Paper 2

An Overview of Current Operational Responses to the Arsenic Issue in South and East Asia

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Summary

1. This paper focuses on the operational responses to natural groundwater contamination in affected countries of South and East Asia. The paper first outlines the health effects of arsenic ingested through water and the different recommended permissible values of maximum concentration of arsenic in drinking water, and presents a critical analysis of the current status of epidemiological knowledge.

2. This is followed by a comprehensive presentation of the operational responses implemented to mitigate arsenic contamination in the study countries, and an assessment of such operational responses in the overall context of the water supply sector. Finally, an attempt is made to highlight the political economy of arsenic mitigation and to assess the options for addressing arsenic from this perspective.

3. The paper also extracts the major lessons learned when implementing short-term and long-term mitigation measures in South and East Asian countries. These are divided into technical, financial and economic, social and cultural, and institutional issues, and are summarized in overview matrices in annex 2.

4. The outcome of the paper is a tool that aims to help decisionmakers in government, multilateral and bilateral institutions, nongovernmental organizations, academics, and water practitioners in general address arsenic contamination of groundwater. By bringing together information from a variety of sources, including published and unpublished literature, results of a specially administered survey, and outcomes of a regional workshop held in Kathmandu in 2004, the paper collates, synthesizes, and makes accessible the vast range of arsenic-related information currently available in order to inform and facilitate concrete operational responses to the arsenic issue.

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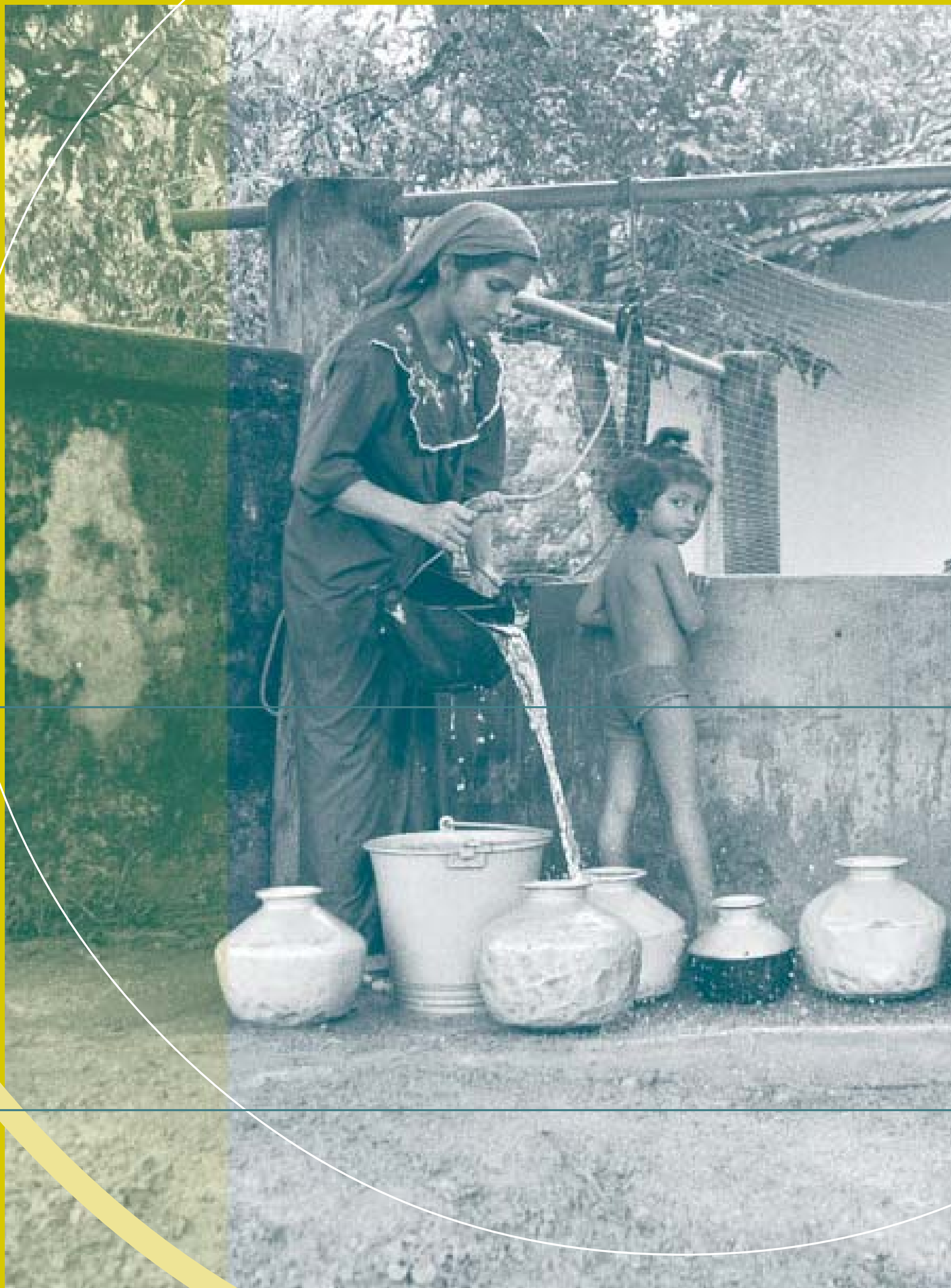

1. Introduction

Natural arsenic contamination of groundwater affects a number of countries worldwide, and specifically in South and East Asia. This paper first reviews the operational responses to natural arsenic contamination of groundwater in Asian countries that have hitherto been developed and carried out; second, it analyzes the success and failure of these responses; and third, it presents practical guidance for stakeholders, at either the country or project level, to better address the arsenic issue. This is critical since governments, the World Bank, and other development partners implement water projects in this region and are responsible for providing safe drinking water. Stakeholders need to be aware of this contamination, have tools to identify it, and have practical information to provide a proactive response or, where the contamination has been identified at a later stage, a reactive response.

The countries in South and East Asia so far identified as affected by natural arsenic contamination of groundwater are Bangladesh, Cambodia, China (including Taiwan), India, Lao People's Democratic Republic (PDR), Myanmar, Nepal, Pakistan, and Vietnam.

This paper deals with natural arsenic contamination rather than contamination of mining and geothermal origins, and with rural rather than urban areas. The focus on natural contamination, which is due to the release of arsenic from sediment to water, stems from the fact that this contamination is still unpredictable, and is thus far more difficult to address than contamination of mining and geothermal origin. Similarly, contamination in rural areas presents a greater challenge than that faced in more compact urban areas.

The operational responses to deal with arsenic that have been implemented to date include screening of tubewells, identification and treatment of those affected by contamination, sharing of arsenic-safe wells, awareness raising, and development of alternative water provision through, for instance, dug wells, pond sand filters, rainwater harvesting, arsenic removal plants, and tapping deep groundwater.

The paper is structured in four chapters. Chapter 1 presents the health effects and the recommended maximum permissible values of arsenic in water. A critical analysis is provided regarding the lack of epidemiological studies on the health effects of arsenic and the current uncertainty regarding safe levels of arsenic in drinking water.

Chapter 2 presents the operational responses implemented in South and East Asian countries. An assessment is made of the lessons learned and the remaining issues on which no conclusions can yet been drawn.

Chapter 3 discusses arsenic mitigation in the overall context of water supply, including an analysis of the priority accorded to arsenic contamination.

Chapter 4 analyzes incentives for stakeholders to be active (or inactive) in implementing operational responses to arsenic contamination. These incentives influence the political economy and are drawn from the lessons learned and other issues analyzed in chapter 2. Due to the large number of countries affected, and recognizing that the political economy varies from country to country, this paper does not address political economy in depth for each individual country but rather discusses incentives generally.

2. Arsenic: Health Effects, Recommended Values, and National Standards

Arsenic is a substance that is carcinogenic – capable of causing cancer. Organic arsenic compounds are less toxic than inorganic compounds, the latter being more commonly found in natural arsenic water contamination. The recommended standards for the maximum acceptable dose of arsenic are based on health risks, but the lack of epidemiological data on low doses of exposure makes the health risks difficult to assess with certainty.

This chapter presents international and national standards for arsenic intake in drinking and irrigation water; the major assumptions regarding the interpretation of epidemiological data used to assess the recommended maximum permissible values and standards; the major health effects of arsenic; the status of the debate on arsenic intake from the food chain; and the effects of trace elements on reducing or increasing arsenic toxicity.

International and National Standards for Arsenic Intake

Regarding arsenic concentration in irrigation water, neither international agencies nor individual countries propose any recommended maximum permissible values. For drinking water, however, due to the carcinogenic nature of the substance, the World Health Organization (WHO) has issued a provisional guideline recommending a maximum permissible arsenic concentration of 10 $\mu g\ L^{-1}$ (micrograms per liter). WHO guidelines are meant to be used as a basis for setting national standards to ensure the safety of public water supplies and the guideline values recommended are not mandatory limits. Such limits are meant to be set by national authorities, considering local environmental, social, economic, and cultural conditions.

Most developed countries have adopted the provisional guideline value as a national standard for arsenic in drinking water. On the other hand, most developing countries still use the former WHO-recommended concentration of 50 $\mu g\ L^{-1}$ as their national standard. Table 1 uses a sample of countries to illustrate the range of values adopted (7 $\mu g\ L^{-1}$ to 50 $\mu g\ L^{-1}$).

Table 1. Currently Accepted National Standards of Selected Countries for Arsenic in Drinking Water

Country/region	Standard: $\mu g\ L^{-1}$	Country	Standard: $\mu g\ L^{-1}$
Australia (1997)	7	Bangladesh (1997)	50
European Union (1998)	10	Cambodia	50
Japan (1993)	10	China	50
USA (2002)	10	India	50
Vietnam	10	Lao PDR (1999)	50
Canada	25	Myanmar	50
		Nepal	50
		Pakistan	50

Source: Ahmed 2003.

The fact that some countries have adopted the recommended maximum permissible value of 10 μg L^{-1} while others still use a value of 50 μg L^{-1} is related to the chronology of recommended maximum permissible values proposed by the WHO (table 2). In 1993 the WHO recommended lowering the maximum permissible value from 50 μg L^{-1} to 10 μg L^{-1} as a precautionary measure because of the carcinogenic effects of arsenic, especially regarding internal cancers. So far most developed countries have adopted this new recommended value as a national standard (table 1).

Most developing countries, however, have not lowered their national standards because they feel they could not afford the associated economic costs, including treatment and monitoring costs. For further discussion of this issue see Paper 4.

Table 2. Chronology of Recommended WHO Values for Arsenic in Drinking Water

1958	First WHO International Drinking Water Standard: 200 μg L^{-1}
1963	WHO recommend lowering guide value to 50 μg L^{-1}
1974, 1984	Affirmation of 50 μg L^{-1} as guide value
1984	WHO Guidelines replace International Drinking Water Standard, providing a basis for national standards by individual countries
1993	WHO provisional guideline recommends lowering guide value to 10 μg L^{-1}

The United States Environmental Protection Agency (EPA) conducted an economic study with concentrations of 3, 5, 10, and 20 μg L^{-1} and found that, given the conditions prevailing in the United States of America, the recommended maximum permissible value of 10 μg L^{-1} represented the best trade-off among health risks, the ability of people to pay for safe water, and the availability of water treatment technology. The standard of 10 μg L^{-1} will be further lowered as treatment technology becomes more affordable. The WHO-recommended maximum permissible value for carcinogenic substances is usually related to acceptable health risk, defined as that occurring when the excess lifetime risk for cancer equals 10-5 (that is, 1 person in 100,000). However, in the case of arsenic, the EPA estimates that this risk would mean a standard as low as 0.17 μg L^{-1} (Ahmed 2003), which is considered far too expensive even for industrial countries to achieve.

The health risks used in the EPA estimate were based on data from an epidemiological study conducted in Taiwan. Since the study only considered the risk of skin cancer and lacked data on internal cancers, and because of several conservative assumptions in the EPA model, the health risks may have been underestimated. On the other hand, the actual rate of skin cancer may be overestimated because of possible simultaneous exposure to other carcinogenic compounds (Ahmed 2003).

Even though the exact health effects of an arsenic concentration of 50 μg L^{-1} have not been quantified, many correlations between internal cancer and low concentration of arsenic have been found. Therefore it is important that localized epidemiological studies are carried out in a strategic manner, to more clearly inform decisionmakers.

Major Limitations of Existing Epidemiological Studies

Humans are exposed to different forms of arsenic from the atmosphere, food, and water. An important distinction needs to be made between inorganic and organic arsenic, inorganic arsenic being the carcinogenic form, though organic arsenic also has adverse health effects. Inorganic arsenic is the only form that occurs in water, and is therefore the focus of this study.[1] The study of kinetics and metabolisms of arsenicals in humans is complex due to the following issues (ATSDR 2002):

- Physicochemical properties and bioavailability vary with form of arsenic.
- There are many routes of exposure (inhalation, ingestion, and dermal).
- The intake of arsenic can be either acute or chronic.
- Length of exposure can be short, medium, or long term.
- The differing susceptibility to arsenic between humans and animals makes the quantitative dose response data from animals unreliable for determining levels of significant human exposure.

