Comilla').

Interaction terms can be added to the regression model to incorporate the joint effect of two variables (e.g. income and education) on a dependent variable (e.g.. arsenic awareness) over and above their separate effects. Interaction terms are added as the crossproducts of independent and/or dummy variables. As mentioned earlier, interaction terms were added to our regression model for the altered survey format used by BRAC. Please note that as with all regression techniques we are able to reveal relationships, but not causality. Demonstration of causality is an experimental and logical problem, not a statistical one.

Regression results 5.4

Here we report on efforts to explain the observed variations in the responses to seven knowledge and four attitude questions in regressions with a set of explanatory variables. We also try to explain answers to four 'willingness to pay' and four 'amount willing to spend' variables or responses. Our explanatory variables include:

1. marital status;
2. years of schooling;
3. monthly income;
4. listening to radio;
5. watching TV;
6. baseline or follow up dummy ('id');
7. the eight dummies for the districts; and
8. the two interaction terms between the dummy for respondents asked questions from the altered survey and districts Chandpur and Comilla.

In the discussion below, if a variable is not noted as significant, then it was insignificant. Results are summarized in table 5.18 on page 148.

Is there any way in which you think you can find out if water contains arsenic? We find the id variable to be significant and positive, indicating that the dissemination program appears to have been successful in increasing the correct response rate. In addition, education was significant, districts varied, and listening to the radio, watching television, and marital status were significant. Lastly, the dummy variable for the altered survey and its interaction term with and the district Comilla were significant.

Can arsenic be removed from water through any means? We find id, income, and education to be significant, consistent with the tables. We find some significant district variation (seven of nine differ from Barisal), and that listening to the radio, watching TV, and marital status are significant. The dummy variable for the altered survey and its interaction with the district Comilla were found to be significant.

Will the skin problem go away if people stop drinking arsenic contaminated water? Here id and education were significant but income was not. This finding is expected given the similarity of response rates by respondents from different income and education levels. We find moderate district variation, and listening to radio to be significant.

Can people die if they drink arsenic contaminated water? Here, we find id to be significant. Income is significant only at the 10% confidence level. We find moderate district variation. The marriage variable is significant for this knowledge question.

Do you know of the government or any other organization carrying out arsenic testing program? We find id, education, and income to be significant, consistent with the tables. Two of nine districts differ from Barisal, and listening to the radio, watching television, marital status, and the altered survey are all significant. We also find the interaction term between the altered survey and the district of Chandpur to be significant.

What does a red mark on a tubewell mean? Here we find that id, income, and education are all positive and significant, consistent with the tables. We find little district variation. Watching television, listening to the radio and marital status are significant.

Can someone spread arsenic disease? Like for the previous knowledge question, the id, income, and education are all positive and significant. Watching television, listening to the radio, marital status, and the altered survey are significant predictors.

Will you share your water source with an arsenic-affected person? The id and education are positive and significant (not income, all consistent with the tables). Also, we find listening to the radio to be significant.

Will you allow your child to play with an arsenic-affected child? Here we find both id and education to be positive and significant (again, not income). We find five of the seven district dummies to be significant, in addition to listening to the radio.

Will you want the arsenic-affected person to leave the village? Id and five district dummies were the only significant predictors, consistent with the tables.

Will you allow your child to marry an arsenic-affected person? The id, income, and education are all significant, as are three district dummies. In addition, watching television, listening to radio and the altered survey are significant.

Willingness to pay for testing: The id, income, and education are all positive and significant. The id result differs from that from tables alone, and note that a regression not controlling for other factors finds id to be not significant. Listening to the radio and watching television are both negative and significant. Marriage, the altered survey, and the interaction term between the altered survey and Comilla also are all significant.

Willingness to pay for maintenance: As expected, we find id, education and income to be positive and significant. We also find three of the district variables to be significant.

Willingness to pay for installing a new tubewell: We find id and income significant, but not education. Eight of nine districts differ from Barisal. Marital status, watching television, and the altered survey are significant predictors as well.

Willingness to pay for maintaining the new tubewell: Id, income, and most of the dummy variables are significant, in addition to 'married', consistent with the tables.

Amount to pay for testing: As above, we find id, income, and education significant here. Most district dummy variables, watching television and the altered survey are too.

Amount to pay for maintenance: Other than moderate district variation, we find income and watching television to be the only significant predictors for this variable. Consistent with the tables, we found little change between the baseline and follow-up surveys.

Amount to pay for installing a new tubewell: Here, in addition to id and income, we find all districts to be significant. The marital status and altered survey variables are also significant, as is the interaction term between survey type and the district Comilla.

Amount to pay for maintaining the new tubewell: Id is negative and significant, as in the tables (six districts dropped in mean willingness to spend, while four increased). Income is positive and significant, and the districts differ significantly from each other. Marital status, watching television, and the altered survey are significant.

In a final regression effort, we are also interested to find out whether the variation in the level of knowledge and attitude (variables which were dependent variables in the above regressions) can serve as explanatory variables for respondents' willingness to pay for a preventive measure (also a dependent variable above, but without these new predictors). We have four 'willingness to pay' variables to explain, i.e. willingness to pay for testing, willingness to pay for maintenance, willingness to pay for installing a new tubewell and finally, willingness to pay for maintaining the new tubewell. On the right hand side of the regression, we have now included 11 (eleven) knowledge and attitude variables.

These new explanatory variables for willingness to pay are:

1. Can one find arsenic in water?
2. Can arsenic be removed from water?
3. Will the skin problem go away if one stops drinking arsenic-water?
4. Can one die if he/she drinks arsenic contaminated water?
5. Can someone, affected by arsenic, spread it to others?
6. Will you share your water source with an arsenic-affected person?
7. Will you allow your child to play with an arsenic-affected child?
8. Will you want the arsenic-affected person to leave the village?

9. Will you allow your child to marry an arsenic-affected person?

10. Are you aware of any government or NGO carrying out arsenic testing?

11. Meaning of the red marking

In the first regression for the dichotomous 'willingness to pay' variable as dependent variable, only explanatory variable number six from the list above is significant. Interestingly, only variable number 11 is significant in the second, third, and fourth regressions, indicating that understanding the meaning of the red marking may be an important predictor for willingness to pay. It is possible this variable acts as a proxy for income more than the other variables, since we know income is an important predictor for willingness to pay.

We ran the same regressions for the four dependent variables where respondents indicate the amounts they are willing to spend. In the first regression, variables number 6, number 7 and number 8 are significant. In the second regression, none are significant. On the question of how much money they would like to spend for installing a new tubewell, variables number 1, number 2, and number 8 are significant. Finally, in the last regression, only variables number 1 and number 2 are significant.

Tubewell ownership, testing and use 5.5

Here we examine tubewell ownership as well as testing and usage in the baseline and in the follow-up survey. We are interested to find out whether arsenic in the tubewell has influenced preventive well switching. We should control for who tested their tubewells. We also want to know if those who switched wells differ from others with well arsenic.

Tubewell ownership, testing, and arsenic contamination & tubewell switching 5.5.1

We see almost no difference between baseline and follow-up in the percentage who own a tubewell. However, the percentage of tubewells that has been tested for arsenic increases enormously, from 9% to 98%. This is not surprising, as only a few people would have been expected to test on their own, before the campaign, which then tested all the wells involved in the survey. Less clear is why we also see a significant increase in the percentage of positive arsenic tests. It could be due simply to random variation, or perhaps due to follow-up-

Table 5.18: Summary of regression results

	Marital status	Education	Income	Radio listening	TV watching	Baseline/ Follow-up (id)	District	Altered survey
Detect As in well	+	+	-	+	+	+	+/-	Comilla
Remove As from water	+	+	+	+	+	+	7/9	Comilla
Skin problems lessen	-	+	-	+	-	+	+/-	-
Die from water with As	+	-	+ (at 10% conf. int.)	-	-	+	+/-	-
Aware of testing	+	+	+	+	+	+	2/9	Chandpur
Meaning of red spout	+	+	+	+	+	+	-	-
Arsenicosis contagious	+	+	+	+	+	+	-	+
Share water	-	+	-	+	-	+	-	-
Child play with patient	-	+	-	+	-	+	5/7	-
Patient must leave	-	-	-	-	-	+	5/9	-
Child marry a As patient	-	+	+	+	+	+	3/9	+
Pay for testing	+	+	+	±	±	+ (see text)	-	Comilla
Pay for well maintenance	-	+	+	-	-	+	3/9	-
Pay for new well	+	-	+	-	+	+	8/9	+
Pay to maintain new well	+	-	+	-	-	+	+	-
Amt. to pay for test	-	+	+	-	+	+	+	+
Amt to pay for maint.	-	-	+	-	+	-	-	-
Amt. to pay for new well	+	-	+	-	-	+	+	Comilla
Amt. to pay for maintenance of new well	+	-	+	-	+	±	varied	+

Meaning of symbols:
- \- insignificant
- \+ significant and positive
- ± significant and negative
- x/y x out of y districts show significance

A district name in the last column denotes the interaction term of that district for the altered survey was significant

survey targeting based on arsenic that we are not yet aware of. Because the early test kits had a higher detection threshold (the detection limit for the original Merck kit was 100 ppb), it is also possible that this result reflects the availability of better field test kits.

The percentage of people who are still using the same tubewell dropped from 92% to 86% between baseline and follow-up surveys. This could be evidence of a beneficial effect of the dissemination. However, we must recall that the follow-up respondents are more educated and slightly richer. Also, we just saw that arsenic is more prevalent in the follow-up group's wells, which could be another reason for not continuing to use the wells.

The percentage of people using the same tubewell when arsenic has been found there, though, increased from 77% in the baseline survey to 86% in the follow-up survey. This might appear to indicate a negative effect of the dissemination on well switching. However, we just saw that the populations who have had a well test shifted radically. Those who had tested their wells on their own, i.e. before the NGO arsenic intervention, may well be a group that is more likely to switch wells upon learning they have arsenic (e.g., a more educated, richer, more socially connected group). Thus different behaviours conditional on a positive test may result not from dissemination but from characteristics. Even though the follow-up group is, on the whole, more educated and slightly richer, the select few driven to test their wells on their own could be an even more active group. This speculation leads to our comparing the groups with tested wells, in Table 5.20 below, which does find that those who had tested their wells in the baseline differ significantly.

Table 5.19: Tubewell usage

	Baseline	Follow-up
% of respondents that own their tubewell	85.9[a]	85.3
% of tubewell that has been tested	8.9[b]	98.5
% of tubewell where arsenic has been found	52.3[c]	73.8[f]
% of respondents still using the same tubewell	92.4[d]	86.1[g]
% still using when arsenic is found in the tubewell	77.3[e]	85.7[h]

a: 659 answered; 566 said there was a tubewell in their home.
b: 2,357 answered; 209 said their tubewell had been tested for arsenic (106 of whom had not responded on ownership).
c: 195 said their tubewell was tested and they knew the outcome of the test; 102 said the test for arsenic was positive.
d: 511 answered; 472 said they were using the same tubewell (415 respondents had reported no test of their tubewell).
e: Of the 102 above who reported positive arsenic tests, 44 answered here; 34 said they were using the same tubewell.
f: 1,327 said their tubewell was tested and they knew the outcome of the test; 979 said the test for arsenic was positive.
g: 783 answered; 674 said they were using the same tubewell.
h: Of the 979 above who reported positive arsenic tests, 742 answered here; 636 said they were using the same well.

Group that tested their tubewell before the baseline survey: In Table 5.20, we report the characteristics of the respondents who tested their tubewell before the baseline survey took place in order to examine whether this group differs (on average) from tubewell owners in the baseline as well as from the entire baseline sample.

We can see that the group that tested their tubewell before the baseline survey is significantly different from tubewell owners in the baseline and the entire baseline population. Those tubewell owners who tested pre-baseline are somewhat richer than the other two groups, and are less educated tubewell owners overall, but more educated than the entire sample.

Table 5.20: Group that tested their wells before the baseline survey

Indicator	Those who tested pre-baseline (209)	Tubewell owners in baseline (566)	The entire baseline sample (2909)
% of people with education =1 (education>2)	78.0	79.3	60.0
% of people with income =1 (income >Tk 4000)	48.5	39.1	33.9
% of people who can read easily	82.5	70.1	50.3
% of people who listen to radio daily	50.7	47.0	36.5
% of people who watch TV daily	45.9	38.3	21.6
% owning a radio	56.3	56.5	44.1
% owning a TV	45.6	38.0	24.2
% having agricultural land	84.2	79.0	77.2
% having electric supply	60.3	55.3	32.0
% having pucca household	4.9	5.3	3.3
% of people who know that arsenic can be detected	66.5	47.0	59.1
% of people who know that arsenic can be removed	46.9	43.7	43.8
% of people who think skin problem will go away	50.5	34.3	32.2
% of people who think people can die from arsenic	77.8	71.5	69.5
% of people who think arsenic is a contagious disease	49.0	35.6	31.4
% of people who will share water source	49.5	39.2	37.5
% of people who will allow the child to play	41.8	37.3	35.5
% of people who will want arsenic patient to stay	51.5	66.3	65.2
% of people who will allow their child to marry	10.5	11.0	5.3
% of people who are aware of testing programs	84.7	49.4	63.3
% of people who know the meaning of 'red' mark	78.0	69.6	44.2

Group that switched to safer tubewell: Out of 1,876 tubewell owners, 1390 (75%) responded about whether their tubewell had been tested for arsenic. Of these, 990 (73%) responded that the test was positive. Finally, of those who reported that their tubewell contained arsenic, only 116 (15%) reported that they were no longer using the contaminated water source. Those who switched represent only 3% of the sample. We want to see whether they are significantly different from those who did not switch.

From Table 5.21, differences between those who switched water source and those who tested but did not switch are ability to read, how frequently they listen to the radio, and watching TV. The average age of the youngest child is much lower for the switchers. We think that respondents may perceive younger children to be more vulnerable to arsenic.

One important result is that compared to the group that tested and did not switch, the test-and-switch group had significantly higher levels of education and listened to the radio and watched TV more frequently. Moreover, the group that tested and switched had higher correct responses rates for every behaviour and knowledge question examined. But it is clear that finding arsenic in the tubewell or having higher levels of education and income does not necessarily mean switching away from the contaminated source.

Table 5.21: Group of well owners who switched source

Indicator	Tested tubewell, switched	Tested tubewell, still using	Untested tubewell, switched	Untested tubewell, still using	All tubewell owners
Average Age of the Youngest Child (years)	6.6	8.4	11.0	9.9	8.7
% of people with education =1 (education>2)	86.3	80.2	76.7	77.5	82.1
% of people with income =1 (income >Tk 4000)	29.1	39.8	20.0	86.9	39.7
% of people who can read easily	72.7	66.0	80.0	66.4	67.0
% of people who listen to radio daily	72.7	47.2	40.0	44.4	48.1
% of people who watch TV daily	53.3	37.5	33.3	32.6	35.7
% of people who know that arsenic can be detected	93.2	86.4	46.7	47.5	77.9
% of people who know that arsenic can be removed	46.2	32.1	40.0	46.2	42.3
% of people who think skin problem will go away	79.5	61.6	26.7	31.7	54.6
% of people who think people can die from arsenic	93.6	90.8	69.0	70.5	85.3
% of people who think arsenic is a contagious disease	91.4	87.8	53.3	43.8	71.0
% of people who will share water source	94.9	83.9	43.3	36.6	71.5
% of people who will allow the child to play	91.5	88.7	40.0	35.7	72.8
% of people who will want arsenic patient to stay	91.5	90.3	66.7	69.8	83.9
% of people who will allow their child to marry	40.2	31.4	20.0	9.7	23.9
% of people who are aware of testing programs	97.4	94.8	43.3	44.1	82.9
% of people who know the meaning of 'red' mark	92.1	83.2	60.0	57.8	85.1

Some summary remarks 5.6

The tables in section 5.3 suggest that the follow-up group is more knowledgeable about problems related to arsenic contamination than is the baseline group. We cannot be sure that the reason is the education campaign, because of the differences between the samples mentioned before, but it is a possible reason. Also, from these tables, we see that the increase is more pronounced among the low income, low education group. This group was much less aware than the richer, more educated group in the baseline, thus there was simply more room for an increase in this group. However, the larger increase may also suggest that the education campaign is indeed playing a role, helping the poorer and less educated to catch up. Figure 5.3 summarizes the average increases in correctly answered questions for the knowledge, attitudes and practices categories. Please note that only one of the two practice related questions has a “right” answer.

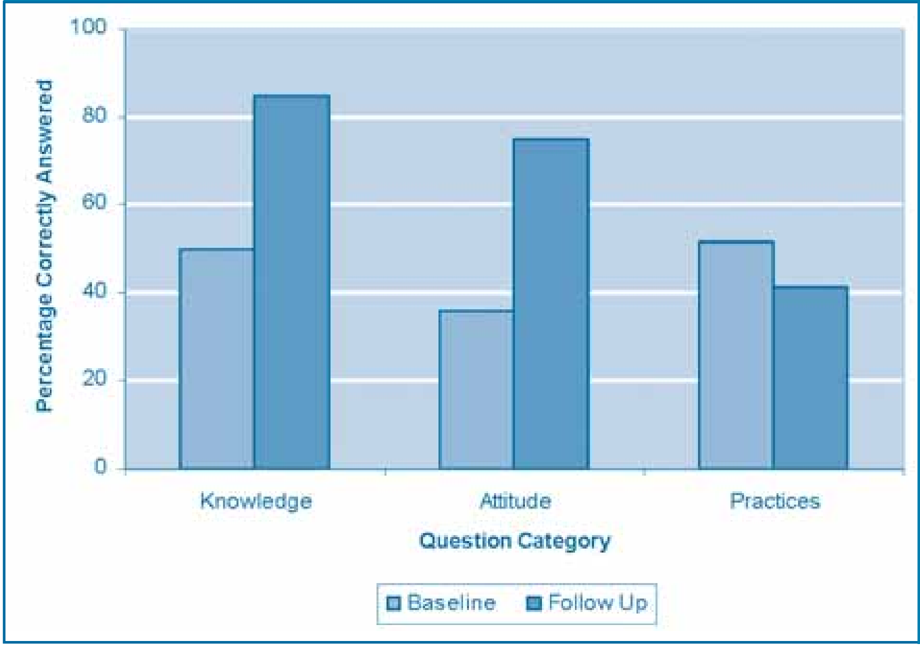
We ran regressions controlling for income and education in order to check whether the difference in the level of knowledge is not due to differences in income and education levels between the baseline and the follow-up groups. In all the 12 regressions the variable 'id' (identifying baseline or follow up survey) was significant. This suggests that dissemination did significantly increase the level of knowledge. We cannot be sure that the difference is not due to unobserved characteristics. We could eliminate this possibility only if the same people had been interviewed before and after.

Dissemination seems to have influenced attitudes in all four questions about attitudes, as shown in section 5.3.2.

The variable 'id' is also significant for the last three 'willingness to pay' questions (i.e. willingness to pay for maintenance, new tubewell and maintenance of new tubewell) and two out of four questions about the amount which a person is willing to pay. On the question of willingness to pay for testing, id does not appear as significant. The reason for this seems obvious - by the time baseline survey took place, 98% of the tubewell were already tested.

We need to explore further why level of knowledge differs across the districts. A possible explanation could be that dissemination programs, as well as baseline surveys, started at different times in different districts - because of the time-lag, the level of knowledge could vary across the districts. There might have been enough diffusion of knowledge through the electronic and print media in the districts where the surveys started late or where the survey was conducted over a longer period of time. In such cases, respondents are likely to be more familiar with the interview questions and are hence likely to know the correct answers by the time they were interviewed. The baseline survey spanned a period from July 1 to August 12 in Brahmanbaria whereas in Chandpur, it took place between July 1 and July 19. Given that the coefficient of district dummy for Chandpur

Figure 5.3: Average percentage of correctly answered questions by category (*)



* Knowledge question 2: "Can arsenic be removed" not included because of the ambiguous responses.

has a negative sign, we can infer that the longer time-span of the survey in Brahmanbaria could be partly responsible for higher percentages of correct responses there.

Another explanation may lie in differences between districts which we do not observe in the data. Factors like how people of one area respond to awareness campaigns or their attitudes towards NGOs or level of religiosity may explain the inter-district variation.

We found that 'gender' is a significant explanatory variable for the last three 'willingness to pay' questions and the last 'amount to pay' question. It is interesting to note that on all 'willingness to pay' and 'amounts to pay' questions, the coefficient of gender is negative. Given that male=0 and female=1, the negative sign of the coefficient of gender implies that female respondents are less likely to say 'yes' to such questions. This is not surprising, seeing that women would generally not be in control of household finances, and thus may be reluctant to commit to more expenditure.

We need to take note of the fact on an average 1,863 respondents answered the knowledge questions during the baseline survey. This is a 64% response rate. In the follow-up, on average 1,362 people responded to these questions. This is a response rate of 88%.

The response rate in the attitude questions rose from 38% in the baseline to 80% in the follow-up, and for the two questions in the practices category the response rate rose from a dismal 2% to (a still very low) 43%. The increase in the response rates can itself be considered an effect of the dissemination program. Those who did not respond during the baseline survey probably did not know the correct answers and hence opted not to respond. If we had those possible wrong responses, then the percentage increase in correct answers between baseline and follow-up surveys would have been even more pronounced. However, there might be other reasons why some people did not respond to these questions during the baseline survey.

The original follow-up survey was completed approximately one year after the baseline survey. This is a relatively short period of time; the true test of the effectiveness of any behaviour change communication campaign is in determining whether people continue to make the desired choices. It would be interesting to do further survey work to investigate current awareness and behaviour regarding arsenic contaminated water.

DISCUSSION

6

6.1 Introduction

This report is the first to bring together the results of blanket well testing (316,951 wells tested), patient identification data (2,682 patients identified) and population survey data (4,453 baseline and follow-up interviews about arsenic-related knowledge, attitudes and practices) in 15 upazilas of Bangladesh. This last chapter discusses some of the main findings and some implications of the analysis of the available data. In many ways, the large volume of data that was available only confirmed the complexity of the situation. The variability in the occurrence of arsenic (but also for example patients) is pronounced. There is no simple mitigation advice that can be applied throughout the country. There is no answer to the question why some family members get arsenicosis, and others do not. Some existing knowledge has been confirmed, while other assumptions have been challenged; just like others, we also found older wells to be more affected. But we find a higher risk in the use of tubewells than others did before us. Some new questions can be asked, and will need follow-up to be answered. Answers to some are now available for use in further arsenic mitigation work.

We wrote this chapter knowing that the problem of arsenic extends to other countries in South- and Southeast Asia. To date, in addition to west Bengal (India) and Bangladesh, arsenic has also been found in the ground waters of Cambodia, China, Laos, Myanmar, Nepal, Pakistan and Vietnam. Programmes for arsenic measurement and mitigation in those countries have often not advanced as far as they have in Bangladesh. So while some of the recommendations may no longer be particularly applicable to Bangladesh, they may benefit programme planners in other countries and for that reason they have been retained here.

6.2 Data collection and management

The overall amount of data available on the 15 upazilas is very large. Although there is pronounced variation in the quality within and across data sets, the overall standard is more than acceptable. The collected data represent a significant investment in time, effort and money, and the key to success in a mitigation programme is getting good results from the data collection effort. The key to good results in data collection is the use of appropriate tools, backed up by appropriate procedures for quality control and monitoring. At the same time we should accept that some imperfection will always remain due to human error and measurement uncertainties. This section presents some observations in hindsight on the process of collection and management of the various data sets.

6.2.1 Well data

When setting up a blanket well survey, one of the early decisions that need to be made is whether to do a well census, or a household census. The focus of a well census is -as the name implies- wells. Each well in a village is located and tested. Households without well are not visited. The advantage is that every well will certainly be covered, and every record in the database relates to one well exactly. A disadvantage is that it is not possible to say what water sources are used by families without a well. In a household census, each household is visited, and if they own a well, it is tested and recorded. Here a special effort will need to be made to identify non-household wells (i.e. public wells and institutional wells), and there will be records in the database which only refer to a household, not a well. A well census may be more appropriate when well and patient surveys are carried out independently, while a household census is very suitable when well testing and patient identification are carried out simultaneously.

In Bangladesh, the household survey approach is followed by BAMWSP, while UNICEF carries out well surveys. Whatever approach is selected, it is important to ensure that collected data fit the national database format. For the UNICEF database this means that various fields related to family health status are included which are never used, but which ensure a 1:1 relationship between the NAMIC national database and the UNICEF database.

Data Collection Forms

A second question to consider early on is the design of the well data collection form. Ideally this should be a national form, designed in consultation with all agencies implementing arsenic measurement programs, and used by everybody. Obviously entries on the form should map to individual fields in the national arsenic database. BAMWSP has successfully managed the introduction of a national form, which to date has gone through one major revision. The experience teaches us that it is better to try getting it right the first time; making changes to data collection forms leads to changes in database structures, and unless extreme care is taken, may lead to existing data becoming incompatible with data collected in the new format. On a small scale, such problems can be fixed; on a national scale, this quickly becomes so difficult that it may never happen. The original data collection form used in Bangladesh shows some of the things to avoid. Pre-defined categories should not be ambiguous (e.g. the well type category included "Deep well" and "Irrigation well". Because this mixes well type and well use, it is unclear how to categorize a "deep irrigation well"). Data categories should be well defined, and not depend on the interpretation of the tester (different organizations use different definitions for what a "deep well" is, making the category into a weak discriminator). Finally, it is better to include certain data fields up front, even if they seem redundant at the time. For example, including space for GPS coordinates of wells is a good idea, even if the use of GPS receivers is not yet widespread. The revised national data collection form includes these improvements and more.

Perverse incentives

Some of the errors present in the database are the indirect result of human nature; they can never be prevented fully, but some careful thought up front and design of systems can hope to minimize them. Well testers are usually paid for their work. Paying them a fixed amount for each well tested will ensure that all existing wells end up in the database. It is also likely that records will be produced for a number of wells which in fact do not exist. Paying testers only for each day worked will mean the work will take longer to complete, without guaranteeing that no phantom wells will be recorded. The testers employed by the UNICEF funded NGOs were paid per well tested, and the database indeed contained non-existent wells. Perverse incentives are hard to remove altogether, but supervision can improve results as long as the supervisor is independent. The fact that wells need to be painted after testing no matter what the outcome helps monitors visually identify wells which have been covered. Requiring testers to hand in used test strips would provide a good check, although it would be logistically difficult where large numbers of wells need to be tested (on average, each of the 15 upazilas had almost 22,000 wells tested. That is a lot of test strips to collect and check). Using GPS receivers to locate all tested wells would make it harder for testers to make up results, although it would be expensive to outfit all teams (in the 15 upazila area, more than 1700 teams of testers were employed. Providing each team with one GPS receiver at a cost of $100.- would have added close to $175,000 to the project costs). In the UNICEF project, three upazilas were covered by a GPS survey after completion of all screening. The survey was implemented by an outside contractor, and it was this survey which uncovered many of the existing inaccuracies (both of a technical and of a human nature). The overall data quality was still found to be very good, at more than 96% accuracy. But checks made it even better.