This paper focuses on the human health effects of chronic exposure to arsenic by ingestion. This focus has been chosen as the main source of arsenic poisoning is through contaminated groundwater, and the secondary source is through the food chain.

In the literature, the health effects of arsenic have been estimated from data from various regions (for example Australia, Argentina, Chile, Taiwan). Nevertheless, clear linkages between a given concentration of arsenic in drinking water and its health effects are difficult because of the following issues:

- In most cases of ingestion, the chemical forms of arsenic are unknown.
- Most studies do not consider the volume of drinking water consumed.
- Most studies do not report the temporal variations of the concentration of arsenic in the source over a long period.
- There is a lack of data about the relative importance of arsenic intake from sources other than drinking water, in particular from the food chain.

Because of these issues, it is difficult to assess the exact health effects for a particular concentration of arsenic in groundwater. The available epidemiological studies present the health effects based on the exposure dose of arsenic, which is defined as the quantity of arsenic that is ingested per kg of weight per day and can be calculated according to equation 1.

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[1] See Paper 1 regarding organic and inorganic arsenic and the oxidation state of inorganic arsenic.

Equation 1. Health Effects of Arsenic Exposure Dose

$$ED = \frac{C * DI}{BW}$$

Where:
ED = exposure dose (mg kg^{-1} day^{-1})
C = exposure concentration (mg L^{-1})
DI = daily intake of water (L day^{-1})
BW = body weight (kg)

When estimating exposure dose one of the usual assumptions is that daily water intake is 2 liters (Ahmed 2003; ATSDR 2002; WHO 2001b). However, based on the literature reviewed, daily intake in rural areas tends to be higher, and varies from 3 to 5 liters (Ahmed 2003; Masud 2000). Importantly, health risk estimations increase as daily intake increases.

It appears that improved nutrition increases tolerance to arsenic contamination. For example, in some arsenic-affected villages of West Bengal in India, families with access to nutritious food show almost no arsenical skin lesions compared with undernourished families, despite the fact that both are consuming the same arsenic-contaminated water. Hence the poor, who are more likely to be malnourished, tend to be most affected by arsenic contamination.

In summary, existing epidemiological studies are still often based on simplifying assumptions that introduce a number of uncertainties when quantifying the relationship between the concentration of arsenic and health effects.

Major Health Effects

This section focuses on the major health effects of arsenic, which include skin lesions, blackfoot disease, diabetes, hypertension, skin cancers, and internal cancers. In annex 5 a detailed matrix of the health effects is provided with (when available) the exposure dose and the concentration of arsenic based on equation 1 with sensitivity analysis of the daily water intake (2, 3, and 5 liters).

Arsenic has various health effects ranging from arsenicosis to skin cancers and internal cancers. However, so far there is still no widely accepted definition of what constitutes arsenicosis, the term used for the pattern of skin changes that occurs after chronic ingestion of arsenic. These skin changes are usually the first symptoms to appear in the presence of high concentrations of arsenic in drinking water. However, two epidemiological studies of chronic ingestion suggest that these lesions could appear for concentrations lower than 100 µg L^{-1}. Another primary noncancer health effect is blackfoot disease, which was first observed in Taiwan. This peripheral vascular disease leads, eventually, to a dry gangrene and the spontaneous amputation of affected extremities (Kaufmann and others 2001).

The cancer effects of chronic exposure to arsenic through drinking water include skin cancers and internal cancers (lung, bladder, and kidney). In 1988 the EPA estimated that in the United

States chronic ingestion of 50 µg L^{-1} results in a skin cancer rate of 1 in 400; in 1992, the EPA estimated that the internal cancer mortality risk is about 1.3 in 100 at 50 µg L^{-1}. In 1999 the United States National Research Council (NRC) estimated the overall cancer mortality risk to be about 1 in 100 at 50 µg L^{-1} (NRC 1999; Smith and others 2002).

Internal cancers are of primary concern since they account for most fatalities resulting from chronic ingestion of arsenic through drinking water. Skin cancers are not usually fatal if they are identified at an early stage, and their external symptoms make diagnosis more likely than with internal cancers.

Arsenic Ingested through the Food Chain

The proportion of inorganic arsenic ingested through food may be significant, even when the arsenic concentration of drinking water is higher than 50 µg L^{-1}. For example, a recent study conducted in Mexico (Del Razo and others 2002), where the concentration of arsenic in drinking water was as high as 400 µg L^{-1}, found that even so 30% of inorganic arsenic intake came from food.

The quantities of organic and inorganic arsenic in food should always be quantified, since the form of arsenic affects its bioavailability and thus its toxicity to humans. Unlike water, where arsenic is always inorganic, food can contain either organic or inorganic arsenic. Different studies have found different proportions of organic and inorganic arsenic in food. For example, an EPA study found the percentages of inorganic arsenic in rice, vegetables, and fruit to be 35%, 5%, and 10% respectively (EPA 1988); a study conducted in West Bengal found the percentages of inorganic arsenic in rice and vegetables to be 95% and 5% respectively (Roychowdhury, Tokunaga, and Ando 2003); and another Bengali study found the percentage of inorganic arsenic in rice to be 43.8% (Roychowdhury and others 2002). This wide range of values shows that the total amount of arsenic (both organic and inorganic) in a food sample cannot be taken as an accurate indication of the toxicity of the sample.

In soil irrigated with water having significant arsenic concentrations, higher concentrations of arsenic were found in the peel or skin of the crops, while lower arsenic concentration were found in the edible part of the raw crops. A study by Das and others (2004) found the arsenic content of some vegetables to be greater than the recommended limit of 1 mg kg^{-1} set in the United Kingdom and Australia. Another concern regarding the use of contaminated water for irrigation is the effect of arsenic on the yield, though this has as yet received little study. There is no current precise definition of what concentration of arsenic in irrigation water would have a quantifiable impact on agriculture yield or on human health.

The amount of arsenic in food seems to be related to both the amount of arsenic in the water used for cooking and the cooking process used. For example, a study (Roychowdhury and others 2002) showed that the concentration of arsenic in cooked rice was higher than that in raw rice and absorbed water combined, suggesting a chelating effect by rice grains. Due to water evaporation during the cooking process, the quantity of water used is important and this also affects the amount of arsenic in food. In addition, another study (Devesa and others 2001) reported no transformation of arsenic at temperatures up to 120°C. Thus, the boiling process used to cook the food probably does not alter the chemical form of arsenic nor the amount of inorganic arsenic in the food at the end of the cooking process (Del Razo and others 2002).

There is no standard maximum level of arsenic in food in South and East Asian countries. In the United Kingdom and Australia the maximum food hygiene standard for the arsenic level in food is 1 mg of arsenic per kg (Warren and others 2003).

Studies related to the interaction of arsenic with other elements are limited. So far, most studies have focused on fluoride, selenium, and zinc. The main findings are that (a) fluoride neither increases nor decreases arsenic toxicity; (b) selenium and arsenic might reduce each other's effects in the body; and (c) a deficit of zinc might increase the toxicity of arsenic. Thus it seems that other elements may play a role in the effective toxicity of arsenic in drinking water.

So far, the intake of arsenic from food seems to depend more on the amount of arsenic in the cooking water than in the water used for watering crops. However, research is still needed to fully confirm that cooking water is more detrimental than irrigation water in the accumulation of arsenic in the food chain.

Operational Responses of Countries in South and East Asia

The operational responses implemented thus far in South and East Asian countries are difficult to compare because most of the information available is for South Asia, particularly Bangladesh, Nepal, and West Bengal in India. Information related to East Asian countries is much more difficult to find in international literature. Therefore, in order to collect more information on operational responses in South and East Asian countries, the study team sent a questionnaire to major stakeholders. The summary of the questionnaire responses is provided in annex 3. In addition, in the context of the study, the World Bank/WSP Regional Operational Responses to Arsenic Workshop was held in Nepal, 26–27 April 2004. The preliminary results of the study were shared with 50 participants representing 7 out of the 11 countries facing arsenic contamination, as well as international organizations, donors, and researchers. The major information and data collected are included in this report.

A summary of operational responses implemented in South and East Asian countries is presented in annex 1.

Initial Responses towards Suspected Arsenic Contamination

Initial responses towards suspected arsenic contamination include well screening and identification of water contamination in tubewells, switching from contaminated to arsenic-safe wells, painting of tubewells, awareness raising, and identification and treatment of arsenicosis patients. These responses are presented in more detail below. Each section outlines the steps that can be taken and, where available, the lessons learned from these mitigation measures. Most of the lessons learned are from Bangladesh, Nepal, and West Bengal (India), since these are the cases for which most information is available.

Screening and Identification of Contamination Levels in Water Sources

Background

Regardless of the scale of arsenic contamination in water, there are two methods of measurement: the field test kit, and laboratory chemical analysis.[2] The field test measures are more qualitative than quantitative. The choice of method for analysis depends on several criteria, including the precision of measurement required.

Choice of Screening Methodology

There are two kinds of field test: those that provide a Yes or No answer and those that provide a range of concentration.[3] The Yes/No field test does not provide useful information for further analysis or for the implementation of mitigation measures. The field test that does provide a range of concentration is only appropriate in certain circumstances. Box 1 outlines parameters that help to determine which test is appropriate, assuming that the laboratory test is efficient and subject to quality assurance.

Quality assurance is necessary to ensure reliability of analysis within a particular laboratory, and consistency of measurement between laboratories. Box 2 (see page 110) provides parameters to assess the capacity of a laboratory to perform analyses in order to facilitate quality assurance implementation and, ultimately, to provide accurate and usable data.

West Bengal in India is the only location where the screening of arsenic is conducted exclusively using laboratory spectrometer analysis, thereby reducing the risk of a well being misclassified as contaminated and thereby lost as a source of water.

Other Asian countries employ a mix of field testing and laboratory testing, or field testing only. With field tests there is a higher risk of well misclassification; this risk can be reduced through, for example, retesting contaminated wells or using multiple testing. For example, in Pakistan 10% of field tests are cross-checked using laboratory analysis; while in West Bengal 3% of the samples analyzed with spectrometer are cross-checked with referenced laboratories using the atomic absorption spectrometer (AAS) (reported at Regional Workshop, Nepal, April 2004).

The only country that is planning large-scale monitoring of screened tubewells is Bangladesh, as stipulated in its National Arsenic Policy approved in March 2004. The National Arsenic Policy

[2] A detailed description of field tests and laboratory analysis techniques is provided in Paper 3.

[3] The Yes/No field test kits do not provide any information on the range of concentration. The only information provided is whether the concentration is higher or lower than the national standard of most Asian countries ($50\ \mu g\ L^{-1}$).

Box 1. Comparison of Field Testing and Laboratory Analysis

Whether to use a field test kit or laboratory analysis is not always a clear-cut decision and must take into account a range of trade-offs related to the cost of the analysis, accuracy of the analysis, time constraints, logistical requirements, and training.

Cost of analysis. In Bangladesh, for example, the reported cost of laboratory chemical analysis is approximately US$8.60 per analysis, while the price of a field test is approximately $0.50. However, in West Bengal, the price of laboratory analysis is approximately $1.60. Thus the difference in cost between the field test kit and laboratory analysis varies in significance from country to country.

Capacity of laboratories (samples/month). Given that there are approximately 11 million tubewells in Bangladesh, there are insufficient laboratories to analyze all samples. Regional laboratories in Bangladesh have a capacity of about 300 samples per month, so additional screening has to be done using the field test kit.

Time needed to process the analysis. The field test provides an immediate answer and, depending on the brand, waiting time varies from 5 to 30 minutes (Kinniburgh and Kosmus 2002). The time required to conduct the chemical analysis will depend on the availability of laboratories near the sampling point and the time needed for actual analysis. This can take months, in contrast to the immediate feedback to well owners provided by the field test kit.

Logistics. It is essential that samples are labeled properly and that the information on whether the well is safe or unsafe is communicated to the communities in a short time and in a reliable manner.

Training. Field test kits are easy to use, so related training is far easier to conduct than that needed to ensure good-quality laboratory analysis. However, the number of people to be trained is higher for field test kits than for laboratory analysis.

Opportunity for decentralization. The field test kit has considerable potential for decentralization and community involvement in the identification of safe or contaminated wells. This community involvement might be lost if only laboratory analysis is used.

makes provision for monitoring of 2% of the safe (green) tubewells every six months. However, there is no specification as to whether field or laboratory testing is to be used, or regarding the procedures to ensure the reliability of water quality analyses.