Well numbering

After the data have been collected, the next source of error occurs during data entry. There are two "technical" sources of error which created many problems. One of these has been the difficulty in establishing a unique identifier for each well. From the perspective of data analysis, this does not matter at all. There we deal with the data as a group of wells. But from the perspective of data storage, identification and retrieval, it matters a great deal. The testers assigned a number to each well, and within one village, each number was supposed to be unique (i.e. each well number occurs exactly one time). The well number is recorded in paint on a permanent structure close to the well (most often this was the doorjamb on the owners' house). Linking this well number to a village number (which in turn is made up of a union number and upazila number) will in theory create a unique well identifier. In this way, it would be possible to identify a well in the field, given the information from the database. Also, internal to the database, the data are split into related parts, such as information on location, details of the owner, and technical information such as well depth, well type and arsenic level. The various parts are linked together through a unique identifying number. This removes redundancy, reduces database size, and improves accuracy and speed. However, many of the assigned well numbers are not unique; they are repeated any number of times inside one village. Inside the database it is relatively straightforward to assign a computer-generated unique number to each well. But since this number is not recorded at the well site, it is useless for physical identification purposes. Using the number assigned by the well tester is no longer unambiguous, and to identify a well in the field needs further identifying information (such as the name and address of the owner). Using uniquely numbered well record forms would be one way to address this issue. The form number is then recorded at the well site (either with or without a further number assigned by the tester), and the number is also entered in the database. This provides the double advantage of not only being able to locate a well in the field, but also being able to locate the physical record form again later (provided these are sorted and retained). A further improvement would be to provide the well owner with a durable card or booklet on which well details are recorded, including the test data, result, form number, etc. Such a booklet could also be used to record the results of any subsequent arsenic tests.

A second major issue is the absence of a computer-based list of location names providing a uniform spelling for each union, mauza and village. The number of divisions, districts and upazilas is small enough to create such a dictionary by hand. However, the number of unions is quite large, and the number of mauzas and villages is not even known. The net effect of this is that names of unions, mauzas and villages have to be typed in by the data entry operator as they appear on the form. Because place names are often spelled differently by different people, this process of data entry leads to more unions, mauzas and villages being listed in the database than exist in reality. Data retrieval based on location then becomes ambiguous or incomplete (listing all wells in the village "East Hasamdia" will not list the wells in "Hasamdia Purba" while they are actually the same). Correcting the spelling of place names down to union level is possible, but was a huge task on the 15 upazila dataset. Correction down to village level was only done for the three-union special dataset, not for the full 15 upazila database. Some countries have a "gazetteer database" with uniform spelling (often in the local language as well as the preferred spelling in the Roman alphabet) and code numbers down to the lowest level, sometimes augmented by GPS coordinates for the centre of each village, district, etc. Typically such databases would be administered by the Dept. of Geography, or the census bureau which would also be responsible for disseminating updates and changes. They are indispensable for large scale surveys such as the well screening going on in Bangladesh, but also data collection efforts such as a census or demographic and health surveys and others. In Bangladesh the Zilla Statistics Books from the Bangladesh Bureau of Statistics provide some of the required information. However, the information is not publicly available in soft format and the only hard copies that were located for the 15 upazila project were outdated. In the absence of an official and publicly available version, it is strongly recommended to create such a database of place names for the area to be surveyed prior to the start of field work. Testers can then be supplied with lists of names and codes for the area they are assigned to, and data entry later will be much faster and more accurate (use of such lists precludes the need to type the names, which in the present survey of some 320,000 wells would have saved millions of keystrokes). Funding the creation of a national gazetteer database would be an excellent idea for a multilateral technical agency typically involved in large scale surveys (UNFPA and UNICEF come to mind).

Data entry

The fact that many NGOs subcontracted the data entry, with operators paid a fixed sum for each well entered led to a problem of duplicate entries (i.e. data for the same well copied a number of times). Such copies are easily removed through an automated process, but their existence demonstrates the importance of minimizing perverse incentives. In addition, some database operators bypassed the data entry system which was responsible for validating data, leading to incorrect or missing information. Central data entry in Dhaka following the completion of testing may have suited the NGOs, in terms of streamlining their work and outsourcing the tedious data processing to specialized agencies, but it did come at a price. Being removed from the well testing operations (in both time and space), it becomes impossible to resolve questions about any of the data collection forms. In addition, one data entry outfit in particular did not perform very well, bypassing all of the data validation built into the database, and omitting many of the (non technical) details for each well.

Future surveys of this nature would benefit from a stricter implementation of data security and validation rules, and from insisting on data entry at upazila level as testing is going on, so questions can be answered by the testing teams. Data should be checked and cleaned by the implementing NGO, and the ultimate recipient (DPHE, BAMWSP, UNICEF or whoever it is) should perform comprehensive tests and checks before accepting data (difficult as that may be in the midst of a large program of field implementation). Other possibilities would be to have all data entered twice by different individuals or agencies, and then compare both datasets. This is the approach typically used for important surveys such as a national census. In the 15 upazila project, this would have added approximately $1,500 to the well screening cost per upazila (five to seven US dollar cents a well).

Patient data 6.2.2

The patient data set is very different from the well data in that the data set is very small, and all available data were provided by only one NGO. The biggest issue with this data set is obviously the fact that the data collected by the DGHS in eight upazilas were never made available. Within the available data, the biggest issues are the inability to link patients with water sources from the well database, and the absence of data on a control group (i.e. non-patients), although it is possible that such data exist but are not available for analysis.

Although the standard national data collection form includes space for patient survey data, this part of the form is not used as widely as the part used for well screening data. The form does not allow a defined link between patients and water source for families with more than one well, but it does allow the identification of a water source used by families with patients but without their own well. There is no national arsenicosis patient database, which is one of the reasons why it is very hard to get information about the number of patients identified.

At a project level, there are two approaches to improving the situation. One is to carry out well screening and patient identification simultaneously. This is not necessarily that straightforward, since the surveys are likely to proceed at a different pace. However, using well designed forms, field data would become less ambiguous. A second option is to carry out patient searches after all wells in a village have been tested for arsenic. Information provided to the household at the time of well testing (form and/or well number, arsenic test result) can then be copied onto the patient data sheet, improving the ability to match patients with water sources.

The patient data showed that it is likely important to consider not only current water use, but also historical water use, since 71% of patients have had symptoms for longer than they have owned a well. At national level, what needs to happen is that a better patient information record sheet is designed, taking into account the needs and issues identified. Since there will always be organizations wanting to carry out their own research, using their own forms, it would be better to design a national form specifying the minimum required data to be collected rather than attempt to design a form that would satisfy everyone for all time (in that sense the situation relating to patient data is more complicated than the well data situation). A National database then needs to be designed based on the data format, with due attention given to the need to link patient and well data (including historical water use data).

Quite separately, guidelines for the distribution of patient data need to be established by the DGHS. The collection of personal medical information is a sensitive subject, and safeguards need to be in place to obtain the informed consent of the individual before the collection of any information, and to safeguard the patients' privacy after diagnosis. It should not be allowed for anyone dealing with the collection of patient data to distribute that data to anyone other than the competent medical authorities in the upazila the patient comes from. Such guidelines may exist already; the need for having them and adhering to them is reiterated here based on the receipt by UNICEF of a list of names and addresses of all patients in the 15 upazilas.

6.2.3 Test Kit data

As pointed out in chapter two, the 6,336 laboratory results show a large variation in terms of the proportion of accurately identified wells, and the spread of false positive and false negative results. Muradnagar upazila presents a real anomaly in that the percentage of red wells in confirmation testing is significantly smaller than the percentage of red wells during upazila-wide screening.

The available data indicate that sensitivity of the used kits reaches 88%, while specificity is 84%. Of the 13.6% false classifications, about half are accounted for by false positives, and half by false negatives. This is not the best result we could hope for, but it is certainly acceptable. In the 15 upazila area, these figures mean that of the 207,582 wells painted red, 14,323 are actually arsenic safe. Their owners are expected to take some action (stop using the water for drinking and cooking, start using a different source of water, or construct a new water supply). Of the 109,369 wells painted green, 7,327 are actually not arsenic-safe. Their owners will continue to drink the water in the belief that it is safe. The percentage of wells accurately classified by the kits is higher at very low and very high arsenic levels. Most of the mis-classifications take place around the 50 ppb level. Since the actual concentration of arsenic in the wells is more relevant than just the exceedence of the standard, counting wells of the wrong colours without considering absolute arsenic concentration paints a picture that looks worse than it is. Taking into account the uncertainty of the identification of wells around 50 ppb, and counting all wells that are classified at exactly 50 ppb as exceeding the standard, the overall contamination rate in the 15 upazilas would move from 66% to 72%.

The changes that need to be pursued to improve these figures are fairly fundamental.

In the first place, the process steps for producing an acceptable comparison need to be defined better. Split samples need to be produced, with one part tested by test kit immediately, and the second part properly preserved and submitted to a laboratory. Quality assurance steps and quality control steps through testing of trip blanks and duplicate samples also need to be included.

More importantly than that even is the identification and use of laboratories which are able to give consistently accurate results. In an inter-laboratory comparison of arsenic analysis carried out in 2001 (Aggarwal, Dargie et al. 2001), less than one third of the 17 laboratories which submitted results to the researchers obtained results that were within 20% of the expected value, leading to the following conclusion:

"Results of this inter-laboratory comparison point to a lack of consistency in the analytical results that have been and are being obtained in Bangladesh. More importantly, drinking water wells where elevated arsenic levels have been found may in fact have low concentrations. Similarly, wells that have been found to be free of arsenic may in fact have substantially higher concentrations. The quality and reliability of arsenic analysis needs to be established and continually evaluated…"

There have been no further comparisons since the one carried out in 2001[1], but there is little reason to assume that general results have gotten better during that time. While a few good laboratories exist, a selection needs to be carefully made. There is no value in paying an (expensive) private laboratory for arsenic testing without adequate assurances of quality control. Likewise, submitting samples to the government zonal laboratories out of a vaguely

[1] This approach was successfully followed in the UNICEF 25 upazila arsenic mitigation project (which started after the 15 upazila project).

expressed desire to support government infrastructure is pointless if it is not known whether the results will be accurate (or worse, when it is known that the results will probably not be accurate). If government support is the objective, spending available funds on a carefully designed quality improvement plan would make sense. If on the other hand, the main objective is to assure the quality results of a testing program, the best available laboratory for the money needs to be identified. In the absence of an acceptable laboratory, repeated tests by test kit will also improve the overall quality of the result (although it will be difficult to separate measurement error from a time-varying component in arsenic levels which may be present).

Lastly, testing programs need to make sure they use the best available field testing equipment. In the BGS survey report (BGS and DPHE 2001) the authors conclude that what is really needed is a test kit that can determine arsenic levels "… within ±20% of the true value or ±5 µg L^{-1} (whichever is the greater), 95% of the time" (p235). At present, we cannot tell whether such a kit exists yet. While a number of new kits have reached the market since the completion of the 15 upazila screening phase, no field-based performance data are available, although laboratory test results indicate that some may perform (much) better than the second generation Merck kit. One of the new kits employs a battery powered photometer to read the colour stain on the test strip, removing the uncertainty attached to relying on the visual acuity of human operators. All third generation kits are (much) more expensive than the second generation kits, but even quite large price increases are easily justified when considering the potential savings for households (from reduced false positive readings) and the health services (from reduced false negative readings). Performance data collected on these newer kits through field verification programmes should be published and disseminated, so that in time better judgments can be made by everybody about the accuracy of any results obtained through the use of a particular kit.

6.2.4 GIS data and mapping

The GIS data set (used in the analysis presented in chapter four) was collected by a private contractor. The main objective of the GPS mapping was to investigate possible uses for spatial data in arsenic mitigation. In the end, it did that, but also served as an unexpected window on the quality of the data collected during the well screening phase of the project. Each well was visited by a field worker with a GPS receiver, who noted the well coordinates in the database with test results. GPS readings were processed at the end of each day at upazila level, and any discrepancies were investigated and resolved. The cost for doing this amounted to approximately Tk. 23.- per well ($0.40). This compared to all other costs of about Tk. 200 ($3.40) per well[2] for the 15 upazila project (for the subsequent 25 upazila project, these costs dropped to approximately Tk. 103 ($1.77) per well).

From a data validation perspective, the mapping exercise has been very useful. In the absence of unique numbers marked on the well (see above), having location coordinates for each well stored in the database may prove useful when it becomes necessary to locate a well again (although this has so far not been tried in practice). Field validation in itself may or may not provide sufficient justification for collecting GPS data. Being able to plot well locations and contamination levels on a map is very useful in quickly discerning contamination patterns, and deciding whether continued well construction in a particular area makes sense. Maps are by far the best tool for doing this; tabulated well data would never attain the same degree of discrimination and clarity (see for example figures 4.4, 4.5 and 4.6). An alternative approach would be the creation by hand of union-level or village-level maps, showing the overall proportion of affected wells, or even individual wells. This could serve as an effective local awareness raising and planning tool. The intent and approach would be different from using an "electronic" approach (to start with there would only be one unique copy of each map), but some of the same objectives could be satisfied.