Another issue to take into account in interpreting test results is seasonal variability. In Cambodia, for example, the major risk aquifer is connected to a river and arsenic levels recorded in tubewells vary seasonally, with lower levels resulting from a wet-season influx of low-arsenic river water into the aquifer (reported at Regional Workshop, Nepal, April 2004).

Choice of Scale of Screening

The screening of water sources can be conducted on a large scale (national, state level) or on a more localized scale (project level). In Bangladesh, West Bengal, and Nepal screening has so far been conducted on a large scale. In other countries where arsenic has been identified, for example Cambodia, Lao PDR, Myanmar, and Pakistan, screening has been

Box 2. Parameters to Assess the Capacity of Laboratory Analysis

The main argument for the use of laboratory analysis rather than a field test kit is the reliability of the results. However, if a given country has weak capacity for conducting chemical analysis, the value added from laboratory analysis could be negated. Therefore it is important to assess the capacity of laboratory analysis, taking into account the following:

- The current availability of the equipment to conduct analyses.
- The current status of the suppliers of this equipment.
- The regular availability of equipment and materials, for example distilled water.
- Whether the financing of equipment and supplies is from a central institution or is done at the laboratory level. This could affect the length of time it takes for supplies to reach the laboratories; in the worst case supply shortages could interrupt work.
- The current training program for laboratory staff, which should take into account available posts in laboratories and staff turnover.
- Sampling and conservation of samples should follow accepted, standard procedures.
- The procedures to ensure quality checks and laboratory certification have to be assessed. This process of certification does not need to be nationwide; it could be carried out among smaller units such as departments. An internal track record of these processes and all analyses performed should be kept at each laboratory. When there is a procedure of certification the level of transparency must be assessed.

conducted on a small scale in some parts of the countries. So what are the criteria that help assess whether the screening should be conducted on a national or local level?

When contamination is identified hydrogeologists and geochemists can, from the first results of screening, make certain assumptions about the potential scale of contamination based on the size and level of use of the aquifer. This will enable them to give advice on the scale of further screening (national, subnational, local) and on the design of the screening grid used to check these assumptions.

In Bangladesh the decision to adopt blanket screening was based on the heterogeneity of the aquifers, which meant that a base sample screening would not accurately represent the level of arsenic contamination of tubewells used for drinking water. In Pakistan the screening is divided into three steps: (a) a sample base screening based on a grid of 10 km x 10 km; (b) further screening using a smaller grid of 2.5 km x 2.5 km; and (c) a blanket screening of the hotspot (reported at Regional Workshop, Nepal, April 2004).

When an aquifer is discovered to be contaminated it is important to identify other vulnerable aquifers in the same area. Vulnerable aquifers are those that are naturally connected to the contaminated aquifer, or are not separated and protected from contamination by an impermeable layer. Similarly, when an aquifer is separated from the contaminated aquifer by an impermeable layer it is not naturally vulnerable unless a connection is created, for example through poor well construction.

It is difficult to predict contamination rates when there is water flow from a contaminated to a safe aquifer. The first step is to assess the exact impact of the dilution effect, which affects the rate at which arsenic concentration will increase and therefore reach the maximum permissible level. It is difficult, however, to determine to what extent arsenic will react with the environment; it may be adsorbed, or it may interfere in biological processes. As a result of these interactions increase in arsenic concentration may be delayed, although there is currently insufficient knowledge and data to correctly model these interactions and to accurately predict this delay. Therefore only the dilution effect is usually taken into account in such models, even though this may result in an underestimation of the period of delay.

Among the factors deciding the scale of the screening is the level of priority accorded by government to the issue of arsenic contamination. The incentives that lead stakeholders, including government, to be active or inactive are addressed in chapter 4. When an agency finds arsenic contamination during the course of a project it is important to define who is responsible for screening beyond the scope of the agency's own project and for implementing the mitigation measures.

Institutional Arrangements for Arsenic Screening in Different Countries

If the government decides to conduct a large-scale screening an institutional model needs to be chosen. So far in most countries two approaches have been applied. The first is to treat the screening as a public good and the second is to consider the screening the responsibility of the tubewell owners. The first model is by far the most common. In this case government, usually assisted by nongovernmental organizations (NGOs) and international agencies, conducts the screening. For example, in Bangladesh and Nepal the government is taking the lead, while in Cambodia, Vietnam, Lao PDR, and China the United Nations Children's Fund (UNICEF) is the main international agency leading the screening. The second model, where screening is demand based, has been applied in India, specifically in West Bengal. UNICEF and the state authorities of West Bengal screen all public tubewells, but private tubewell testing is the responsibility of the owner. Information on the availability of laboratories is provided and widely disseminated. So far, there is not enough information to determine whether one model is more efficient or effective than the other.

Remaining Issues and Lessons Learned

Technical issues:

- Regarding the choice between the field test kit and laboratory analysis, one option proposed in the literature is to use the field test kit for large-scale screening and cross-check using laboratory analysis when the capacity assessment is satisfactory.
- The best way to reduce the risk of misclassification, for both the field test kit and the laboratory, is to provide adequate training to ensure precise measurements, and to maximize, when possible, the number of repetitive analyses.
- Although there is a high degree of heterogeneity in arsenic concentration within a given area, correlation among neighboring wells can help identify some misclassification.

- It is important to consider the scale of screening (large scale, project scale) in relation to other factors.
- Test for possible interference of field test kit results by other constituents of the water, which may account for some of the false positives and negatives.[4]
- The frequency of the screening is significant where there is high seasonal variability of arsenic in tubewells, as in Cambodia.
- Screening should be conducted because arsenic is flavorless and odorless; the only way to identify it is to test for it. In addition, if the measurement is wrong there is no simple way to become aware of the mistake.

Social and cultural issues:

- The use of the field test kit tends to create curiosity and thus constitutes a tool for awareness raising.

Economic issues:

- The monitoring of screened wells is still an issue in many countries. After the initial screening, should the priority be to screen all tubewells or only the safe ones? The rationale of retesting a contaminated well is to identify any misclassification, knowing that in some hotspots a safe tubewell could be the only source of arsenic-safe and bacteriologically safe water. Costs, however, are a significant factor, and the benefits of rescreening schemes need to be assessed.
- For longer-term decision-making, universal sampling has certain benefits compared to sample-based screening. However, it is worth noting that one of the lessons learned in Bangladesh is that if a well is not tested in a contaminated area and if people do not have convenient alternative solutions, they will use this well assuming that if it has not been tested then it should be safe.

Institutional issues:

- The choice of screening model (the public-good approach or demand-based screening).
- The dissemination of data, both for screening conducted by government agencies and by NGOs, is critical to ensure the transparency of information.

Summary Remarks

The following guidelines are applicable when deciding on the method of testing (field test or laboratory analysis):

- If the field test kit is the method of screening then 3% to 10% of the samples should be cross-checked with laboratory analysis.
- The capacity of laboratory analysis should be assessed to ensure that quality assurance is implemented.

[4] False positives have an actual concentration lower than 50 µg L^{-1}, but are falsely labeled unsafe as the field test shows a concentration higher than 50 µg L^{-1}. False negatives have an actual concentration higher than 50 µg L^{-1}, but are falsely labeled safe as the field test shows a concentration lower than 50 µg L^{-1}.

- If using large-scale screening, the first screening could use a large grid with a few samples, but with adequate regional distribution to enable hydrogeologists and geochemists to identify contaminated and vulnerable aquifers. These results would provide a first approximation of where the hotspots are situated and which zones should be prioritized to conduct a more precise screening and to implement mitigation measures.
- Although not operationalized in the sample of countries that are the subject of this study, a monitoring plan is of utmost importance.

Well Switching, Painting of Tube Wells, and Awareness

Background

When screening is conducted and arsenic-contaminated wells (those with levels above the accepted standard) are identified, the first step to mitigate the local population's exposure might be sharing of safe tubewells. Therefore, awareness campaigns need to make clear how to recognize safe tubewells. So far arsenic screening accompanied by the physical marking of safe or contaminated tubewells takes place in Bangladesh, Cambodia, Nepal, Pakistan, and West Bengal in India. A tubewell is considered unsafe if its concentration of arsenic is higher than the national standard.

So far, all the countries that have marked tubewells have done so in different ways. In Bangladesh, Cambodia, and Pakistan, the spouts of the contaminated tubewells are painted in red if the concentration of arsenic is higher than 50 µg L^{-1} (the national standard) and in green if the concentration of arsenic is lower than 50 µg L^{-1}. In Nepal, a cross (X) is painted on the tubewell if the concentration is higher than 50 µg L^{-1} and a check (v) is painted if the concentration of arsenic is lower than 50 µg L^{-1}. In West Bengal, it was decided that confusion could best be avoided by marking only the safe tubewells; those with a concentration of arsenic lower than 50 µg L^{-1} (the national standard) are painted in blue.

Widening Awareness of Water Quality

There is a need to make sure that communities use only safe tubewells. Many countries have increasingly developed groundwater supplies because of the poor bacteriological quality of surface water, a common problem in the surveyed countries. The use of groundwater reduces the risk of waterborne disease, but has brought with it the need to explain clearly that the clean water from some tubewells contains poison that can neither be seen nor tasted.

In order to avoid confusion among communities, people should be informed that clear and clean water might be contaminated with arsenic. In Bangladesh and in West Bengal in India UNICEF has developed a well-researched information package. Other materials have also been developed by the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) and NGOs. All materials are used widely. In Nepal the National Arsenic Steering Committee (NASC) has developed a standard information package to help clarify the sometimes contradictory messages related to bacteriological and arsenic contamination of water. However, there is still further need for the development of awareness campaigns on poor water quality.

Participants at the Regional Arsenic Workshop emphasized the need to ensure that awareness campaigns use community-specific communication methods. In Cambodia, for example, awareness campaigns use puppets, a popular form of entertainment in the country.

Remaining Issues and Lessons Learned

Social and cultural issues:

- It has been widely disseminated that dug wells are less arsenic-contaminated than tubewells; therefore some people think that the problem is associated with the technology being used. As a result, there is a possibility that some people may conclude that the problem is not in the groundwater quality per se but that it is associated with their tubewell and the way to fix it would be to purchase another handpump.
- Since most wells are privately owned, neighbors may be reluctant to share. In addition, most tubewells are situated in the courtyard of houses so there is a privacy issue. Sharing of arsenic-safe wells as a solution can therefore not be taken for granted.
- If the density of users at each well increases, some people are afraid that their tubewells will become arsenic contaminated as well.
- The complaints related to sharing safe tubewells include excessive wear on equipment; new users do not clean up after themselves; and people come at late hours. In some hotspots there are simply not enough safe tubewells to meet demand for drinking water.
- When people say they have no other water source, they may actually mean that they have no other tolerable source. Sharing is perceived as a reduction in the quality of life.
- Women, who traditionally collect water, might not be allowed in some places to leave their immediate household unaccompanied.
- In Bangladesh the choice of red to indicate arsenic contamination seems, in some cases, to be confused with iron precipitation, which leaves an orange-red color.
- Awareness campaigns must explain clearly that arsenic is not a germ that can be killed by boiling water.
- In some places people are having difficulty distinguishing arsenic-related skin discoloration from other skin diseases or infections.
- Color and sign interpretation of marked tubewells is a new concept for some people.
- Repetition is important, because experience shows that memory and motivation fade in time.
- In many countries the identification of arsenic implies an increase of collection distance and time due to the change in water source; therefore women's work load increases substantially. This also needs to be factored into the provision of arsenic-safe water.
- Awareness campaigns should be carried out regularly and not only at the time of screening.
- For years groundwater has been presented as the "safe" source of water; thus the arsenic-related message contradicts conventional wisdom about safe water. However, the awareness campaign related to poor surface water quality should not stop because of the more recent problem of arsenic contamination.

Technical issues:

- Tubewells should be retested and repainted regularly, since painting can be altered during the rainy season.

Summary Remarks

When arsenic is identified, ensure that safe tubewells are marked and that the choice of color or marks is understandable to communities. Whether unsafe tubewells should be marked or not is still an open question; the consensus seems to be that in the case of blanket screening the preferable approach is to mark the unsafe tubewells, while in the case of sample base screening it may be preferable not to mark unsafe tubewells.[5]

Awareness campaigns should address arsenic contamination, but also maintain awareness about poor surface water quality. There is a need to address both quality problems and not substitute awareness of the health risks due to arsenic for awareness of the risks related to poor surface water quality. In addition, the awareness campaign should use community-specific communication methods in order to reach the maximum of people in the community.

Patient Identification

Background

Patient identification, also called case finding, may be passive or active. Passive patient identification is simply allowing individuals to present themselves for treatment, while active patient identification involves going out to the field to examine individuals for signs of arsenic-related disease.