Once collected, spatial data may prove useful in ways not foreseen at the time (for example the existence of a national well database with coordinates allowed the use of position, depth and age in selecting wells for sampling for a national water quality assessment in Cambodia. (Feldman and Rosenboom 2001)).

The continued use of GPS receivers in well screening programs (or the introduction there where they have not been used up to now) is strongly supported. The financial costs are low, and there are multiple benefits in the short- and long term.

[2] Including NGO costs, testing, mobilization of communities, awareness raising and KAP baseline and follow up, but excluding the cost of test kits, IEC materials or patient identification.

6.2.5 Use of data

A last remark is related to the use of data. The investment in the collection, storage and processing of data becomes even more valuable when it can be used quickly and easily in planning and decision making for arsenic mitigation programmes. To date, this has not been done enough. Although data interpretation and display can take sophisticated forms, it should not be necessary to have a database or GIS specialist present to make data accessible to management. It is also not necessary to be complicated to be useful. There is nothing wrong with producing and using simple reports (e.g. a listing of the most heavily affected communities). It is always possible later (if needed or desired) to progress to more varied ways of interrogating and displaying of data. Linking well data to GIS software and a query system can allow complicated questions to be answered quickly and visually (e.g. "show a map of XX upazila with all wells deeper than 150 meters and older than 10 years which exceed 50 ppb arsenic"). However, having such a system is not a prerequisite for making good use of available data.

6.3 Well testing and the use of test kits

It has been observed many times by many people that the use of test kits in mass screening programs is the only feasible approach where the laboratory testing infrastructure to cope with the demand of such programs does not exist. There is little to add to that truth other than the observation that apart from technical necessity, a great advantage of the use of test kits is the credibility it gives to the results in the eyes of the well owner.

At the time of the 15 upazila project, the focus was still on the organisation of externally funded, large scale testing programs that covered all wells in a large area in a short period of time. At present however, all wells in the most heavily affected upazilas have been tested (blanket testing in 238 upazilas was completed in March of 2004). This does not mean that the need for testing is over, but it does mean that the nature of the need is changing.

What will be required now is an approach to testing that is long-term and of low intensity. Newly constructed wells will need to be tested, the performance of arsenic removal systems will need to be monitored, well owners may want to re-test their own wells occasionally, and so on. This sort of testing will still need to be done by test kit, but the service will need to be locally organized and locally funded; it is unlikely that an external donor will be ready to finance the needs for this approach. To make testing services accessible at the local level, two things need to be available:

- A local supply of test kits
- A person or institution willing and able to perform the testing on demand

While a number of arsenic test kits are available through distributors in Dhaka, there are no suppliers yet outside the capital. To make a testing service reliably available, this will need to change. A further improvement in availability and security of supply would be the actual production of test kits (or reagent re-fills) in country. The actual service could be provided in a variety of ways. A purely private provider is one option (e.g. obtaining a test through a local pharmacy, a water supply provider or a hardware shop which sells hand-pumps). Making water testing services available through local offices of the DPHE or through government upazila health centres would be another one. Providers would need to be trained in kit use, and an (informal) licensing system deserves consideration. Different providers could operate simultaneously in one area, and would probably end up serving different groups of people. For example, an arsenicosis patient might have his well water tested at the upazila health centre, while someone wanting to construct a new well would probably ask the contractor to test the water for him. The question whether test data collected this way should be added to the national database, and if so, how this could be facilitated would need to be carefully considered. Without a supervision or other quality control mechanism, it may be too risky to add just any data to the database.

When such services are established, thought should also be given to what other (chemical) constituents could be tested for besides arsenic. The DPHE has established guidelines for water quality monitoring, and the shift from mass screening to local level "maintenance testing" is an opportune time to start considering the integration of arsenic into overall water quality monitoring programs.

While the variations in arsenic level throughout most of the country are adequately mapped, the variations in arsenic levels over time are much less well known or understood. Addressing this gap in our understanding is important, but will take much longer than the initial countrywide screening exercise. While we know that over the very long term arsenic levels will go down (as the aquifer is flushed), it is possible that locally, or even generally, levels will rise before they fall. To be able to determine what long term trends (if any) exist, high quality monitoring data over a long period will be required. To be able to make a valid judgment about changes in arsenic levels over time, the best available laboratory methods will need to be employed for testing monitoring wells, so that measurement inaccuracies do not influence the result (in other words, any observed change in level is very likely to reflect a true change, rather than a change due to measurement error). Setting up a long term monitoring program is not a trivial undertaking. Careful well selection (including a range of depths, geologic horizons and ages) needs to be followed by continuing attention to sampling, sample preservation, testing and QA/QC procedures.

6.4 The (continued) use of dug wells, shallow tubewells and deep wells

The 15 upazila data have confirmed the enormous variation that exists in arsenic levels from place to place. Overall well contamination rate may be close to 66%, but that average hides variations from a low of 20.2% (Damurhuda) to a high of 98.4% (Shahrasti). The average across the project area is much higher than the national average of 27%, but this is expected, since the survey focused on upazilas which were known to be affected. In each of the upazilas there are communities where 100% of the tubewells exceed the arsenic limit, as well as communities where none of the tubewells do. The obvious initial conclusion is that there is no "one size fits all" solution to the problem. The question is whether anything beyond the obvious can be recommended.

The almost immediate reaction to the discovery of arsenic in shallow tubewells has been to officially discourage the continued construction of such wells, and instead to focus on deep wells ("deep" in this context meaning deeper than 500 feet (152 m)). In due course doubts were expressed about the advisability of using deep wells (for a variety of reasons), and shallow dug wells were offered up as a viable, arsenic safe alternative.

6.4.1 Deep wells

First deep wells. The 15 upazila data show a picture that is slightly more complicated than what is often presented (i.e. "by and large, deep wells are safe"). The overall contamination rate for deep wells, at 9.4% is certainly much lower than for all wells combined. But here too, the average hides a big range. Babuganj has the highest number of deep wells of the 15 upazilas (1,082 wells, or 39% of the total) but has the lowest deep well contamination rate at 1.8%. In contrast, three of the north-eastern upazilas (Bancharampur, Homna and Muradnagar) have few deep wells, but very high deep well contamination rates. In Bancharampur for example, much less than one per cent of all wells are deep wells, but 76% of the deep wells exceed 50 ppb in arsenic. In fact, a larger proportion of the deep wells is contaminated than of all wells. For all but those three upazilas however, contamination rates for deep wells are all (much) lower than contamination rates for all wells. This seems to suggest that with careful selection and careful well construction deep wells can be pursued as an arsenic safe alternative in 12 of the 15 upazilas. This would be true, were it not that having arsenic safe water does not necessarily mean that the water is safe for drinking. While no specific data for the deep wells in the 15 upazilas are available, the BGS study (BGS and DPHE 2001) found boron and manganese[1] levels which exceed the WHO health-based guideline values (0.5 mg/L for both) in deep wells. The JICA deep aquifer study (JICA 2002) also found manganese exceedences in addition to lead levels which exceed the WHO guideline value (0.01 mg/L) although they do not exceed the Bangladesh standard for lead (0.05 mg/L). And finally, the USGS has found constituents of health concern in deep boreholes in Chandpur district[2], but those data were not yet available at the time of writing. This all would suggest that at a minimum, the following steps should precede any decision to use deep wells for domestic water supplies (provided that there are no current government policies that prohibit their use altogether):

- Ensure that deep well arsenic contamination rates are actually low enough to justify drilling a deep well;
- After verifying their depth, sample nearby deep wells and perform a full metals analysis on the sample (or better yet, an analysis of all inorganics with guidelines or national standards established based on health effects or consumer acceptance);
- Based on the test results, decide to move ahead with construction, or abandon it;
- If a deep well is constructed, make sure to follow current government guidelines and construction standards for deep wells;
- After construction, analyze the water for constituents of health significance.

[1]The WHO health-based guideline value (GV) is provisional. The epidemiology of arsenic exposure is uncertain, and the GV is based on projections from health effects after occupational exposure through inhalation.
[2]Personal communication, John Whitney, USGS.

6.4.2 Dug wells

Dug wells in the 15 upazilas are very small in number, with Bancharampur the only exception (it has close to 500 dug wells, which is 64% of the total). The proportion of wells affected by high arsenic levels is invariably lower than the overall percentage of affected wells in each upazila. Across the board, about 11% of dug wells (up to 60 feet in depth) are arsenic unsafe, with a range from 0% to 100%. This is much lower than the overall contamination rate of all wells of 66%. The primary explanation for this would be that arsenic release is sensitive to redox conditions, and redox conditions around a dug well (open to the atmosphere) are likely to be very different than those around a tubewell of the same depth. The generally low contamination rate offers a possible approach to obtaining arsenic safe water, as long as it is realized that in exchange for low arsenic, users may be getting high levels of bacterial contamination. Elevated nitrate levels, turbidity, colour and odour are some of the other potential issues which may make a dug well either a health risk, or make it unacceptable to users. Substituting the acute effects of micro-biological contamination for the chronic effects of arsenic is a bad idea. In addition, improper construction, or construction at the wrong time of year (e.g. during or just after the monsoon season) could result in a well which falls dry at some point during the dry season, which would probably lead to families reverting to their (contaminated) tubewells again. Dug wells, if constructed at all, should extend deep enough so that the bottom of the well is below the water table throughout the year, proper construction methods should be followed, including the construction of a well apron and sanitary seal, and a pump for the withdrawal of water should be fitted.

6.4.3 Shallow tubewells

Finally, the question should be asked whether shallow tubewells should still be used. The fact that nationally, only 27% of wells exceed the arsenic standard may seem hopeful; yet the extreme variation in levels over short distances means that this one overall figure is of little practical value. Arsenic levels depend a great deal on local geology, and local geology is very variable. So making a prediction about likely arsenic status of a well based on an understanding of local geology would probably be a non-starter. In the 15 upazila area, the percentage of affected wells is more than twice the national average. This would seem to speak against sinking any more tubewells. At a 67% contamination rate, three wells would need to be constructed on average to end up with one uncontaminated one. This would triple the price of a well, potentially putting it outside the reach of a household. Yet, examining the available data allows us to refine the picture somewhat. In Damurhuda for example, the overall contamination rate is low, and this holds for all depth intervals. Constructing a tubewell would involve a risk, but perhaps an affordable one. Having access to well coordinates in addition to arsenic levels would allow the construction of a map identifying areas with high and low risk (if these exist). Babuganj on the other hand has uniformly high risk for arsenic exceedence up to 500 feet well depths. It would be pointless to construct a shallow tubewell in that upazila. The use of village contamination maps can help to identify arsenic safe areas where well construction might be attempted.

Decisions about the continued use of tubewells (or any other wells for that matter) need to be informed by local data. No blanket advice or approach is possible. As long as no local data are available on trends in arsenic levels over time (and it will take many years to collect such data), any decision to construct a shallow tubewell carries with it a certain risk that the water may show increased arsenic levels over time, even if it does not at the time of construction. To complicate matters even further, the same water quality concerns raised for deep wells also exist for shallow wells. Manganese at levels of health significance is found in more shallow wells than deep wells, as are barium and uranium. Any decision about continued well construction should take these findings into account. This point reinforces the need for a more comprehensive approach to (chemical) water quality monitoring, as also indicated in the previous section.

A last observation is that formulating advice based on data is one thing; evidence on the ground however suggests that few people wait for, or listen to any advice on well construction. Rates of construction have increased every year, and the discovery of arsenic did not change that. A proper response to this phenomenon would need better information on people's ideas about arsenic: do they construct new wells because they believe arsenic levels will be lower, or do they continue constructing wells because they are not interested in the subject, or believe they will not be affected?

6.5 Health

The health dimension of the arsenic crisis has always remained the least understood and least well explained. While from an engineering perspective it is possible to give fairly precise information about the dimensions of the problem (in terms of numbers of wells affected, their depth and location, etc.) and lots of data exist to draw on, from a health perspective we are less able to give answers based on unambiguous data. The 15 upazila data set has not fundamentally changed that picture. Based on upazila-wide averages, we can say that high arsenic concentrations in wells lead to higher prevalence of arsenicosis, and that the same relationship holds true at village level. No arsenic exposure levels were available for patients, and little light was shed on risk factors, patterns of occurrence and so forth.

In the 15 upazila area, there are 0.78 patients per 1,000 population exposed to excess arsenic in their drinking water. This hardly signifies a public health crisis; to compare, under 5 and infant mortality rates are 77 and 51 per 1,000 live births respectively. Given the enormous differences and apparent contradictions in arsenicosis prevalence by upazila (highly affected upazilas with few patients, barely affected upazilas with many patients) one question that comes up is whether there is something wrong with the survey methodology. On the other hand, there remains the distinct possibility that a complex interplay of many different factors explains the observed pattern. After all, it is very clear that the development of arsenicosis is influenced by diet, genetics, nutritional status and lifestyle choices, as well as the level and duration of arsenic exposure.

One explanation which is sometimes advanced for the absence of larger patient numbers is the fact that most of the tubewells are very young. As we saw in chapter two, half the wells were installed in the last five years. Since the skin symptoms typical of arsenicosis usually need anywhere from five to 15 years to develop (Ahmed 2003, p. 285), the absence of patients is entirely logical, or so the theory goes. If this were true, we could consider ourselves to be in a window of opportunity. With exposure left unchecked, patient numbers would begin to dramatically increase in five to ten years. But everything done today to reduce the exposure to arsenic would translate into smaller numbers of patients later on.