In Bangladesh and Nepal patient identification is often carried out during tubewell screening. Although arsenic can cause a variety of health conditions, most patient identification has been based on skin lesion-related symptoms.

In West Bengal patient identification is mainly passive, although the Joint Plan of Action, between the state and UNICEF, has initiated an epidemiology survey. The first step is the training of doctors and NGOs to properly identify patients and to suggest appropriate mitigation measures; active identification has also been suggested.

Training of Testers in Patient Identification

When patient identification is carried out alongside tubewell testing, the testers must be provided with sufficient training to distinguish between skin lesions related to arsenic ingestion and other skin lesions, bearing in mind that (a) there is still no universally agreed case definition of arsenicosis disease; and (b) the actual extent to which exposed persons will develop skin lesions and other arsenic-related conditions is difficult to predict. Therefore the capacity building of testers and health workers is critical to ensure reliable patient identification.

[5] *Blanket screening means that 100% of the tubewells in a given region are tested. Sample base screening means that a selection of tubewells is screened and from that data conclusions are drawn as to the levels of contamination in the other tubewells.*

Identification Based on Skin Lesions and on Laboratory Analysis

Some people are subclinically affected by arsenic even though they do not show skin lesions. For example, in contaminated areas in Bangladesh, some studies have shown that children and adults without skin lesions at present may have high concentration of arsenic in their hair, nail, and urine samples. Therefore, patient identification based solely on the presence of skin lesions may underestimate actual numbers affected by arsenic.

However, identification of arsenic-affected patients using laboratory analysis of nail, blood, and hair samples is very expensive and requires strong laboratory capacity, and implementation on a large scale is not generally feasible.

Current Estimate and Projections of Number of Arsenicosis Patients

The current estimates of the number of patients with arsenicosis in South and East Asian countries is summarized in table 3. A review of studies conducted in parts of the world other than Asia projects that, if the at-risk population continues to drink arsenic-contaminated water, between 16% and 21% of the population will be affected (WHO 2001a). This projection is based on the assumption that the estimation of the population at risk is accurate, the clinical case

Table 3. Current Population at Risk in Asian Countries

Region/country	Present estimation of number at risk in millions (% of total population)	Number of arsenicosis patients identified so far	Year of first discovery
East Asia			
Cambodia	Max. 0.3 (2.7%)	-	2000
China	3 (0.2%)	522,566	1980s
Lao PDR	-	-	-
Myanmar	5 (10%)	-	1999
Taiwan	0.2	-	1960s
Vietnam	11 (13.7%)	-	1998
South Asia			
Bangladesh	35 (28%)	10,000 (partial results)	1993
India (West Bengal)	5 (6.25%)	200,000	1978
Nepal	0.3 (3.4%)	8,600	1999
Pakistan	-	242 cases per 100,000 people based on the results of 10 districts	2000

- Not available.
Sources: Bhattacharya 2002; Ng, Wang, and Shraim 2003; Kinniburgh and Kosmus 2002; WHO 2001a; Smith, Lingas, and Rahman 2000; Berg and others 2001; information reported at Regional Workshop, Nepal, April 2004.

recognition is accurate, and survey results of other regions can be generalized. However, the 16–21% estimate has no reliable statistical confidence intervals. For example, in Bangladesh a study conducted by the Massachusetts Institute of Technology estimated the arsenic health burden through a model of dose-response function (Yu, Harvey, and Harvey 2003). The study predicted that long-term exposure will result in approximately 1.2 million cases of hyperpigmentation, 600,000 cases of keratosis, 125,000 cases of skin cancer, and 3,000 fatalities per year from internal cancer. Another estimate of the arsenic-related health burden in Bangladesh concluded that the total risk of cancer would be equal to 375,000 affected people (Ahmed 2003). So far, these two figures are the only quantification of the potential arsenic-related health burden. They depend heavily on epidemiological assumptions and demonstrate how the lack of reliable epidemiological information adds uncertainties to the projected number of people at risk.

Lessons Learned and Remaining Issues

Social issues:

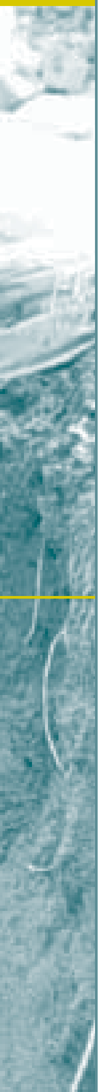
- Gender sensitivity: In Bangladesh, for example, each team engaged in tubewell screening and patient identification surveys includes at least two females.
- Actively include information that arsenicosis is not contagious to ensure that the community will not stigmatize arsenicosis patients due to misinformation.

Economic issues:

- Patient identification and medical referrals, along with public education, should be integrated into all tubewell testing efforts. This seems to be the most cost-effective way to actively identify arsenicosis sufferers.
- Identification of arsenic-affected patients is generally based on the skin effects, which are not necessarily the first symptoms. However, identification based on laboratory analyses is too expensive to be implemented at large scale.
- Arsenic can cause a variety of health conditions, thus there is still the issue of identification of those patients who do not develop skin lesions. The cost of the epidemiological survey required to identify all such patients would be prohibitive. However, such studies could be conducted on a small scale in order to allow estimates of the scope of the arsenic problem in a country or region within a country.
- The most efficient way to conduct a nationwide survey is in conjunction with an existing population program.

Technical issues:

- There is a need to ensure proper training of tubewell testers and health workers so that they can distinguish between the skin lesions resulting from arsenic exposure and other skin lesions.
- Standardized criteria for diagnosing and grading skin lesions must be developed and carefully followed. The WHO is leading an effort to develop such criteria. When finalized they should be widely used by government institutions and by all organizations engaged in case finding, treatment, and surveillance.



Summary Remarks

There is a clear need to improve information about the epidemiology in arsenic-affected populations. This needs to happen in a strategic manner, and can be achieved by combining patient identification with well screening. At the same time, targeted epidemiological studies need to be carried out in order to supply data to assist arsenic mitigation activities in Asian countries.

Treatment Management of Arsenicosis Patients

Background

Although a number of clinical treatments have been advocated, there is no universal medical treatment for chronic arsenicosis. The only measure that will prevent future damage is to supply the patient with drinking water that is free from arsenic and, if it is administered at an early stage, it seems to remedy past damage caused by arsenic. The first priority should be to remove people from the source of exposure and then follow up with symptomatic management. To date, there are no well-designed studies to show whether cessation of exposure leads to improvement in skin keratoses. However, anecdotal interviews of patients suggest that mild to moderate keratosis improves with cessation of exposure.

Chelation, which is often presented as a treatment of arsenicosis, has been proven effective mainly in cases of acute poisoning. The principle of chelation therapy is to provide the patient with a chemical to which arsenic binds strongly, and which is then excreted in urine. The provision of such treatment could remove large stores of arsenic (from acute exposure) from the body in a matter of hours. However, although chelation might have a positive result in some patients with chronic poisoning, so far there is no complete study that assesses its effectiveness for chronic exposure. In addition, it is difficult to ascertain to what extent improvement in skin lesions after chelation therapy is attributable to the therapy, and to what extent it is attributable to cessation of exposure. Therefore, patient improvement after chelation therapy does not provide sufficient evidence of its effectiveness (Kaufmann and others 2001; NRC 1999).

Evidence from Taiwan suggests that some nutritional factors may reduce cancer risks associated with arsenic. It has been proposed that providing vitamins and improving diet may be of benefit to patients. In particular, vitamin A is known to be beneficial in the differentiation of various tissues, particularly the skin. If the doses given are not excessive, there are other nutritional benefits to be gained. Thus, it is recommended that all patients with skin lesions be given multivitamin tablets and that research projects be undertaken to establish whether or not they are effective for patients with arsenicosis (NRC 1999).

Arsenic is a probable contributor to causation of diabetes mellitus and hypertension. For this reason, urinary or blood glucose and blood pressure should be tested in all patients with arsenicosis and appropriate treatment and monitoring should be started if necessary (Kaufmann and others 2001).

In Bangladesh people identified with skin lesions are given vitamins and ointment. In West Bengal (India), under the Joint Plan of Action, a network of clinics will be set up at the district, subdivision, and block level. At the same time, in both countries, studies are being conducted to provide a better estimation of the arsenic impact on human health.

Remaining Issues and Lessons Learned

Social issues:

- The fact that arsenicosis is not treatable with folk remedies should be emphasized in awareness campaigns (Some of the scarce literature on social issues regarding arsenic suggests that some people may spend a considerable portion of their income trying to find a homemade cure).
- The fact that the only way to prevent arsenic contamination is not to drink contaminated water should be emphasized in awareness programs.
- Ensure that treatment protocols are easy to follow.
- Ensure that people are informed about the fact that arsenicosis is not contagious.

Technical issues:

- Awareness campaigns should stress that chelation cannot be viewed as a successful treatment while exposure to arsenic-contaminated water continues.
- Advanced keratoses are extremely debilitating and complications such as superimposed fungal infections may cause serious problems. Providing moisturizing lotions and treatment for infections may be beneficial and should be part of routine care in advanced cases.
- Arsenic has adverse health effects other than skin lesions, such as diabetes, and these diseases have to be treated as well.
- In remote rural areas clinics, equipment, and expertise are generally unavailable, so training of health workers should be conducted to help patients in the absence of effective treatment. However, in some countries health and population sector programs might not have the capacity to conduct the required nationwide training for all clinical workers within a short period of time.

Institutional issues:

- Health and water supply institutions need to work together since the major treatment for arsenic is an alternative safe water source.
- Doctor absenteeism might be another important factor in some countries. For example, a recent study conducted in Bangladesh estimated doctor absenteeism to be around 75% in rural areas (Chaudhury and Hammer 2003). This is a critical issue, especially if health workers do not have adequate training to help patients affected by arsenic contamination.

Summary Remarks

The preferable approach is to ensure that identified patients have follow-up treatment in the local health institution. The capacity building of health workers in remote rural areas is critical and health and water sector professionals need to work together to make sure that people have access to information and to medicines.

Longer-Term Responses

Longer-term responses are institutional and technical. The institutional aspects are mainly related to the country's arsenic policy and strategies. Technical longer-term responses can be divided into two types based on the source of water: surface water and groundwater. Surface water responses include pond sand filters, rainwater harvesting, and piped water supply. Groundwater responses include dug wells, deep tubewells, piped water supply, and arsenic removal treatment plants.

Institutional Longer-Term Responses (Arsenic Country Policy)

Background
A country can respond to arsenic contamination by establishing an arsenic policy and/or strategy. The objective is to provide overall direction and guidance for dealing with arsenic and to set priorities for operational responses in the short, medium, and long terms.

So far, Bangladesh is the only country to have adopted a national arsenic policy (March 2004) and to have developed a detailed plan of action. The policy seeks to identify the nature and extent of the problem through screening and patient identification and to provide guidelines for mitigation of arsenic contamination through (a) public awareness; (b) provision of arsenic-safe water supply with a preference for surface water over groundwater, and the promotion of piped water supply when feasible; (c) diagnosis and management of patients; and (d) capacity building at all levels (from government to local communities). The arsenic policy also recommends mapping of the country's deep aquifer to ensure that deep wells will be built in regions where deep groundwater is separated from the shallow aquifers by a substantial impervious layer.

In Nepal the National Arsenic Steering Committee (NASC) is chiefly responsible for arsenic strategy. It has formulated national guidelines, which detail the steps to be taken to address arsenic contamination of groundwater and stipulate how safe and unsafe tubewells are to be marked. The NASC has also produced a standard set of information, education, and communication materials for awareness promotion within the community.

In Cambodia a recently established arsenic committee is working closely with UNICEF and a number of NGOs. The committee organizes screening of tubewells and provides different stakeholders with field test kits. In Pakistan, UNICEF is also working closely with the provinces in the screening of tubewells and other water sources.

In India, in 1999, UNICEF entered into a strategic alliance with the government of West Bengal through a Joint Plan of Action, which incorporates the following: (a) a community-based water monitoring system; (b) alternative technologies for supply of arsenic-free water (including arsenic removal at the household level and piped water supply); (c) health surveillance, patient identification, and early treatment programs; (d) awareness campaigns; (e) research on arsenic health effects in women and children; (f) networking and information sharing among stakeholders; and (g) monitoring mechanisms at all levels. The Joint Plan of Action effectively constitutes a strategy to deal with arsenic contamination in the short and long term.

Summary Remarks

It is important for relevant institutions to have short-term and long-term strategies for dealing with arsenic contamination. As is apparent in South Asia, no single strategy is applicable to all countries or localities. In Bangladesh and Nepal the government, in collaboration with a variety of stakeholders, is the focus of strategy, while in West Bengal the choice has been made to elaborate a plan in conjunction with an international agency, in this case UNICEF. These experiences show that (a) there is now a body of information — as evidenced in this paper — that permits the design of such policies and strategies, despite continuing uncertainty about many features of arsenic contamination; (b) more information is still needed to enable governments and other stakeholders to be more specific in defining proposed actions; and (c) policies and strategies need to be flexible enough to incorporate any further information that will become available over time. The final challenge is to ensure that such policies or strategies are enforced.

Technical Longer-Term Responses Based on Surface Water

Background

Longer-term responses based on surface water include pond sand filters, rainwater harvesting, and piped water supply. Technical details for each of these operational responses are provided in Paper 3. This section focuses on the lessons learned and their implementation.

The pond sand filter technique is based on a filtration process by which water is purified by passing it through a porous medium. Slow sand filtration uses a bed of fine sand through which the water slowly percolates downward.

In Bangladesh pond sand filter technology has been used for arsenic mitigation but the level of acceptance has been low, due in part to doubts about the bacteriological quality of water. One pond sand filter can supply the daily drinking and cooking water requirements for 40 to 60 families. In the literature, Myanmar is the only other country in the study region using ponds as a mitigation option for arsenic contamination.

Rainwater is used in many parts of the world to meet demand for fresh water. The principle is to collect rainwater, either via a sheet material rooftop or a plastic sheet, and then divert it to a storage container. In the study region there have been reports of use of this technique from Bangladesh, Cambodia, and Taiwan.

Piped water supply can use surface water after simple water treatment. Generally, treatment is needed to reduce turbidity and includes chlorination to protect against bacteriological contamination of surface water. Bangladesh and India are employing the piped water option as a major component of their mitigation strategies, and Cambodia is also using this technique. Bangladesh is now embarking on a large pilot operation to implement piped village water supply. In India, in particular in West Bengal, this response has also been recommended on a larger scale for multiple villages. In general, the level of acceptance for the piped water supply option is high because of its convenience.

Remaining Issues and Lessons Learned

Pond sand filters – social and cultural issues:

- The community should pledge involvement in operation and maintenance of the pond sand filter.
- Increasingly, in Bangladesh, ponds have become important sources of income because of fish culture, so farmers are reluctant to give up their ponds for pond sand filter construction.
- Some users have complained about the taste of water from this source.
- Pond sand water is generally contaminated with pathogens. The bacteriological quality of water fluctuates between a little over the WHO/Bangladesh standard to hundreds of times higher than that.

Pond sand filters – economic issues:

- The initial capital cost of construction is high – about US$430-690, depending on the size of the pond sand filter.

Pond sand filters – technical issues:

- The selected pond should not be used for fish culture, watering and washing livestock, or other domestic purposes, and should be protected from such activities.
- The selected pond should be perennial.
- The quality of water varies seasonally and is improved with the addition of bleaching powder solution.

Rainwater harvesting – social issues:

- Some users complain about the taste of the water.
- It has been reported from Bangladesh that the return to rainwater harvesting may be viewed as a step backwards to several decades ago when it was quite widely used.
- In Cambodia rainwater harvesting has been practiced for a long time and is reported to be well accepted.

Rainwater harvesting – economic issues:

- In Bangladesh the cost of a rainwater harvesting system is an issue.
- In addition, this solution does not cover the dry season, when another mitigation measure must be used, adding to the cost.

Rainwater harvesting – technical issues:

- Rainwater harvesting is a useful alternative to other sources, but in areas with a prolonged dry season it can only be a partial solution.

- Water quality is a concern: the first rain may flush impurities, including animal feces, off the roof. Not storing the first rain and cleaning the roof reduces the risk of inadequate water quality.

Piped water supply – social issues:
- This option functions best in larger villages where density is high enough to ensure viability.
- It is important to ensure that all people are connected, in particular the poorest segment of the population.
- Appropriate institutional arrangements for operation and maintenance of the system should be in place.

Piped water supply – economic issues:
- Affordability by different income groups within the community needs to be considered.
- Operation and maintenance needs to be covered by the price of the service.

Piped water supply – technical issues:
- A high level of skill is necessary for design and construction, and capacity building among local artisans is an important consideration.
- A high level of skill is also needed for operation and maintenance.
- Permits monitoring of one single source for water quality rather than multiple sources in one village.

Summary Remarks

This section has examined some of the advantages and disadvantages of the operational responses using surface water. Taking into account such factors, certain solutions may present themselves as the best trade-off between the range of options that may be applicable in a given situation. However, care must be taken to devise solutions that address fully the goal of providing drinkable water, rather than addressing only the problems related to arsenic contamination. Table 4 (see page 124) summarizes the options.

Technical Longer-Term Responses Based on Groundwater

Background

The longer-term responses based on groundwater include dug wells, deep tubewells, piped water supply, and arsenic removal filters or plants. The technical details of each of these operational responses are provided in Paper 3. This section focuses on lessons learned from their implementation.

Dug wells are excavated below the water table until the incoming water exceeds the digger's bailing rate. They are typically lined with stones, bricks, tiles, or other material to prevent collapse, and are covered with a cap of wood, stone, or concrete to prevent contamination from the surface. This option has been used in Bangladesh and Nepal. The UNICEF Plan of Action proposes dug wells as a mitigation option in Myanmar.

Table 4. Summary of Responses to Arsenic Contamination Based on Surface Water

Operational responses	Advantages	Disadvantages
Pond sand filter	Technically easy to implement	Poor bacteriological water quality Low service level Complaints about the taste of water Selected pond sand filter should be used only for drinking water
Rainwater harvesting	Technically easy to implement	Poor bacteriological water quality when not adequately maintained Low service level In some regions, cannot provide water for the entire year Complaints about the taste of the water Can only be a partial solution in areas with prolonged dry season
Piped water supply	Adequate water quality when treatment is carried out correctly Sustainable source of supply	High level of skill necessary for design and construction Issues of operation and maintenance and management must be considered Other issues include affordability and system coverage

One major concern related to dug wells is that recent investigations show that some dug wells are also contaminated with arsenic (APSU 2004). Indeed, some dug wells in Bangladesh, China, Myanmar, and Nepal have been found to have arsenic contamination.

The deep aquifers in Bangladesh, West Bengal in India, and Nepal have been found free of arsenic thus far. However, in other places, including China, deep groundwater has been found to be even more contaminated with arsenic than shallow groundwater. This means that measurement of the contamination level must be conducted before any exploitation of deep groundwater. In the case of Bangladesh, the assumption is that the pre-Holocene aquifer has been flushed and therefore all mobile arsenic has been leached from this aquifer, while in China this process might not have taken place. A more detailed explanation is presented in Paper 1.

In Pakistan the preliminary findings of UNICEF screening showed no arsenic in the deep groundwater, though the number of samples was limited (reported at Regional Workshop, Nepal, April 2004). In Cambodia the main issue related to use of the deep groundwater is the poor yield of deep tubewells, which adds significantly to the unit cost of the investment. In Cambodia the general acceptance of rainwater harvesting makes it a viable alternative to use of deep groundwater.

In Bangladesh and Nepal mapping of groundwater is being conducted to identify at which depth arsenic-safe groundwater is located and to identify where the shallow groundwater (Holocene plain) is separated from the deep groundwater (Pleistocene terrace) by a clay layer. The existence of this clay protects deep groundwater from potential contamination by shallow groundwater. So far, there is still no wide consensus on whether groundwater mapping should be conducted through geophysical investigations or on a case-by-case basis when drilling wells. In India the Central Groundwater Board has conducted research on the deep aquifer in West Bengal. Bangladesh, Nepal, and West Bengal already use deep groundwater as a mitigation option for arsenic contamination. UNICEF proposes use of deep groundwater in its Plan of Action for Myanmar.

In Bangladesh, as in several other countries, the debate centers on the following issues: whether deep groundwater should be used or not; the risk of arsenic-contaminated water leaking from the shallow to the deep aquifer; and what assurances there are that the deep aquifer sediments will not also release arsenic into the water at some future point. One important way to handle all these uncertainties is to strengthen groundwater management, which includes a monitoring process, regulation of deep groundwater exploitation, and a process of collecting and storing data that would be helpful for further research on potential chemical contamination.

A detailed explanation of the different arsenic removal technologies is provided in Paper 3. Arsenic removal plants can be located at the household level or community level. At the household level, the arsenic removal unit could be located in the house or attached to the tubewell. This mitigation measure has been implemented in Bangladesh, Nepal, Vietnam, and West Bengal in India. UNICEF also proposes its implementation in Myanmar. However, concern has been expressed in Cambodia that the unit may be difficult to maintain at the household level (reported at Regional Workshop, Nepal, April 2004). A pilot is currently being developed in Bangladesh to investigate this concern.

Community arsenic removal plants can be useful for small villages and have been implemented in Bangladesh, India, Vietnam, and Taiwan. In general, the main issue on the technical side is how to ensure the effectiveness of arsenic removal technologies in the field, and, on the institutional side, how to ensure large-scale implementation and sustainability.

Lessons Learned and Remaining Issues

Dug wells – social and cultural issues:

- In a number of areas issues of taste and odor, and the possibility of bacteriological contamination, are hindering acceptance of dug well water for drinking.
- Use of handpump technology can aid acceptance of the dug well but there have been complaints about the smell associated with chlorination.

Dug wells – technical issues:

- Bacteriological contamination levels of dug well water are often unacceptable.
- Monitoring of arsenic contamination is needed, especially during the dry season.
- Use of dug well handpumps enables bacteriological quality to be improved and maintained at an acceptable level by regular chlorination.

- Proper lining and a well-designed apron are crucial for prevention of surface water contamination.
- The community should ensure that dug wells are kept in sanitary condition.
- Yield is reduced when the water table drops in the dry season or if abstraction is greater than recharge.

Deep tubewells – social and cultural issues:

- Due to the cost of installation, deep tubewells are usually shared by several (or many) households. This may mean that people have to walk long distances to collect safe water.
- The shortage of deep wells means that people have to wait a long time to get water.

Deep tubewells – economic issues:

- Initial capital cost is high, around US$700-800.

Deep tubewells – technical issues:

- Since there is no clear understanding so far of the processes by which arsenic is released into water, there is still discussion as to whether deep groundwater will remain arsenic safe after medium-term or long-term exploitation.[6]
- There is also the need to ensure that the correct technique for drilling deep tubewells is used and that it taps the deep groundwater (not the shallow).

Deep tubewells – institutional issues:

- Groundwater management must be implemented to ensure that deep tubewells are used only for drinking and cooking purposes.

Piped water supply:

- Issues are the same as those for piped water supply using surface water except that treatment for bacteriological contamination is usually not necessary; however, arsenic removal treatment may be necessary.

Arsenic removal filters at the household level – social and cultural issues:

- The process is time consuming, and the smell and taste are not always good.
- Water becomes warm after standing for the recommended time, and cold water is preferred for drinking.
- Too many water storage containers are required.
- People are not in the habit of filtering their water.
- The unit is not always easy to operate and maintain.
- The advantage is that it allows rural households to continue using their handpumps.
- There may be difficulties in obtaining the necessary chemicals.

Arsenic removal filters at the household level – economic issues:

- The technology is expensive, and operation and maintenance costs may be high.

[6] *This is in the case of countries where deep groundwater is not contaminated, such as Bangladesh and Nepal.*

Arsenic removal filters at the household level – technical issues:

- The concentration of remaining arsenic in some cases remains higher than the standard.
- When using alum treatment, the health risk of alum remaining in water is a concern.
- Monitoring is more difficult to conduct at the household level.

Arsenic removal filters at the community level – social and cultural issues:

- There is a need to organize responsibility for maintenance to ensure the sustainability of the water treatment unit.

Arsenic removal filters at the community level – technical issues:

- Monitoring is easier to conduct at the community level than at the household level.

Arsenic removal filters at the community level – institutional issues:

- There needs to be a routine for checking that water is arsenic safe.
- If the source is surface water there should also be a process for checking its bacteriological quality.
- Effective supply chains need to be developed for large-scale and sustainable solutions. Local government should be involved in ensuring effective supply chains.

Table 5. Summary of Responses to Arsenic Contamination Based on Groundwater

Operational responses	Advantages	Disadvantages
Dug wells	Technically easy to implement contamination	Poor bacteriological water quality Some dug wells might also have arsenic Possible low level of acceptance Low service level
Switch to safe aquifer	Can provide potentially good water quality, but needs to be monitored	Difficult to predict whether the alternative aquifer will become contaminated Potential low level of service
Arsenic removal technology	Good chance of sustainability at the community level	Proven and sustainable option not yet generally available at household level Difficult to monitor at household level People do not always like the taste of the water Operation and maintenance may be complicated

Summary Remarks

Table 5 summarizes the advantages and disadvantages of each of the described operational responses, enabling an assessment of the trade-off most applicable to a given situation. However, some operational responses, while addressing the problems related to arsenic contamination, may give rise to water quality problems, and therefore do not address fully the target of providing drinkable water. Such partial solutions should be avoided whenever possible.