The answer to the question whether prevalence is just low and is likely to stay that way, or whether we are in a window of opportunity which we need to use well to avoid an exponential growth in patient numbers later, depends in part on the water sources people use before they have a well. The number of wells is growing exponentially, but all the people installing new wells of course used some source of water before obtaining their own. This prior source of water could also very well be a tubewell, say owned by a neighbour, or in a public place. If this is true, the "window of opportunity" explanation springs a leak, since in that case arsenic exposure could have started long before the construction of the new well. The patient data from seven upazilas suggest that many well owners already drank well water prior to installing their own. However, this needs further confirmation through more focused surveys.

It is important to try to shed light on some of the uncertainties surrounding the health impacts of arsenic in drinking water. The availability of funding for emergency and long term mitigation activities will in part depend on a clearly demonstrated health impact. For the government, treating arsenic measurement and mitigation as a practical priority will be easier if the economic costs of inaction can be modeled. This means that a candid assessment of the burden of disease needs to be made, preceded by an assessment of the available data. Detailed, focused surveys using quantitative arsenic measurements in wells and trained medical personnel are most likely to provide the quality of data that is required for meaningful analysis.

At the same time, any ongoing patient screening should ensure that not only data from patients are collected, but also from a control group of non-patients (both exposed and not exposed to arsenic in water). While many health related surveys are carried out on a regular basis (e.g. the Health and Demographic Survey every two years, the Demographic Health Survey every three years, and the UNICEF funded MICS regularly) these surveys do not include the sort of information on water use and arsenic contamination that would be necessary for a meaningful comparative analysis of arsenicosis patients and non-arsenicosis patients (worse, the general surveys are likely to include patients in their sample; especially the HDS which surveys a large sample of 41,400 households).

6.6 Communication and awareness raising

According to assessments done at the time, until 1998 there was little focused communication on arsenic, and awareness of the occurrence and effects of arsenic was generally low. A national campaign using a range of messages, materials and strategies was developed and implemented. It is this campaign which was also used in the 15 upazila project, and which was assessed in the KAP survey. The essential tasks of the campaign are to inform people about arsenic in drinking water, to change behaviour where necessary, and to maintain a new practice or attitude.

The KAP survey shows that knowledge and attitudes have definitely changed for the better. Raised knowledge levels have not necessarily led to (sustained) changes in behaviour however, as shown by the continued construction of shallow tubewells, and by interviews with well users during a mid-term evaluation (Akhter 2003; Planning Alternatives for Change LLC and Pathways Ltd 2003). Shallow tubewells are still being constructed at a high rate, and the use of arsenic safe water by owners of contaminated wells (e.g. through sharing) is often sporadic at best. There is anecdotal evidence that source switching is more prevalent and better sustained in those communities with arsenic patients, but by and large not enough is known about the values and beliefs related to arsenic which influence or determine behaviour. A study of the anthropology of arsenic in Bangladesh could help in formulating campaign messages aimed at more permanent behaviour change.

In terms of the current campaign, there are a number of changes that need to be considered. The KAP survey result hinted at the possibility that information about arsenic removal from water was not understood; the number of correct replies actually went down in a number of areas. In the second place, a shift in programme focus needs to be accompanied by a shift in information. Well testers used to be the single most important source of information on arsenic for the well users (Akhter 2003). However, mass well screening campaigns will soon be a thing of the past. This begs the question what other dissemination route(s) can be identified once the screening is over. Also, as the focus shifts from measurement to mitigation, the sort of information required will change. Practical approaches to obtaining arsenic safe water should receive a lot more attention, as well as information on how to obtain a single "private" test. While much information on mitigation options is universally valid (e.g. the possible use of rainwater catchment tanks), a lot of uncertainty exists too. Deep wells may be suitable and allowed in some areas, but not in others, and the same may go for shallow tubewells. Sharing of wells is a feasible (albeit short term) solution in some areas, but not in others, depending on the pattern of contamination (chapter four). The best course of action is not always clear, and revised campaign messages should find a way to deal with that uncertainty.

Given the current knowledge about the effectiveness of the campaign, as well as the gradual (but pronounced) shift in programme focus, this is an ideal time to revisit the IEC campaign materials and strategy and bring it up-to-date.

Arsenic mitigation 6.7

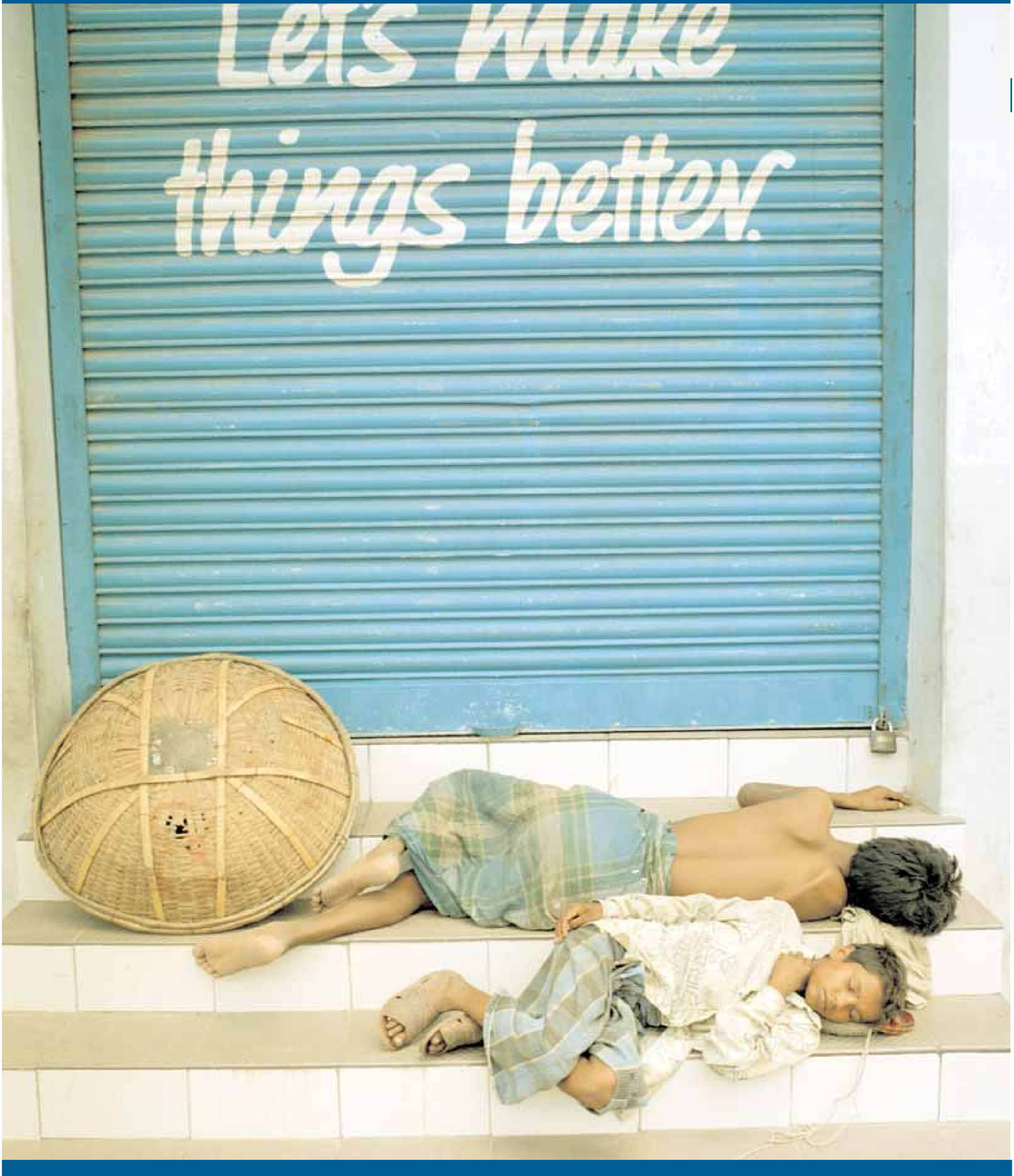
The last phase in the sequence of activities that starts with awareness raising is mitigation. The focus of mitigation should clearly be on the provision of improved water supplies. Water is both the cause and the cure of the arsenic crisis. It may be possible to alleviate suffering or symptoms from arsenicosis through medicine, but it is not yet possible to cure arsenicosis following this route.

Improved water supplies can be pursued through arsenic avoidance (rain water harvesting, surface water treatment, arsenic safe (deep) wells, or arsenic removal. All have their advantages and disadvantages, most of which are very well summarized in the UN synthesis report on arsenic (WHO 2001).

In some ways for individuals considering available water sources, the choice comes down to balancing the acute threat of biologically contaminated surface water with the chronic threat of arsenic in ground water. In Bangladesh, people have clearly voted through their actions. Wells continue to be constructed, and existing surface water treatment systems used to supply drinking water (such as the pond sand filter) are not popular in communities at all (although Caldwell et al (2003) suggest surface water is still preferred for cooking, this could not be confirmed in the 15 upazilas).

We should also realize that it is possible (even likely) that people continue to construct wells for the convenience they afford, not primarily for the health benefits (even though health benefits are likely to accrue from the increased water use resulting from a higher level of service provided by a household well. See for example Howard and Bartram (2003). It is by now well accepted by the professional community for example that households which choose to build a latrine often do so not for reasons of improved health, but for reasons of status, privacy and convenience. A similar mechanism may be at work in water supply construction (at least in Bangladesh, where a family well with pump can be constructed in a few days, at a low cost).

Oftentimes, mitigation approaches are built around what is technically feasible (deep wells are an option, or not. Treatable surface water is available, or not). Mitigation programmes should accept that in addition to what is possible, individuals and communities have their own reasons to prefer certain water supply solutions, and need to find ways to respond to community preference. The consequence of doing this means moving away from a "one size fits all" approach towards "messier" solutions. Some will prefer household solutions, others communal ones. There will be arsenic removal, and arsenic avoidance. Cheap and expensive, simple and complicated. This is not to say that all programmes should offer all solutions. But if the data from the 15 upazilas (and all data that came before it) show one thing, then it is that there is no silver bullet. All solutions are local; a simple solution that will work everywhere does not exist. Compounding the situation further is the fact that all mitigation efforts will need to consider water quality issues and risk substitution. Developing Water Safety Plans (as described in the third edition of the WHO Guidelines for Drinking Water Quality) offers a comprehensive and consistent approach to evaluation of risk. For a detailed discussion on this subject, see Howard (2003). Local data need to be used for planning locally, and for implementing locally appropriate solutions. The sooner everybody bites this particular bullet -government, technical agencies and donors alike- the sooner it will be possible to move ahead with providing safe drinking water in arsenic affected areas, and begin to truly reduce exposure throughout the country. For the 15 upazilas, priority action should clearly be focused on the most affected communities identified as part of the overall data analysis.


things better.

7 Summary and Recommendations

7.1 Summary: state of the arsenic in the 15 upazilas

Of the 316,951 tested wells, 65.5% exceed the 50 ppb arsenic standard. The remaining 109,369 wells stay below the standard, and of those, 31,750 (29%) have non-detectable arsenic levels.

The highest proportion of affected wells is located in the estuarine deposits of the active Meghna floodplain (86%>50 ppb), while the lowest proportion of affected wells can be found in the deltaic silt and sand of the Ganges delta (52%>50 ppb). The most affected upazila is Shahrasti (98.4%>50 ppb) and the least affected upazila is Shib Char (44.8%>50 ppb). The vast majority of all wells are privately owned.

In the project area, 20% to 73% of households have a well, with the average being 50%. Each well has an average of eight family members using it. Looking at all users (also outside the family of the owner), there are on average 18 reported users per well, and an average of 64 wells per 1,000 people. The proportion of wells out of order at any one time is very small, at 4.4% overall.

Three and a half million well users are exposed to arsenic levels in excess of 50 ppb, and half of those users are exposed to levels in excess of 100 ppb..

There are a total of 574 villages in the 15 upazilas where all wells are contaminated. A total of 1,724 villages (58% of the total) has 80% or more of their wells affected. These are the villages that should receive priority attention for mitigation according to the national arsenic policy. In addition to those priority villages, 72% of all schools in the area do not have access to arsenic-safe well water.

Half of all the existing wells in the area were constructed since 1995; i.e. after the discovery of arsenic. Wells older than 25 years were found to have significantly higher arsenic levels than younger wells.

The majority of wells are constructed in the 50 - 150 feet depth interval, which is the same interval where most of the arsenic affected wells are found. In the past five years, the proportion of wells over 500 feet in depth has increased, and the proportion of very shallow wells (<15 feet) has decreased. Other than that, the depth distribution is remarkably even over time.

Dug wells and deep wells (> 500 feet) are not always arsenic safe, but they offer substantially lower risk than shallow tubewells between 15 and 500 feet in depth. Some 11% of all dug wells exceed the 50 ppb arsenic level, and 9.4% of all deep wells.

2,682 patients were identified, which translates to a prevalence of 0.78 per 1,000 exposed individuals. There are one and a half times as many male patients than there are female ones in the areas for which disaggregated data exists.

The average well arsenic concentration in villages with patients is 240 ppb, which is higher than the project area average. There is a significant correlation between average arsenic concentration and arsenicosis prevalence after the removal of outliers from the data. Villages with patients have a higher proportion of red wells (78%) and wells are on average two years older than across the whole area.

Patients had symptoms for an average of 3.6 years before being diagnosed. Patient identification by village health workers in health camps led to a 75% false positive identification rate, which makes them a poor choice for the task.