Dissemination of Information

Regional Arsenic Networks and National Databases

The development of a database provides stakeholders with access to information. Institutionally, it is useful to ensure that data are stored following a specific process and are checked and cleaned. Dissemination, accessibility, and transparency of data are critical for an issue as sensitive as water contamination. Scientifically, a database provides a baseline that can aid identification of a long-term trend. For example, the lack of a historical baseline in Bangladesh means that it cannot be ascertained whether arsenic has always been present in the groundwater or appeared only after exploitation of the aquifer.

In Bangladesh the National Arsenic Mitigation Information Center (NAMIC), a component of the BAMWSP, is responsible for collecting data related to arsenic. NAMIC collects its own data under the auspices of the BAMWSP and additional data from other stakeholders according to an agreed format. Some of the data are provided online (www.bamwsp.org). In addition, NGO-Forum provides a list of the major governmental agencies, international agencies, and NGOs that work in arsenic contamination (www.naisu.info).

In Nepal, with the support of the United States Geological Survey, the Environmental and Public Health Organization has prepared a national database for arsenic, which currently contains 18,000 arsenic level readings. Pakistan and Cambodia (annex 3) also have databases to centralize all the information from arsenic screening. In the three countries the contribution to the database is on a voluntary basis; however, in Cambodia, the Ministry of Rural Development and UNICEF make receipt of testing kits dependent upon contribution to the database. In India the Central Groundwater Board also has a web page with some arsenic-related data (www.cgwaindia.com/arsenic.htm).

Regional information can be exchanged through the Asian Arsenic Network (AAN) (www.asia-arsenic.net/index-e.htm).

The Global Positioning System (GPS) can be used to locate tubewells on a database, though differentiating individual wells may be difficult where the density of tubewells is greater than the resolution of the GPS, as may occur in Cambodia and Bangladesh (reported at Regional Workshop, Nepal, April 2004). Whatever method is used to differentiate wells in such circumstances should be practical enough to be used by all stakeholders, allowing levels of arsenic in individual wells to be monitored over time.

Summary Remarks

Once established, a database should be sustainable. In some cases a database is developed within a project and the collection of data is dependent on project financing. The institutional process to ensure the sustainability of data is usually not given priority at this time. However, during such projects the technical process of data collection, including where to measure and at what frequency, should be developed in parallel with the institutional process to make sure that cost recovery of the data collection takes place after project closure. This raises the issue of whether or not access to data should be free of charge; and, in the event of a charge, whether usage would be sufficient to ensure cost recovery.

3. Arsenic Mitigation in the Context of the Overall Water Supply Sector

Background

Most South and East Asian countries where groundwater arsenic contamination has been identified have inadequate surface water quality, mainly due to microbial contamination. In these countries solutions to water supply problems may require a trade-off between the long-term health effects of a contaminant such as arsenic and the short-term health effects of microbial contamination.

Access to Improved Water Sources in Asian Countries

Until recently, most sectoral programs concentrated on the lack of access to improved water supply. Table 6 shows the increase in access to improved water sources in South and East Asian countries during the 1990s. However, other problems, such as inadequate sanitation, are still present in the region (table 7) and, despite improvements, child mortality remains high (table 8).

Table 6. Access to Improved Water Sources in Selected Asian Countries

Country	Population with access to improved water source (%)					
	1990			2000		
	Urban	Rural	Total population	Urban	Rural	Total population
Bangladesh	99	93	94	99	97	97
Cambodia	-	-	-	54	26	30
China	-	-	71	-	-	75
India	88	61	68	95	79	84
Lao PDR	-	-	-	61	29	37
Nepal	93	64	67	94	87	88
Pakistan	96	77	83	95	87	90
Vietnam	86	48	55	95	72	77

- Not available.
Sources: World Bank 2003a: www.wsp.org/07_eastasia.asp; www.wsp.org/07_southasia.asp.

Arsenic Priority Compared to Bacteriological Water Quality Priority

Available data indicate that the rate of mortality due to waterborne diseases is greater than that resulting from arsenic contamination. Based on information in the literature, the best estimate of mortality due to diarrhea in Bangladesh is 120,000–200,000 people per year, of which possibly half can be attributed to drinking of pathogen-contaminated water (Alaerts and Khouri 2004). Similarly, the best estimates put mortality due to arsenicosis at 20,000–40,000 people per year.

Table 7. Percentage of Population in Selected Asian Countries with Sanitation

Country	Population with access to sanitation (%)					
	1990			2000		
	Urban	Rural	Total population	Urban	Rural	Total population
Bangladesh	81	31	41	71	41	48
Cambodia	-	-	-	56	10	17
China	-	-	29	-	-	38
India	44	6	16	61	15	28
Lao PDR	-	-	-	67	19	30
Nepal	-	-	20	-	-	28
Pakistan	52	23	36	82	38	62
Vietnam	-	-	29	-	-	47

- Not available.
Sources: World Bank 2003a: www.wsp.org/07_eastasia.asp; www.wsp.org/07_southasia.asp.

Table 8. Child Mortality Rates in Selected South and East Asian Countries

Country	Infant mortality rate (per 1,000)		Under-five mortality rate (per 1,000)	
	1980	2001	1980	2001
Bangladesh	129	51	205	77
Cambodia	110	97	190	138
China	42	31	64	39
India	113	67	173	93
Lao PDR	135	87	200	100
Nepal	133	66	195	91
Pakistan	105	84	157	109
Thailand	45	24	58	28
Vietnam	50	30	70	38

Source: World Bank 2003a.

However, it is not known whether arsenic morbidity is higher than waterborne disease morbidity. Thus, there are insufficient data to resolve the issue of how to prioritize between short-term contamination of surface water and long-term contamination by arsenic.

As regards contamination with arsenic, certain criteria can help assess the level of priority that should be given to the problem: (a) the concentration of arsenic in drinking and cooking water; (b) the spatial distribution of the contaminated tubewells; and (c) the proximity of other water sources that are safe.

There is a positive correlation between the concentration of arsenic and its health effects. If the only available sources have high arsenic concentrations (more than a few hundred $\mu g\ L^{-1}$) and most of the tubewells are contaminated, there is practically no access to safe water. In this case the morbidity of arsenic is very high, and the shift to surface water might be considered, providing adequate chlorination is carried out or that people are advised to boil water for drinking purposes. If the average concentration of arsenic is less than 100 $\mu g\ L^{-1}$, there is a longer timeframe for planning action. Solutions such as either providing surface water safe from arsenic and bacteria, or piped water either from surface water or another aquifer, can be properly planned to ensure that people get access to safe water. Another scenario could be that some tubewells have high concentrations of arsenic but the percentage of contaminated wells is low, which means that people will still have access to safe water within a reasonable walking distance. This kind of case-by-case or village-by-village analysis can provide insight into suitable steps to be taken.

The financial sustainability of any water supply technology is necessary to ensure long-term sustainability of the supply, and must include operation and maintenance of the system, be it wells, pond sand filters, or piped water supply. Such recurrent costs and responsibilities for incurring them will vary according to such factors as whether the water supply is private (for example individually installed household wells) or operated by the community.

In the shift to arsenic-safe options governments will have to involve communities in cost sharing, both for capital costs and for long-term operation and maintenance. With water supply provision still free in a number of countries, this relatively new concept may not be widely accepted by government or by users. Indeed, moving from surface water to groundwater allowed people to have clean clear water almost free of charge in terms of operation and maintenance costs. Now that some tubewells can no longer be used, alternative safe sources of water may have high operation and maintenance costs. Users would have to pay for water on a regular basis and receive a quality of service equal to or less than that available with tubewells. Therefore, as applicable in a given country, willingness to pay studies will be crucial in deciding what mitigation options are not only technologically appropriate but also socially accepted in the long run. Such studies have been carried out by the Water and Sanitation Program in, for example, Bangladesh (WSP 2003) and have played an important role in informing policy decisions regarding the introduction of piped water supply.

Definition and Identification of Arsenic Contamination Hotspots

Color coding of tubewells has been used to signify which wells are arsenic safe and which are not (see section above). There is no record in the literature of more than two colors being used to identify degrees of contamination; for example, one color could indicate an arsenic concentration less than 10 μg L^{-1}, another could indicate the range 10–50 μg L^{-1}, another the range 50–200 μg L^{-1}, and another a concentration higher that 200 μg L^{-1}. Such levels of precision would be possible in countries where laboratory testing was the norm, but not in countries that rely on field test kits. Also, use of additional colors would add complexity to any awareness campaign. However, an advantage would be that users could tell which of the contaminated tubewells were less harmful and which more harmful. A long-term advantage could be that if the national standard in some countries was lowered to, for example, the present recommended maximum permissible value of the WHO (10 μg L^{-1}) tubewells would not have to be rescreened and reclassified, and sufficient data would be available to enable costing of the measures associated with adjustment of the national standard.

The problem of prioritizing mitigation measures for arsenic contamination is illustrated by Bangladesh, where emergency villages are defined as those with more than 80% of tubewells contaminated. However, this does not always provide a full enough picture on which to base operational responses; for example, 80% of tubewells contaminated with, say, 60 μg L^{-1} may be less harmful than 70% of wells contaminated at an arsenic level of 200 μg L^{-1}. Therefore, when definition of hotspots is based only on the percentage of tubewells with a concentration of arsenic higher than WHO guidelines or national standards, there is insufficient information to develop a plan of action.

Remaining Issues and Recommendations

Institutional setting of water quality monitoring is a concern. Which institution should be responsible for the first screening and the monitoring? Should the operator or an independent organization such as an NGO or the community conduct them? What about sustainability and transparency and access to the related data?

Since some countries such as Bangladesh, Nepal, and India also have the option of using deep groundwater, the legal aspects of groundwater management will have to be taken into account. Especially where exploitation of deep groundwater is concerned, should permits be introduced to ensure that the deep groundwater will be used exclusively for drinking and cooking purposes or is it assumed that, because of the cost, people will not use the deep groundwater for irrigation purposes? Hence, for long-term planning, there is a need to develop and strengthen the legal framework for groundwater management.

Although arsenic contamination is covered far more in the international media than waterborne diseases, this should not imply that the bacteriological quality problem faced by South and East Asian countries should be put aside. The decision regarding the setting of priorities has to be taken based on criteria such as the level of contamination of arsenic, and the access to safe water based on bacteriological and chemical parameters.

4. Incentives for Different Stakeholders to Address Arsenic Contamination

The major stakeholders in natural arsenic contamination are water users, government, NGOs, donors, and international agencies. The incentives for each stakeholder to be active in addressing the issue are different. While a government would be expected to be more influenced by public pressure, for example in the run-up to elections, an international agency might be more concerned with the reputational risk associated with its choices. The incentives for an NGO may stem less from public pressure or reputational risk (although this could also be possible) than from the wish to influence decisions in a given sector. When no other stakeholder is addressing the issue, there is an incentive for the users themselves to act to remedy the situation. Incentives discussed here are the number of people at risk, number of arsenicosis patients, rural and urban areas affected, national and international media coverage, cross-sector responses needed, water service pricing, short-term versus long-term solutions, reputational risk, and transparency of the mitigation measures.

Number of People at Risk

The number of people at risk from arsenic contamination does not seem in itself to be an incentive for stakeholders to become active. Those at risk are those drinking contaminated water; only a certain proportion will develop the clinical symptoms of arsenic poisoning. Ahmed (2003) estimated the percentage of the total population at risk to be about 25% in Bangladesh, 6% in West Bengal (India), and 2.4% in Nepal. Fewer data are available for East Asian countries than for South Asian countries, perhaps due to lack of identification of the problem, though in Vietnam the percentage of the population at risk has been estimated at 13%, or 11 million people (Berg and others 2001). Lack of information, however, prevents an accurate current assessment of arsenic contamination in East Asian countries.

Number of Arsenicosis Patients

The number of actual arsenicosis patients might be considered more of an incentive for stakeholders to become active. For example, while the estimate of the percentage of population at risk in Vietnam is double that of West Bengal, the number of (identified) arsenicosis patients is reported to be nil in Vietnam compared to around 200,000 in West Bengal (WSP 2003). There is no indication from the literature that Vietnam is in the process of providing mitigation measures on a large scale for the at-risk population. It is important to note that the use of groundwater in Vietnam is quite recent (less than 10 years). Since the latency of arsenic-related diseases is between 10 and 15 years, Vietnam could register a large number of arsenicosis sufferers in a few years – which would increase the incentive to address the issue, but unfortunately at already a very advanced stage. Hence, the first identification of arsenicosis patients is a greater incentive for government, donors, NGOs, and international agencies to act than the population-at-risk measurement. This is not surprising, given the many other issues that developing countries have to contend with, but investments in patient screening and epidemiology now could prevent costly emergency mitigation interventions later.

Rural and Urban Areas

Except in the cases of Vietnam and Cambodia, arsenic-contaminated groundwater has mainly been detected in rural areas. In urban areas it is easier to deal with the arsenic problem when there is a point source water supply. For example, in Hanoi water treatment plants use aeration and sand filtration for iron and manganese removal from the pumped groundwater, which also eliminates some arsenic from the raw groundwater, although in some cases this is not enough to reduce it to levels below the national standard. In such circumstances, established facilities can be upgraded to address the arsenic problem. On the other hand, in rural areas, the problem is far more complicated because water sources are dispersed and difficult to improve on an emergency basis. Provision of mitigation measures by government and donors may take a long time, though NGOs might be more flexible and better suited to act quickly at this decentralized level. Even so, the scale of the problem is significant.

Importantly, rural populations often have less political clout than urban populations, which are typically more informed and politicized. Rural populations also suffer from the organizational problems that tends to afflict large groups with many free riders, weakening their voice as a group. This may in turn weaken the incentive for politicians to address arsenic contamination in rural areas.

National and International Media

National media coverage can be an incentive for stakeholder activity since there is reputational risk associated with providing unsafe water. However, this type of media coverage may act as a disincentive to action; if it is alarmist or factually inaccurate then certain stakeholders may prefer to avoid possible controversy.

International media coverage might also create an incentive by raising global awareness, encouraging international agencies to orient their projects to take into account arsenic issues, and governments to commit more money to this purpose. However, care must be taken that this shift will not cause governments to reallocate resources from other equally important but less publicized problems.

For the media themselves, there is an incentive to cover such controversial issues as arsenic contamination because they increase circulation. However, the short-term coverage is often in contrast to the long-term, chronic nature of the problem.

Institutional Aspects

Arsenic is a cross-sectoral issue in that it involves water supply, water resources management, health, and (rural) development institutions. This can create difficulties if the institutions do not coordinate with one another. Transparency in the choice of mitigation measures can be an incentive encouraging stakeholders to be active and to work together.

The pricing of water supply services provides users with an incentive to hold providers accountable for water quality. This is not always an incentive for government to implement charges for water supply services since they then become accountable. Tubewells in rural areas provide clean water that is almost free in terms of operation and maintenance costs. However, most of the solutions to address arsenic contamination will be less convenient and some mitigation measures will involve a charge for water supply service, which can be a difficult reform to introduce in some countries.

Short-Term versus Long-Term Solutions

Government, international agencies, and NGOs might feel greater incentive to implement short-term solutions rather than long-term solutions that are less immediately rewarding. The development of arsenic policies and strategies can be a means of increasing the likelihood that long-term solutions will be implemented as well.

Reputational Risk

Reputational risk can act as an incentive to make government and international agencies active. However, as in Bangladesh, the controversy surrounding arsenic contamination may discourage certain stakeholders from risking their reputations by becoming involved in the issue. This has delayed decision-making on such mitigation measures as the use of arsenic-free deep groundwater, which could provide safe water in the short and medium term.

Table 9 provides a conceptual summary of the political economy of arsenic contamination of groundwater. It provides an indication why — up to now — mainly donors and international agencies and some country governments have been responding to arsenic contamination. Clearly, as more arsenic-affected areas are being identified and as the number of arsenicosis patients is going to rise, it can be expected that stakeholders will become more active. It is, however, important that in the meantime a more rational basis for dealing with arsenic contamination is created in order to avoid delayed — or exaggerated — responses.
An important aspect in this regard is investment in epidemiological studies and economic analyses, as outlined in Paper 4.

Table 9. Conceptualized Incentive Matrix: Stakeholder Incentives for Action on Arsenic Issues

Incentive factors	Government	Donors/international agencies	NGOs
Number of people at risk	Low incentive	Low incentive	Low incentive
Number of arsenicosis patients	Great incentive	Great incentive	Great incentive
Rural areas	Low incentive	Medium incentive	Medium incentive
Urban areas	Great incentive	Medium incentive	Medium incentive
National media coverage	Great incentive	Medium incentive	Low incentive
International media coverage	Great incentive	Great incentive	Low incentive
Water pricing and accountability	Medium incentive	Great incentive	Low incentive
Transparency in choice of mitigation measures	Medium incentive	Great incentive	Medium incentive
Availability of short-term solutions	Great incentive	Medium incentive	Great incentive
Availability of long-term solutions	Medium incentive	Medium incentive	Low incentive
Perception of reputational risk	Great incentive	Great incentive	Low incentive

Low incentive Medium incentive Great incentive

5. Conclusions

In certain areas, natural arsenic contamination of groundwater has made effective access to safe drinking water difficult to achieve. If the concentration in water of a chemical parameter, such as arsenic, is higher than the maximum permissible national drinking water standards, the water is considered contaminated and no longer potable. In Bangladesh, for example, arsenic contamination has reduced the amount of safe drinking water by about 20% in the last decade.

Two main issues generate substantial uncertainties in accurately predicting the impact of specific short-term or long-term mitigation measures. The first is the lack of understanding of how arsenic is released from sediment to water, and the second is the lack of epidemiological data on the health impact of low concentrations of arsenic in drinking water. Indeed, since the arsenic release process is not fully understood, it becomes difficult to be certain that a given mitigation measure will always provide arsenic-safe water. Also, since the epidemiology of arsenic is not fully understood, estimation of the real health outcome for lower arsenic concentrations provided by a given mitigation measure is difficult. For example, regarding the exploitation of the deep (Pleistocene) aquifer, so far no arsenic has been found in deep tubewell water in Nepal, West Bengal, or Bangladesh. However, due to these uncertainties, whether deep groundwater will remain arsenic safe in the long term, and what the real health outcome of using deep groundwater compared to other mitigation measures will be, are difficult to determine.

Practically speaking, mitigation measures should be implemented as soon as arsenic has been identified. While the success of implementation depends mainly on socioeconomic factors such as people's acceptance of an option and its capital cost, scientific understanding of arsenic has value added on the quantification of impacts, but not on the implementation of mitigation measures per se. Therefore, instead of delaying implementation until arsenic contamination is fully understood, both implementation and scientific investigation should be conducted in parallel.

At the policy level (that is, action the government needs to take), when arsenic contamination is identified in groundwater there is a need to assess:

- The scale of contamination: As the first screening results become available hydrogeologists and geochemists should recommend whether the screening needs to be implemented at the project level or if national screening needs to be conducted.
- The emergency level based on the population at risk, the number of arsenicosis patients, the time of exposure, and the concentration of arsenic in water.

Based on the contamination scale and the emergency level, government should implement a regional emergency plan of action with short-term and long-term components to mitigate arsenic contamination. Potential emergency and short-term responses include dug wells, pond sand filters, rainwater harvesting, arsenic removal filters at the household level, and use of a safe aquifer. Potential long-term operational responses are arsenic removal plants at the community level, piped water supply, and use of a safe aquifer.

At the implementation level (that is, action that needs to be taken at the project level), when arsenic is identified, there is a need to conduct the following actions:

- Ensure that the appropriate government institution is informed about the contamination.
- Ensure that the data are available and properly stored for further scientific research on the contamination, and are also available to different stakeholders that either use the water or implement water projects in or beyond the project area.
- Ensure that in the project area the government requires the operator to check arsenic on a regular basis and makes the results available to stakeholders.

Whether the project should be continued is a decision for both the institution or international agency and the government. There is a need to ensure that arsenic mitigation occurs in an integrated manner with ongoing projects.

One of the questions for donors and international agencies is whether a water project where arsenic is identified should be pursued or not. Knowing that arsenic has long-term health effects and that poor surface water quality has short-term effects, the question is how to address both issues in a balanced way. If the project is to continue, government should provide assurances that appropriate measures will be taken to mitigate the arsenic contamination.

Finally, arsenic contamination has changed people's minds about the generally accepted rule that "groundwater equals safe drinking water". Although such water may be bacteriologically safe recent events have cast increasing doubts on its chemical safety. There are still other sources of water contamination in South and East Asian countries that need to be addressed, such as fluoride, manganese, sodium, iron, and uranium, in addition to bacteriological contamination. A development agency's target should be to ensure that all the mechanisms for water quality monitoring are set and implemented now, either for surface water or groundwater, to reduce the risk of providing unsafe drinking water.

Annex 1. Operational Responses Undertaken by South and East Asian Countries

Activities (✔ indicates presence of activity)	East Asia						South Asia			
	Cambodia	China	Lao PDR	Myanmar	Taiwan (China)	Vietnam	Bangladesh	India	Nepal	Pakistan
Assessment of the arsenic situation										
Screening (field test)	✔	✔	✔	✔		✔	✔	✔	✔	✔
Screening (laboratory)						✔	✔	✔	✔	✔
Mitigation activities										
Water sharing	✔						✔		✔	
Dug well				✔			✔	✔	✔	✔
Rainwater harvesting	✔			✔	✔	✔	✔			
Pond sand filter							✔			
Deep tubewell				✔		✔	✔	✔	✔	
Household water treatment	✔			✔		✔	✔	✔	✔	✔
Community water treatment	✔[a]	✔			✔	✔	✔		✔	
Long-term collection and dissemination of information										
Arsenic monitoring program	✔[b]					✔[b]	✔[c]			
Database	✔						✔	✔	✔	✔
Dealing with arsenic at the national or state policy level										
Arsenic policy						✔	✔			
Arsenic committees/ programs	✔	✔					✔	✔[d]	✔	

[a] The water treatment is based on blend of safe and potentially contaminated water. [b] Only for piped water supply. [c] Incipient. [d] The Joint Program of Action (JPOA) with UNICEF.

Annex 2. Matrices for Implementation of Operational Responses to Arsenic Contamination

Table 1. Technical Issues

Issues	Recommendations	Expected outcomes
Screening method selection (field test versus laboratory analysis)	If field tests are chosen, then a percentage of samples should be cross-checked with laboratory analysis. If laboratory analysis is chosen, ensure capacity is sufficient and a quality assurance mechanism is implemented	Establish standard operating procedures to ensure reliability and consistency of arsenic concentration data
Technical capacity for measuring arsenic concentrations	Adequate training must be provided and refresher courses should be required, otherwise technical assistance needs to be made available after the closure of the project Provide training-for-trainer courses to ensure capacity is retained and sustained	Train people for a first screening, but ensure that they will be available for monitoring
Assessing extent of arsenic contamination in the shortest time possible	Determination of whether to screen a large or local area should be left to a hydrogeologist. Conduct a first screening using a large grid to acquire critical information on the location of the hotspots where precise screening should be conducted Sampling strategy — whether to screen all tubewells or just a small percentage — must be decided by the responsible agency	Information on the extent of arsenic contamination is critical in the development of a pragmatic action plan and an assessment of appropriate operational responses
Ensuring that alternative water sources present safe levels of bacteria and other chemical parameters	Ensure the community is properly trained in the operation and maintenance of different operational responses (dug well, pond sand filter, rainwater harvesting, water treatment, piped safe water) Ensure alternative potable water sources are also regularly monitored for contaminants	Improve water quality by preventing a pollutant shift to the water quality problem, say from arsenic to bacteria or to some other chemical
Ensuring that mitigation measures specify and delineate acceptable materials and quality standards to be used	Each mitigation measure must include clear specifications of the minimum quality required Ensure a functional process is in place to verify contractors are following the mitigation requirements	Increased sustainability of mitigation measures through enhanced quality of equipment used

Contd. on next page

Issues	Recommendations	Expected outcomes
Providing patients with adequate treatment	Provide arsenicosis patients with vitamins, moisturizing lotions, and treatment for infections Maximize patient contact with a preventive health approach by planning treatment for other diseases, such as diabetes	Reverse arsenic effect or, at least, reduce people's suffering and the morbidity rate from arsenic-related diseases
Marking tubewells regularly	Retest tubewells once or twice a year	Make sure that people have easy access to tubewell safety information listing which tubewells are safe or unsafe
Cross-checking collected data among different stakeholders	For example, NAMIC data in Bangladesh have been cross-checked with data collected by Columbia University	Preserves reliability of collected data in a cost-effective way
Ensuring that alternative water sources have the capacity to meet demand	–	Avoids a water shortage that forces people to drink contaminated water