A combination of melanosis and keratosis is present in 68% of patients. Urinary arsenic levels are elevated in 55% of patients, and nail arsenic levels are elevated in almost all patients for whom this was tested. There is no significant correlation between urinary arsenic levels and severity of melanosis or keratosis. Likewise there is no correlation between nail arsenic levels and severity of symptoms. There is no significant difference in nail arsenic levels in patients who have been exposed for a period exceeding five years, or who have been exposed for a period up to five years.

Patterns of contamination shown on union maps for three areas show some promise for locating arsenic safe zones and -depths, where depth alone does not always provide very useful information for mitigation programmes. The maps also make it clear that the prospect for sharing wells differs significantly across unions. Access to a green well within 100 meters of a red well exists for 94% of wells in one union, 43% in another, and only 23% in a third.

Arsenic related knowledge and attitudes have improved throughout the area, sometimes dramatically so. The increase is more pronounced among people with low education, and low income. The increase may suggest that the education campaign is helping people to catch up with the higher income, higher education segment of the population who were better informed to start with.

Recommendations 7.2

Throughout this report some larger and smaller suggestions have been made for changes to existing practice, as well as some new work. Those will be summarized here, together with some final remaining observations.

Well screening 7.2.1

1. Test kits are of sufficient quality to be used for mass screening campaigns. Use data from screening programs to determine sensitivity and specificity of the newer kits. Disseminate such performance data, and use them as a criterion for selection.

2. Create clear QA/QC procedures for the confirmation of field test kit results before embarking on surveys. At a minimum include (i) a list of acceptable laboratories (ii) rules for the number of results to be confirmed (iii) guidelines for sampling and sample preservation, and (iv) rules for the use of split samples, trip blanks and repeat analyses.

3. Bangladesh has a functioning national arsenic database. Other countries facing a situation similar to the one in Bangladesh are strongly encouraged to set up such a national (water quality) database too. Make this useful by making the description (or the full system) freely available to all potential users. Data validation rules should be built into the system, and bypassing validation should not be possible.

4. Use of a well designed national data collection form constitutes an integral part of setting up a national database. Ensure standard data collection forms are numbered, to simplify the inclusion in the database of unique identifying numbers for all wells.

5. Where one exists, make the national gazetteer database available as part of a national water quality or well database. Where no gazetteer database exists, create "location dictionaries" for the area to be surveyed, prior to the screening.

6. Provide a durable record to well owners with details of the test(s) carried out, and their results.

7. Map test results, preferably in digital (i.e. reproducible) form, making use of GPS technology. Present results from mapping and database in a format useful to communities and project managers for the planning of mitigation measures.

8. Establish long-term ground water quality monitoring programmes alongside rapid screening efforts. Use designated monitoring wells which are sampled at regular intervals.

7.2.2 Patient identification

9. In patient surveys, use quantitative measurement methods for determining arsenic exposure of suspected patients. Link patient data with current water use data, but also investigate historical water use as much as possible. Design national data collection forms bearing in mind the requirement for recording changing water use practices over time.

10. Minimize false positive patient identifications, preferably by using trained doctors for the task.

11. Collect case control data alongside patient data, allowing the comparison of patients and non-patients.

12. Establish guidelines for the collection and distribution of patient data, addressing the

need for confidentiality, as well as the need for program planners to have access to patient information to target specific (parts of) communities. Establish these guidelines through national institutions (DGHS, MOH) and make sure they are known to project implementers.

Awareness raising 7.2.3

13. Follow up on KAP changes (chapter 5) and identify whether change is sustained, growing or diminishing.

14. Find out what drives continued tubewell construction (e.g. a belief that new wells provide safe water; a disinterest in the issue or something else), and use the information to inform campaign messages.

Mitigation 7.2.4

15. In the project area, focus mitigation in Muradnagar, Shahrasti and Bhanga as being worst affected.

16. Use the list of communities with 100% of their wells affected (on the accompanying CD) to focus priority mitigation efforts. After that, continue with all communities where 80% or more of the wells are arsenic contaminated.

17. To protect children, include schools without access to arsenic safe water in mitigation plans (see list on attached CD). Investigate the feasibility of including affected schools as priority mitigation targets in the Bangladesh National Arsenic Policy.

18. The National Arsenic Policy currently includes the proportion of wells affected as the main indicator for mitigation priority (all villages where >80% of wells are affected are considered a priority). Find out whether arsenic concentration in wells can be included as a primary criterion for mitigation, since exposure level is correlated with development of arsenicosis.

19. Wherever possible, let decisions on the (continued) use of shallow tubewells and deep wells be guided by the local situation, based on local data. Establishing clear guidelines for local decision making will be cheaper and more realistic than imposing blanket solutions.

7.2.5 Follow-up to this report

20. This report presents a first comprehensive look at the data from the 15 upazilas, and more work could be done on it. This is especially true for data at the local level. More or less at random, three unions were selected for a closer look. More of the data can be considered at union level, especially with a view to formulating locally appropriate advice for mitigation options.

21. The well data show rather high deep well contamination rates in three upazilas. The total number of deep wells in those upazilas with arsenic above 50 ppb is small, only 65. It would be advisable to visit some or all of those wells, to measure their depth, and to re-test the arsenic level. Confirming or denying that a relatively large proportion of deep wells is contaminated would usefully to inform the debate on the continued use of deep wells.

22. On the health side, it would be useful to pursue the existence of a data set on a control group of non-patients. If such data exist and can be obtained, a comparative analysis of the two datasets should be completed, rather than a description of patient data only, as done in chapter three.

23. Throughout the previous chapter there have been some allusions to the need for looking at water quality beyond arsenic. It is important that projects begin to address water quality comprehensively, rather than only from an arsenic perspective. There is a practical component to this (i.e. ensuring that community water supplies provided meet all relevant national standards, not just the arsenic one) as well as a more research oriented component to determine which chemicals need to be monitored where, and how this is best done. Water Safety Plans dovetail well with the need for mitigation planning.

24. Lastly, it would be useful to look across Bangladesh's borders for a moment. As mentioned before, arsenic contamination in ground water affects at least nine countries in South- and Southeast Asia. Bangladesh is the country with most experience in addressing this problem, certainly from a perspective of mass screening of wells and identifying patients. In many ways, other countries already benefit from Bangladesh's experience. A Bangladesh arsenicosis expert traveled to Cambodia for example to set up the first patient survey there. Representatives from many arsenic affected countries visit Bangladesh to observe and discuss work in well screening, patient identification, mitigation, etc. Based on the experience with well screening and patient identification in Bangladesh, especially by BAMWSP, DCH and UNICEF, and given the probable need to implement similar surveys in other countries, it would be helpful if a field guide for setting up screening programmes were developed.

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Annex 1: Summary of Well Data

	Group :			1: Deltaic (Gangas)							2: Alluvial						3: Chandina alluvium			4 (dt)	5 (de)	
	Item	Calculation (source and unit)		[illegible] 1	[illegible] 2	[illegible] 3	[illegible] 4	[illegible] 5	[illegible] 6	Sub Total 1	[illegible] 7	[illegible] 8	[illegible] 9	[illegible] 10	[illegible] 11	Sub Total 2	[illegible] 12	[illegible] 13	Sub Total 3	[illegible] 14	[illegible] 15	GRAND TOTAL
	Administrative Data (1-4)																					
1	Unions	DB	No.	8	13	17	12	10	19	79	6	21	14	23	14	78	15	9	24	8	6	193
2	Villages	DB	No.	147	200	240	187	186	286	1,344	141	217	227	387	186	1,160	315	176	491	78	48	3,161
3	Families	DB	No.	28,504	11,669	34,307	21,475	11,927	17,907	126,189	17,956	29,608	15,841	29,098	16,987	111,501	25,320	16,320	41,640	5,318	3,647	288,295
4	Population ('000)	Census ans. 1993		254	223	390	251	240	359	1,717	315	457	250	624	268	1,914	366	218	584	159	138	4,512
	Well Status and Type (5-9)																					
5	Wells in database	DB	No.	29,920	12,034	38,230	22,200	13,762	29,977	152,322	20,426	21,684	19,829	32,077	19,427	122,612	28,095	16,994	45,089	5,808	2,880	331,443
6	Wells out of order	DB	No.	1,904	918	549	1,314	767	503	6,115	610	1,056	996	552	804	4,029	1,791	409	2,200	1,026	244	14,491
			%	6.0	7.6	1.6	5.9	5.6	1.8	4.0	3.0	5.9	5.0	1.7	4.1	3.9	6.4	2.8	5.1	17.7	6.3	4.4
7	Wells tested	DB	No.	27,945	11,116	34,791	20,999	12,995	29,394	147,217	19,807	20,799	19,833	31,020	18,623	110,079	26,304	16,475	42,779	4,773	3,609	318,551
			%	99.0	92.4	98.4	94.1	94.4	98.1	96.0	97.0	94.1	99.0	99.3	99.9	95.1	93.6	97.1	94.9	82.2	93.7	96.6
8	Institutional wells	DB	No.	11,052	622	1,080	882	1	1,128	16,364	2,258	1,202	3,884	1,072	744	9,220	1,163	652	1,815	2	216	27,000
			%	39.0	5.2	4.8	4.3	0.0	3.9	10.7	11.5	4.0	19.9	3.3	3.9	7.9	4.1	3.9	4.0	0.0	8.2	8.4
9	Household wells	DB	No.	27,067	11,411	33,680	21,348	13,761	28,841	136,978	18,067	20,394	15,946	31,006	18,681	114,092	26,932	16,311	43,243	5,807	2,534	303,654
			%	70.0	94.8	95.2	95.7	100.0	96.3	89.3	88.5	96.0	80.4	96.7	96.2	92.4	95.9	96.2	96.0	100.0	91.8	91.6
	Well Ownership (all wells: 10-14)																					
10	Govt wells	DB	No.	2,799	4,430	2,443	1,629	1,306	1,214	14,821	3,444	3,453	2,469	2,666	1,596	13,828	2,169	881	3,050	2,128	677	33,482
			%	7.0	36.8	6.9	8.2	9.5	4.1	9.1	16.9	16.6	12.5	8.3	8.2	11.8	7.7	5.1	6.7	36.8	17.6	10.1
11	NGO wells	DB	No.	348	86	93	122	360	56	971	21	256	17	34	216	544	128	44	172	261	110	2,058
			%	0.8	0.7	0.3	0.5	2.7	0.2	0.6	0.1	0.8	0.1	0.1	1.1	0.4	0.5	0.3	0.4	4.5	2.9	0.6
12	Community wells	DB	No.	73	89	368	287	102	129	1,079	29	166	50	309	140	730	164	441	605	11	39	2,558
			%	0.2	0.7	1.1	1.3	0.7	0.4	0.7	0.1	0.6	0.3	1.0	0.7	0.6	1.3	2.6	1.6	0.2	1.0	0.8
13	Private wells	DB	No.	36,791	7,491	32,333	19,839	11,946	28,519	136,908	16,618	27,627	17,298	29,048	17,329	107,900	25,344	15,478	40,822	3,408	3,013	291,937
			%	91.9	61.5	91.6	89.4	86.8	95.1	89.2	81.4	87.3	87.2	90.5	89.2	87.4	90.2	91.2	90.6	58.8	79.3	88.1
14	Other wells	DB	No.	110	29	73	113	35	63	435	313	118	23	28	155	637	90	140	230	5	11	1,309
			%	0.3	0.2	0.2	0.5	0.3	0.2	0.3	1.5	0.4	0.1	0.1	0.8	0.5	0.3	0.8	0.5	0.1	0.2	0.4
	Well Type and Use (all wells; single variables) (15-20)																					
15	Shallow	DB	No.	35,028	11,636	34,414	22,109	13,202	29,217	145,606	18,206	31,192	16,238	31,060	18,774	115,660	27,066	16,365	43,431	4,637	3,754	313,146
			%	97.7	98.7	97.4	99.1	95.9	97.5	95.0	90.1	98.5	81.9	98.8	96.6	93.7	96.3	96.5	96.4	82.8	97.5	94.5
16	Deep	DB	No.	121	80	242	183	531	730	1,873	42	348	379	182	561	1,382	118	378	496	1,109	78	4,348
			%	0.3	0.7	0.7	0.7	3.9	2.4	1.2	0.2	0.8	1.9	0.6	2.9	1.1	0.4	2.2	1.1	19.1	2.0	1.3
17	Tara	DB	No.	154	2	31	3	0	1	191	29	7	71	7	12	126	64	29	94	0	2	403
			%	0.4	<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.1	<0.1	0.4	<0.1	0.1	0.1	0.2	0.2	0.2	<0.1	0.1	0.1
18	Dug	DB	No.	162	22	43	15	17	3	262	564	155	110	18	13	860	43	9	52	1	7	1,182
			%	0.4	0.2	0.1	0.1	0.1	<0.1	0.2	2.8	0.5	0.6	0.1	0.1	0.7	0.2	0.1	0.1	<0.1	0.2	0.4
19	Irrigation...	DB	No.	4,429	287	600	8	11	6	5,336	1,313	44	2,968	8	53	4,386	791	180	971	1	2	10,699
			%	11.1	2.4	1.7	<0.1	0.1	<0.1	3.5	6.4	0.1	15.0	<0.1	0.3	3.8	2.8	1.1	2.2	<0.1	0.1	3.2
20	...of which priv. owned	DB	No.	4,411	284	594	8	11	5	5,311	1,305	42	2,966	8	52	4,373	757	160	917	1	2	10,604
			%	99.6	99.0	99.0	100.0	100.0	100.0	99.5	99.4	95.5	99.9	100.0	98.1	99.7	95.7	88.9	94.4	100.0	100.0	99.1

	Item	Calculation (source and unit)		1: Deltaic (Ganges)							2: Alluvial						3:Chandina alluvium			4 (dt)	5 (dm)	
				[illegible] 1	[illegible] 2	[illegible] 3	[illegible] 4	[illegible] 5	[illegible] 6	Sub Total 1	[illegible] 7	[illegible] 8	[illegible] 9	[illegible] 10	[illegible] 11	Sub Total 2	[illegible] 11	[illegible] 13	Sub Total 3	[illegible] 14	[illegible] 15	GRAND TOTAL
21	Domestic...	~Irrig	No.	36,000	11,747	34,730	22,294	13,751	28,957	147,979	18,132	31,697	16,961	32,069	19,374	118,233	27,304	15,794	44,398	5,008	3,849	320,749
			%	85.9	97.6	98.3	100.0	99.9	100.0	96.5	93.4	99.8	85.0	100.0	99.7	96.6	97.2	99.9	97.8	100.0	99.9	96.9
22	...of which priv. owned	DB	No.	32,290	7,117	31,739	13,933	11,935	28,455	121,509	15,314	27,382	14,354	29,032	17,268	103,450	24,537	15,518	39,935	3,405	3,011	281,335
			%	91.0	60.6	91.4	69.4	86.8	95.1	89.9	80.1	87.3	84.6	90.5	88.1	86.9	90.0	91.3	90.5	59.6	79.2	87.7
23	Other	DB	No.	35	2	5	6	1	5	58	75	6	56	822	14	956	11	4	15	1	7	1,087
			%	0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.4	0.0	0.3	2.6	0.1	0.8	<0.1	<0.1	<0.1	<0.1	0.2	0.3
	Population Coverage (functioning wells) (24-31)																					
24	Domestic HH wells	DB	No.	26,943	10,431	22,634	20,172	12,983	28,347	121,870	17,631	28,746	15,169	20,821	17,974	109,939	28,037	15,729	40,828	4,791	3,242	280,481
			%	71.0	94.4	33.8	90.1	99.9	96.4	89.4	88.3	95.5	90.5	96.8	95.5	92.7	95.4	95.8	95.4	102.2	92.7	91.4
25	...privately owned	DB	No.	24,548	6,655	20,922	18,690	11,374	27,550	110,008	14,387	25,921	13,110	20,227	16,542	98,147	23,203	14,853	38,122	2,790	2,746	231,617
			%	91.1	63.7	94.9	92.7	87.6	97.3	91.1	91.6	90.2	86.8	92.4	92.0	89.3	82.7	94.4	93.4	58.4	82.1	90.1
26	...government owned	DB	No.	2,095	3,687	1,532	1,120	1,162	690	10,256	2,983	2,816	1,959	2,005	1,099	10,851	1,435	287	1,852	1,751	481	26,891
			%	7.8	35.2	6.7	5.6	3.0	2.4	7.8	16.3	9.8	12.9	8.8	6.1	9.9	5.7	2.8	4.5	36.8	14.4	9.5
27	P.5 Users/HH well (fs)	DB	No.	6	6	6	6	6	6	6	7	6	7	7	6	6	7	7	7	6	7	6
28	P.5 Users/HH well (usr)	DB	No.	9	16	15	10	15	9	10	15	12	11	11	15	11	10	10	10	15	20	10
29	Pop. Coverage (fsize, '000)	DB	No.	196	69	242	141	96	203	957	145	200	117	259	123	847	245	149	394	32	34	2,261
			%	73.1	31.0	67.2	66.6	45.1	96.3	59.7	46.3	43.7	46.9	41.4	45.9	44.2	67.0	69.2	67.4	20.4	24.3	53.3
30	Pop. Coverage (users, '000)	DB	No.	349	256	535	364	222	312	2,130	281	501	282	614	273	1,951	440	258	704	257	168	5,133
			%	154	110	127	141	130	97	136	85	110	113	98	102	102	122	117	121	102	109	117
31	Domestic HH well/1000		No.	106	47	84	80	54	79	77	56	63	61	49	67	57	69	72	70	30	24	64
	Arsenic Levels (functioning wells) (32-34)																					
32	Arsenic > 0	DB	No.	10,977	334	3,498	383	183	189	15,616	1,653	868	2,793	593	6,221	11,833	2,269	121	3,490	1,018	282	31,798
			%	28.9	2.8	15.0	1.8	1.2	0.6	12.6	8.4	2.9	14.8	2.8	27.9	9.8	12.8	0.7	8.2	22.2	7.2	10.3
33	>= 50 ppb	DB	No.	30,206	2,965	16,555	2,074	3,299	18,217	71,406	5,204	3,973	7,156	2,152	9,022	26,467	7,625	265	7,890	1,146	520	109,759
			%	79.8	26.9	47.6	9.3	28.3	65.2	48.5	26.3	13.2	38.2	6.8	63.3	24.0	29.0	1.3	18.4	24.0	14.4	34.8
34	< 50 ppb	DB	No.	7,608	8,131	18,226	18,312	8,706	13,177	76,811	14,603	26,818	11,877	29,373	8,701	90,368	18,678	16,210	34,889	3,627	3,066	207,983
			%	20.2	73.1	52.4	90.1	74.7	44.8	51.5	73.7	86.7	62.0	93.2	46.7	76.0	71.0	96.4	81.6	76.0	85.6	65.5
	Well Depth and Age (functioning wells) (35-39)																					
35	Max depth	DB	ft	2,000	2,000	2,200	8,100	7,602	2,001	8,106	2,001	2,001	8,000	2,068	1,008	8,000	2,002	7,050	7,080	8,000	1,370	8,000
36	Median depth	DB	ft	90	145	110	75	100	50	90	70	95	60	94	100	90	95	75	95	60	60	90
37	Mean depth	DB	ft	98	150	123	87	143	64	101	69	102	64	97	107	102	104	80	97	254	75	103
38	Oldest well	DB	yrs	102	102	102	102	102	101	102	102	102	108	102	84	108	102	30	102	102	86	108
39	Median age	DB	yrs	7	7	6	6	7	7	7	7	7	6	7	6	7	7	7	7	6	7	7

Notes:
DB = Database
Row 21: domestic wells are counted as those which are not irrigation wells
Rows 27 and 28: P.5 is shorthand for median value
Fs = family size
HH = Household size
So row 27: median no. of users per household well based on recorded family size;
row 28: median no. of users per household well based on no. of recorded users per well.

Annex 2: National Data Collection Form v.1

BAMWSP	**Bangladesh Arsenic Mitigation Water Supply Project**	Upazila	
		Union	
	National Survey Program	Village	
	Tubewell and Health Information Survey	Para	
		Surveyor	
Form No: Emergency	**Methodology: Household based / Institutions**	Ward Team #	
Screening Programme /5		Date	

1. I.D.	**2. Name & Address**	**3. [Family Size]**		
5 digits		M	F	Total

4. Tubewell Related Data

Type of test kit

Well ID	Status	Owner	Yr of inst	Depth (ft)	Type	# users	Arsenic level (mg/l)	Painted?
	1-operational 2-out of order	1 government 2 NGO 3 community 4 Private 5 Other			1 Shallow 2 Deep 3 Tara 4 Dug well 5 irrigation 6 other			1 Green 2 Red

5. Arsenic Related Health Information

S.I.	Age	M	F	Manifestations					Year started	When had diarrhoea last	Source of dr. water
				Black Spots in Body	Black/ White Spot	Rough Spots on sole	Ulcer on Palm/ sole	Gangrene In leg			1 stw 2 dtw 3 dug well 4 pond 5 other

Death with symptoms of arsenic	Male		Female	
Name of data collector		Date		
Name of ward members/team leader		Signature		

Annex 3:
District Variation Tables KAP Survey Analysis

In the tables that contain percentages broken out by districts, illustrating district variation, certain cells below will contain the entry 'NA'. In some cases, this is due to a lack of response from respondents. In other cases, notably in responses from Jessore and Faridpur, the 'NA' entry is due to the discrepancy between the surveys caused by differences in survey format (see chapter 5, "Data" section).

Part II A: Knowledge Questions

Whether one can find arsenic in water

In the follow-up, 89.06% of the respondents in Narail respond correctly compared to 66.34% of the respondents from Brahmanbaria (note: consider dropping, since discrepancy is less striking). We might expect that the respondents of Brahmanbaria, who have higher levels of education and income, would be more responsive to dissemination and hence would respond more correctly in the follow-up. We don't see that happening here.

Table 1: Arsenic in water--Variation within and across the districts.

1= Yes, 0= No + Don't Know		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi.	Madari.	Narail	Jessore	Farid.
% Correct	Baseline *(1419)*	79.78	26.32	53.77	73.08	66.99	43.06	56.82	1.82	66.45	63.51
	Follow-up *(982)*	100.00	66.34	86.93	100.00	99.67	97.25	96.00	89.06	79.00	81.00
	Total (2401)	90.43	50.59	63.33	94.44	79.02	75.69	77.66	62.84	68.66	66.79

Whether arsenic can be removed from water

In Table 2, in Barisal, Brahmanbaria, Chuadanga, Comilla, and Madaripur the percentage of correct responses decreases. For the other districts it increases between baseline and follow-up. This inconsistency is intriguing and raises the issue of how the question is interpreted or, put another way, what the correct response is depending on interpretation.

Table 2: Arsenic removal from water--Variation within and across the districts

1= Yes, 0= No + Don't Know		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Correct	Baseline *(1074)*	50.56	53.03	42.77	57.69	58.25	17.65	43.75	5.45	42.95	32.56
	Follow-up *(634)*	45.45	20.79	57.29	55.00	54.33	68.81	8.63	7.03	49.00	65.00
	Total (1708)	47.87	33.53	46.96	55.56	56.81	49.15	25.20	6.56	44.01	38.65

Whether symptoms will go away if respondent stops using arsenic water

In Table 3, we see the largest increases in the districts of Chuadanga and Comilla, with a large increase in the districts of Brahmanbaria and Narail as well. Munshiganj, interestingly, experienced a marked decline between the baseline and follow-up surveys.

Table 3: Symptoms disappear--Variation within and across the districts

1= Yes, 0= No + Don't Know		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi.	Madaripur	Narail	Jessore	Farid.
% Correct	Baseline *(210)*	25.84	35.38	26.19	15.38	15.87	30.99	49.43	12.73	NA	NA
	Follow-up *(726)*	39.39	77.07	43.43	99.00	95.98	6.42	57.75	57.81	NA	NA
	Total (936)	32.98	60.90	38.30	81.75	76.72	16.11	53.87	44.26	NA	NA
% still using when arsenic is found in the tubewell	baseline	60.00	100.00	0.00	NA	100.00	100.00	78.95	100.00	NA	NA
	follow-up	59.57	61.94	93.62	94.12	93.29	85.45	100.00	98.55	NA	NA

Can people die if they continue to drink arsenic water?

In table 4 we see a significant increase between baseline and follow-up in each district in the correct response, with the exception of Munshiganj, where follow-ups were not available. The increase in Comilla is more significant, however, than in the other districts.

Table 4: Can you die from arsenic in water--Variation within and across the districts

1= Yes, 0= No + Don't Know		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi.	Madari.	Narail	Jessore	Farid.
% Correct	Baseline *(1419)*	79.78	26.32	53.77	73.08	66.99	43.06	56.82	1.82	66.45	63.51
	Follow-up *(982)*	100.00	66.34	86.93	100.00	99.67	97.25	96.00	89.06	79.00	81.00
	Total (2401)	90.43	50.59	63.33	94.44	79.02	75.69	77.66	62.84	68.66	66.79

Whether respondent knew of any organization carrying out arsenic testing?

The correct response rates for this question were similar in the follow-up survey, although there was significant variation in the response rates in the baseline survey. Narail experienced the most dramatic increase, followed by Brahmanbaria. Compared to the other districts, the increase in the correct response rate in Jessore was relatively minor.

Table 5: Awareness of arsenic testing activity--Variation within and across the districts

1= Aware, 0= Not Aware		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi.	Madaripur	Narail	Jessore	Farid.
% Aware	Baseline *(1555)*	40.45	24.06	47.66	50.00	76.85	76.39	72.16	9.09	81.41	63.97
	Follow-up *(1484)*	94.95	98.53	99.49	99.00	98.99	95.37	91.92	96.09	90.00	100.00
	Total (3039)	69.15	69.14	62.55	88.89	84.98	89.78	82.62	69.95	82.92	70.73

What does the red spout mean?

In certain districts, notably Narail and Chuadanga, very few respondents answered this question in the baseline survey (5 and 3, respectively), making analysis difficult. The response pattern for the district of Munshiganj was puzzling, as only one respondent out of 109 answered the question correctly in the follow-up survey. The districts unaffected by the low initial response rate, other than Munshiganj, experienced a similar increase in correct response rate.

Table 6: Meaning of the red pump spout - Variation within and across the districts

1= Red Means Arsenic		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Correct	Baseline *(858)*	71.43	62.50	29.63	100.00	51.55	14.29	88.57	100.00	54.70	33.26
	Follow-up *(1082)*	94.95	99.02	96.58	100.00	99.50	0.92	97.39	77.53	94.00	95.00
	Total (1940)	92.04	97.65	43.23	100.00	66.36	3.65	94.05	78.72	61.62	44.84

Can Someone Spread Arsenicosis?

Though there is significant increase in correct responses in each district, we notice greater increases in the Barisal and Chuadanga. Jessore increased only by about 1.5 percent.

Table 7: Is arsenicosis contagious? Variation within and across the districts

1= No		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% No	Baseline *(769)*	32.58	50.78	18.33	23.08	37.74	42.25	48.00	43.64	35.68	18.48
	Follow-up *(1182)*	97.96	85.29	68.34	100.00	83.16	96.33	83.84	63.28	37.00	40.00
	Total (1951)	68.84	71.99	32.75	84.13	54.38	75.00	67.02	57.38	35.92	22.51

Part II B: Attitude Questions

Should a person suffering from arsenicosis be allowed to share same water source?

We see increases in the percentages saying 'yes' in each district. However, in Narail, significantly fewer people say 'yes' in the follow-up survey compared to the respondents in the other districts. Barisal, Chandpur, Chuadanga, Comilla, and Munshiganj all experienced increases in excess of 60 percentage points in the correct response rate.

Table 8: Sharing water sources with an arsenicosis patient--Variation within and between districts

1= Yes		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Yes	Baseline *(247)*	31.48	46.62	28.57	26.92	9.09	23.61	60.80	14.55	NA	NA
	Follow-up *(1004)*	98.99	90.24	91.84	100.00	85.43	96.33	90.95	58.59	NA	NA
	Total (1251)	67.02	73.08	72.86	84.92	66.42	67.40	76.80	45.36	NA	NA

Should a child be allowed to play with an arsenic-affected child?

In the low-income, low-education district Narail, the percentage responding 'yes' is the lowest, for both the baseline and the follow-up surveys. We see the most significant increases over time in correct responses in Chuadanga, Chandpur, Comilla, and Munshiganj districts.

Table 9: Children play with arsenicosis affected children--Variation within and across the districts

1= Yes		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Yes	Baseline *(234)*	24.71	42.11	33.33	26.92	34.85	34.72	45.45	12.73	NA	NA
	Follow-up *(1029)*	92.93	96.57	98.99	100.00	97.49	97.25	89.74	52.34	NA	NA
	Total (1263)	60.64	78.07	79.43	84.92	81.89	72.38	68.73	40.44	NA	NA

Should an arsenic-affected person leave the village?

The increase in correct response is somewhat higher in Narail and Madaripur, but fairly similar across districts. Overall, the increase is not as high as we observed in case of other knowledge and attitude questions due to the relatively high correct baseline response rate.

Table 10: Should arsenicosis patient leave--Variation within and across districts

1= No		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% No	Baseline *(428)*	66.29	69.70	87.80	69.23	75.76	80.28	51.14	47.27	NA	NA
	Follow-up *(1054)*	91.92	84.88	98.99	99.00	98.99	98.17	91.84	84.38	NA	NA
	Total (1482)	79.79	78.93	95.71	92.86	93.21	91.11	72.58	73.22	NA	NA

Will you allow your child to marry an arsenic-affected person?

Fewer people in low-income, low-education district Narail will allow their child to marry an arsenic-affected person. The most substantial increase was found in Chuadanga, the only district where respondents answered correctly more than half the time.

Table 11: Can your child marry an arsenicosis affected person? Variation within and across the districts

1= Yes		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Yes	Baseline *(119)*	10.11	11.36	4.89	19.23	3.31	15.28	10.80	0.00	4.70	1.85
	Follow-up *(302)*	48.48	38.42	21.11	65.00	29.10	33.94	14.21	14.84	6.00	5.00
	Total (421)	30.32	27.68	9.57	55.56	12.79	26.52	12.60	10.38	4.93	2.44

Part II C: Practice and Actions Questions

Did you ever take water from an arsenic contaminated source?

Since there are few responses in the baseline survey, we cannot infer anything statistically in terms of changes between baseline and follow-up surveys.

Table 12: Did you ever drink water with arsenic--Variation within and across the districts

1= Yes		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Yes	Baseline *(32)*	60.00	40.00	0.00	0.00	NA	33.33	44.83	50.00	NA	NA
	Follow-up *(443)*	39.35	90.67	88.24	96.00	97.12	71.79	52.25	83.58	NA	NA
	Total (475)	38.64	89.39	65.22	95.05	97.12	67.82	49.70	82.61	NA	NA

Do you still take water from that source?

We only have 35 responses in the baseline making is impossible for us to say anything conclusive about variations between baseline and follow-up surveys within each district.

Table 13: Do you still drink contaminated water--Variation within and across the districts

1= Yes		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Yes	Baseline *(16)*	66.67	50.00	NA	NA	NA	33.33	46.15	100.00	NA	NA
	Follow-up *(270)*	58.06	54.60	93.75	62.50	53.40	1.79	100.00	80.36	NA	NA
	Total (286)	58.82	54.55	93.75	62.50	53.40	3.39	83.33	80.70	NA	NA

Part II D: Willingness To Pay Questions

The response rate between districts is remarkably similar. In some cases, respondents in Narail were less willing to spend money on these measures. The lower level of income and wealth of the respondents from Narail is perhaps responsible for this difference.

Table 14: Willingness to pay--Variation within and across the districts

		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
% Yes, for testing the tubewell	Baseline *(2458)*	96.63	*88.72*	92.26	*88.46*	*95.73*	*88.89*	*93.18*	*52.73*	*82.26*	*92.84*
	Follow-up *(1468)*	95.96	97.08	74.87	*100.00*	*98.66*	*93.58*	*81.50*	*71.09*	*94.90*	*100.00*
	Total (3926)	96.21	92.96	87.25	97.62	96.81	91.71	86.97	65.57	84.45	94.17
% Yes, for maintaining the tubewell	Baseline *(652)*	95.91	88.55	23.81	*88.46*	*87.88*	*92.65*	*89.14*	*45.45*	*NA*	*NA*
	Follow-up *(1073)*	98.98	99.31	67.35	*100.00*	*98.99*	*99.06*	*89.50*	*90.32*	*NA*	*NA*
	Total (1725)	97.33	94.18	54.29	97.62	96.23	96.55	94.13	77.05	NA	NA
% Yes, for installation of a new tubewell	Baseline *(2456)*	98.86	89.47	90.43	*80.77*	*97.67*	*88.73*	*83.52*	*74.55*	*97.86*	*89.38*
	Follow-up *(1533)*	98.99	96.06	92.39	*100.00*	*91.30*	*96.26*	*99.50*	*95.31*	*96.00*	*95.00*
	Total (3989)	98.93	93.45	90.99	96.03	95.33	93.26	92.02	89.07	97.54	90.43
% Yes, for maintaining the new tubewell	Baseline *(2457)*	98.88	88.72	90.84	*76.92*	*97.28*	*91.55*	*84.66*	*74.55*	*95.94*	*95.61*
	Follow-up *(1530)*	97.98	95.52	94.42	*100.00*	*91.25*	*95.37*	*98.50*	*94.53*	*96.00*	*95.00*
	Total (3987)	98.40	92.81	91.86	95.24	95.07	93.85	92.02	88.52	95.95	95.50

For districts we see similar trends, e.g. less follow-up willingness to spend for 'testing the tubewell' and more for other categories. The variation across districts for 'maintaining the tubewell' is significant, as three districts experienced drops in this willingness. Respondents from Narail are willing to spend significantly less than other districts for all categories other than 'testing the tubewell'. Differences in income and wealth between districts may explain this, though Chuadanga's willingness's are comparable to others'.

Table 15: Amounts willing to pay - Variations within and across the districts

		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi	Madaripur	Narail	Jessore	Farid.
For testing the tubewell	Baseline	65.69	65.49	29.05	36.09	37.03	88.05	24.39	51.38	24.45	28.25
	Follow-up	55.87	11.75	25.59	15.24	31.81	136.42	18.79	16.32	34.02	27.06
	Total	65.54	38.47	28.20	19.14	35.10	177.77	21.58	24.79	26.13	28.03
For maintaining the tubewell	Baseline	108.36	71.96	65.50	94.78	145.86	314.60	28.78	38.00	NA	NA
	Follow-up	109.43	220.07	53.71	114.12	166.77	201.52	26.57	27.28	NA	NA
	Total	108.93	153.79	59.21	110.50	162.02	243.93	27.55	26.66	NA	NA
For installation of a new tubewell	Baseline	1183.66	140.30	10.93	106.19	37.36	302.50	852.93	52.90	19.53	3.94
	Follow-up	2098.72	519.36	242.43	262.90	490.70	292.78	1095.58	86.32	790.16	369.50
	Total	1168.11	375.07	79.09	238.53	198.03	213.22	992.49	79.51	155.28	72.53
For maintaining the new tubewell	Baseline	450.55	94.49	2.32	58.50	12.72	332.22	49.78	76.45	0.00	0.02
	Follow-up	118.25	59.57	28.51	21.46	45.20	92.93	43.01	15.78	14.38	17.14
	Total	475.37	72.75	9.04	27.63	24.04	183.20	45.92	22.24	2.76	3.18

Part IV: Tubewell Ownership, Testing and Use

From Table 16 below, we see that compared to respondents from the other districts, fewer people own a tubewell in Barisal, Jessore, and Narail, but the percentage of tubewells in the baseline that have been tested for arsenic is higher in Barisal, Munshiganj, Madaripur, and Narail than in most of the other districts. We notice the lowest percentage of well testing positive for arsenic in Chuadanga and Comilla. The percentage of respondents still using the same tubewell is relatively constant across districts, except in Barisal and Brahmanbaria, where a lesser percentage is using the same tubewell. This is also true for the percentage of people who still using the same tubewell after arsenic was found.

Table 16: Well ownership: Variation within and across the districts

		Barisal	Brah.	Chand.	Chuad.	Comilla	Munshi.	Madaripur	Narail	Jessore	Farid.
% own a tubewell	baseline	80.90	91.73	78.57	88.46	87.88	84.72	95.45	52.73	NA	NA
	follow-up	72.16	93.17	88.38	100.00	88.96	94.50	95.00	73.44	39.00	82.00
% of tubewell that has been tested	baseline	19.44	6.14	9.13	4.35	3.55	34.43	28.57	17.24	5.56	5.77
	follow-up	100.00	99.48	99.49	100.00	98.63	99.01	99.48	94.51	87.80	97.00
% of tubewell where arsenic has been found	baseline	76.92	75.00	55.26	0.00	11.76	38.10	40.43	75.00	68.00	76.00
	follow-up	67.14	91.76	96.86	51.00	67.82	55.00	65.08	81.18	86.11	68.04
% of respondents still using the same tubewell	baseline	78.26	96.67	81.82	100.00	98.18	97.73	93.57	89.29	NA	NA
	follow-up	59.57	65.91	93.62	94.23	93.33	87.88	100.00	96.00	NA	NA

Annex 4:
KAP Survey Observations by District and NGO

District	NGO	Observations	Baseline	Follow-up
Barisal	NGO Forum	199	99	100
	ISDCM	1	1	0
Brahmanbaria	CDIP	211	106	105
	ISPCM	200	100	100
Chandpur	Grameen	200	100	100
	BRAC	549	449	100
Chuadanga	ISDCM	201	101	100
Comilla	Grameen	200	100	100
	ISDCM	198	99	99
	BRAC	549	449	100
	CDIP	1	0	1
Madaripur	GUP	400	200	200
Munshiganj	DCH	211	102	109
Narail	EPRC	232	102	130
Jessore	BRAC	568	468	100
Faridpur	BRAC	533	433	100
		4453	2909	1544

It appears that 3 observations may have been miscoded. They can be checked or not used.

Annex 5: Summary of BRAC and non-BRAC KAP Survey Differences

Q#	Question Description	In BRAC Survey?
---	Surveytype (ID)	Yes
---	District	Yes
1	Sex	Yes
2a	Age	Yes
2b	Married	No
2c	Number of children	No
2d	Age of youngest child	No
2e	Occupation	Yes
2f	Education	Yes
2g	Can read or write	No
3a	Items owned by household	Yes
3c	Agricultural land	Yes
3d	Electricity	Yes
3e	Total household income	Yes
4a	Listen to radio	Yes
4b	Watch TV	Yes
6	Household structure	No
12c	Can you determine if water contains arsenic	Yes
12e	Can arsenic be removed from water	Yes
13c	Will problems caused by arsenic go away	No
13e	Can people die from drinking water w/arsenic	No
14a	Can people spread arsenic-related illness	Yes
14c	Should someone w/arsenicosis share water sources	No
14d	Should a child w/arsenicosis be allowed to play w/others	No
14e	Should a person w/arsenicosis leave the village	No
14f	Would you allow your child to marry a person w/arsenicosis	Yes
15a	Aware of organization testing for arsenic	Yes
15f	What does a red mark on a tubewell mean	Yes
16a	Do you ever take water from wells where arsenic was found	No
16b	Do you still take water from the well where arsenic was found	No
17a	Do you have a tubewell in your home	Yes
17b	Has this tubewell been tested	Yes
17c	What did the test show	Yes
17d	Are you currently using this tubewell	No
20b	Would you be willing to pay for tubewell testing	Yes
20c	How much	Yes
20d	Would you be willing to pay for maintaining tubewells	No
20e	How much	No
20f	Would you be willing to pay for installation of new water supply	Yes
20g	How much	Yes
20h	Would you be willing to pay for maintaining new tubewells	Yes
20i	How much	Yes

Q#	Notes
2e	Categories don't overlap, can still determine farmer/no
2f	Categories don't overlap, assume literate = educated
20b - c	Respondents are given option of providing labour or $
20f – i	Respondents are given option of providing labour or $

Not Just Red or Green