Table 2. Financial and Economic Issues

Issues	Recommendations	Expected outcomes
Choosing a mitigation option based on the benefits and costs	Assess both expected benefits and costs of mitigation options	Create basis for rational decision-making on mitigation options and programs
Assessing pricing affordability for the poor	Conduct a willingness to pay study to determine the range of water fees people can afford	Ensures cost recovery of operation and maintenance costs with minimal burden on the poor segment of the population
Deciding which stakeholder(s) should pay for the screening and the monitoring of tubewells, patient identification, and awareness campaigns	–	If a progressive financial mechanism for screening and monitoring is not identified from the beginning, when donors leave the collection of data is likely to stop
Reducing the costs associated with screening and patient identification	Tubewell testing should be done in concert with patient identification	Allows for cost-effective patient identification
Finding mechanisms to compensate people that may lose income because of mitigation measures	Create a public-private fund to compensate those most impacted by economic loss, for example people who cannot use their pond for fishing purposes, people who experience a lack of privacy because they share safe tubewells	Sustainability of these emergency or short-term solutions

Table 3. Social and Cultural Issues

Issues	Recommendations	Expected outcomes
Dissemination of data	Create a website where data might either be available free of charge or with clear steps on how the data can be purchased. Provide, at minimum, the following information: (a) geographical distribution of affected areas; (b) location of arsenic-contaminated tubewells; and (c) number of affected persons or identified patients	Transparency of the information related to the extent of arsenic contamination
Paradigm shifting away from "clear water equals safe water"	Make it clear through public announcements that while surface water is unsafe, some clear groundwater can also be contaminated. Indeed for many years people in Asian countries have immediately associated clear groundwater with potable drinking water and turbid surface water as unsafe to drink	Increasing people's willingness to have their water monitored Increasing public awareness that water contaminants are not always visible
Coordination between scientists and donors to ensure information disseminated to the public is consistent	There will always be some uncertainties and therefore many possible answers. However: (a) scientific community and scientists must agree on one (simple) story to tell the public; (b) qualify statements by clearly explaining what facts are known with certainty and what information is still debatable. Publicly state assumption made, if applicable	Avoids confusing people on the origin and potential extent of the arsenic contamination problem
Coordinating operational actions among stakeholders	Avoid testing always the same villages and families within the affected area by different stakeholders, but instead try to cover the largest geographical areas	Increases the coverage of people who have access to safe water
Finding incentives to increase people's willingness within communities to share safe wells	Limit the number of people who have to share the same tubewell. Work with the community to create a feasible community plan that maps out which family should go to the other	Spreads the social burden and avoids taxing the goodwill of the (same) few people who willingly offered their help
Making sure that for patient identification	Avoid creating gender-related issues at the time of examination by including a male and female examiner in	Addresses sensitive gender issues Avoids underestimating the number of

Issues	Recommendations	Expected outcomes
there are women on each team	each team (case study: Bangladesh)	female arsenicosis patients
Creating legible and understood marks on tubewells located in rural communities	Create a design or color-coded mark culturally sensitive to people in the rural area Place design or mark in an easily recognized and visible location near the tubewell	Enhances effectiveness of the awareness campaign by easily reaching a wide audience
Ensuring health workers and doctors take the time to explain preventive measures	Promoting the use of vitamins is not sufficient as a preventive or treatment measure at early stages of arsenicosis contraction; the only option that exists is to stop drinking arsenic-contaminated water. Stress that there is no cure for advanced-stage arsenicosis	Drives message home to people: advanced-stage arsenicosis is not treatable
Maintaining public awareness about arsenic and other water-related diseases associated with poor microbiological quality of surface water and water sources, such as dug well, ponds, etc.	Ensure continued production of messages to the public that explain surface water is unsafe and contaminated	Avoids a simple problem shift of the risk from arsenic to bacteria

Table 4. Institutional Issues

Issues	Recommendations	Expected outcomes
Ensuring poor people will be equally served in the provision of mitigation measures	Provide a subsidy to ensure that poor communities can afford cost of services	Applies a fair price for water to each segment of the population
Coordinating activities between water and health sectors, and their corresponding institutions	Propose projects where institutions of both sectors are the implementing agencies Develop workshops coving topics relevant to both sectors Create a transparent information dissemination system between the sectors and institutions for general announcements, workshops, meetings, etc.	Improves institutional efficiency by avoiding wasteful spending on similar action items Creates forum to address potential interinstitutional conflicts of interest Increases institutional accountability by preventing finger pointing of responsibility on important social issues
Identifying incentives to strengthen the weak health sector of remote rural areas	Create an economically based incentive, such as higher wages or increased promotion probability Develop alternative solutions, such as providing additional training free of charge to health workers	Improver the health sector service in remote rural areas
Implementing a decentralized policy strategy implies a large number of trainers and trainees	Create multilevel and multidiscipline training sessions to generate a multiplier effect	Reaches the maximum number of people in a cost-effective way

Issues	Recommendations	Expected outcomes
Effectively introducing groundwater legislation, especially in the case when an alternate aquifer is safe to use	Introduce water rights and well exploitation permits and licenses	Creates incentive for reasonable or reduced groundwater uses, such as for drinking and cooking purposes only Increases the sustainability of groundwater usage
Identifying the responsible stakeholder(s) for the screening and monitoring of water quality	Ensure that each stakeholder has a clear understanding of their responsibility	Clearly defines which institution is accountable if the screening or monitoring is not conducted
Providing external elements such as chain supplies for water treatment	–	Ensures the sustainability of the chosen option
Introducing database management	Establish an archive system Ensure data are properly cleaned and stored	Increases information availability for further research or other general purposes

Annex 3. Operational Responses to Arsenic Contamination: Questionnaire Results

Country	Four countries responded to the survey: Bangladesh, Cambodia, Nepal, and Pakistan
State/Province (if applicable)	
Country national standard for arsenic ($\mu g\ L^{-1}$ or ppb)	50 $\mu g\ L^{-1}$ for all respondent countries
Answer provided by: (Name/institution/address/email)	BRAC, AusAID, FAO, UNICEF, Partners for Development, Irrigation Ministry of Nepal

The questionnaire was in two parts. The first part focused on general issues regarding the operational responses towards arsenic contamination, and the second focused on implementation aspects of these operational responses. The tables below indicate the questions in the left column, and summarize country responses in the right column.

Part 1. General Issues Survey

Water resources availability and use in the country

Questions	Results
How much groundwater and surface water respectively is used countrywide for drinking water supply, irrigation and industry?	In Bangladesh, Nepal, and Pakistan groundwater is used first and foremost for irrigation (by a large margin), then for drinking water supply, and finally for industrial purposes.
What is the percentage of groundwater and surface water used in the rural and in the urban areas respectively for drinking water, industry and irrigation?	Not enough answers to provide any regionwide conclusion.
a) When and by what institution/person was the first discovery of arsenic in groundwater made? b) What are the areas, so far, identified and what percentage of the country consists of these contaminated areas?	Except for Bangladesh, where the first screening was conducted in 1993, the first screenings in Cambodia, Nepal, and Pakistan were conducted between 1999 and 2000. Distribution of contaminated areas within the four countries was as follows: in Bangladesh, contamination occurred in the deltaic areas; in Cambodia, in the areas close to the Mekong River; in Nepal, in the southern Terai plain; in Pakistan, in the provinces of Punjab and Sind.

Regulatory framework

Is there a specific national policy, law (or protocols) regarding arsenic? If not, why not? If yes, which institution is responsible to implement these? (Please provide a summary/ copy of the policy/law/protocol/decree.)	Bangladesh is ahead of the other countries with respect to its national arsenic policy.
Is there a groundwater law in the country? When was it instituted? If not, is one under development (law already initiated, law under development, or no law)?	So far there is no groundwater law in the four countries. However, Nepal is in the process of reviewing a draft groundwater law, and in Pakistan UNICEF and the Ministry of Environment are planning to initiate one during 2004.
Is there a surface water or general water law in the country? When was it instituted? If not, is it under development (law already initiated, law under development, or no law)?	Cambodia, Pakistan, and Nepal each have a surface water law. In Nepal the surface water law was instituted in 1992.
Is there a national database on arsenic contamination? If not, why?	All four countries have a database.
Is contribution to the database enforced by law or is it voluntary?	It is voluntary in Bangladesh, Nepal, and Pakistan, and mandatory in Cambodia as the contribution to the database is a condition for receiving a testing kit from UNICEF and MRD.

Mitigation measures

When was the first regionwide screening conducted? And when was the first nationwide screening conducted? Was a systematic marking of the contaminated/ safe tubewells/other sources done? How was the marking done? If no screening conducted either regionwide or nationwide, why?	All four countries mark tubewells in the screening process. In Bangladesh, Cambodia, and Pakistan the marking is based on colors, specifically green and red. In Nepal, markings take the form of either a cross or a check (√).
Which arsenic-related activities are being undertaken in your country?	Patient care has not been implemented so far in Nepal or Pakistan.
To your knowledge, which governmental institution/NGO/development partner is carrying out these activities?	UNICEF is involved in the four countries, in particular in Cambodia and Pakistan. In Bangladesh the number of stakeholders is much higher than in other countries. The major NGOs in Cambodia are RDI and PDF.

Mitigation measures	
Are the different actors coordinating these activities? If yes, by whom and how is it done? Is the coordination effective? Why? If not, why not?	Regarding the coordinating agencies: there was no consensus in Bangladesh; in Cambodia, UNICEF is seen as taking this role; and in Nepal the National Steering Committee for Arsenic is the coordinating agency. Pakistan has not yet begun a nationwide coordination effort.
How many tubewells/other water supply sources are there in the country? How many tubewells/other sources are there in the arsenic-affected areas? How many tubewells/other sources have been screened? Will all the tubewells/other sources be screened in the long term? If not, why not?	The only country for which the number of tubewells is reported is Bangladesh, with about 10 million tubewells. The number of tubewells is not reported in Cambodia, Nepal, or Pakistan.
What is the tone of the national media coverage regarding arsenic contamination?	The tone of the national coverage of arsenic contamination has been reported as: alarmist in Bangladesh and Nepal; fact based in Pakistan; and nonexistent in Cambodia.
How would you rate, on a scale from 1 to 3, the arsenic problem compared with other problems faced by your country?	The arsenic problem is rated as very important in Bangladesh and Pakistan; and of medium importance in Cambodia and Nepal.
Which institution/NGO/international organization is the main driver in addressing the arsenic issue? How did this institution come to take the lead?	UNICEF is seen as the main driver in addressing arsenic issues in both Cambodia and Pakistan; in Nepal it is the Department of Water Supply and Sewerage; and in Bangladesh several agencies have been reported as being the main drivers: DPHE, DANIDA, UNICEF, and the World Bank.
When exploring a new source of water, are there standard protocols about the chemical parameters to check water quality for drinking water supply, or irrigation?	Bangladesh and Cambodia have a standard protocol for drinking water supply. None of the four countries seems to have a standard protocol for irrigation.
Is arsenic one of the parameters of these protocols? If yes, is arsenic occurrence a factor in the decision about the choice of using the water source? And if it is detected, what are the actions conducted regarding this contamination?	Although arsenic is a parameter of the protocol in Bangladesh and Cambodia and should be a factor in the decision as to whether to use the water source, it does not seem to be implemented.

Part 2. Specific Implementation of Mitigation Measures

Implementation aspects of mitigation measures	
Is there any monitoring for the screened tubewells/other water supply sources? If yes what frequency and how is it done? If not, why?	In all four countries limited or no monitoring is reported.
What method is used for the screening? (e.g. field test kit, laboratory or both). Is cross-checking of field test and laboratory analysis applied? If yes, how is it done?	Field test kits are used for screening in all four countries. Cross-checking with laboratories is reported in all countries.
What are the main problems encountered in the process of screening, both on the technical and on the institutional side?	Ensuring the effectiveness of the field test. Limited capacity of government staff. The transport of samples from the field to laboratory.
Describe the present awareness campaign (TV, radio, newspaper, etc.) What are the lessons learned on the best way to communicate information about arsenic?	TV, radio, and distribution of printed material are the media used for the awareness campaign. Lessons learned: Use community-specific communication methods, e.g. karaoke (when applicable), video. Verbal communication with the community is one of the most effective means of communication. Mitigation should accompany awareness campaigns as providing an alarmist message without providing a solution is counterproductive.
What mitigation measures are already applied and tested (e.g. dug well/surface water/rainwater harvesting/water treatment/deep groundwater/ others)?	Screening is the mitigation measure that has been conducted in the four countries. So far, all the mitigation options have been tested in Bangladesh. In Cambodia dug wells, rainwater harvesting, community water treatment, and ceramic filters for surface water treatment have been implemented. In Nepal water treatment at the household level has been tested on an experimental basis. In Pakistan dug wells are used and household-level treatment is being promoted.
How are mitigation measures (dug well/surface water/rainwater harvesting/water treatment/ deep groundwater/others) selected (e.g. feasibility study, community decision, central agency)?	In Bangladesh and Cambodia all the implemented mitigation options are selected at the community level. In Nepal screening is selected by the central agency and donors, while household water treatment is only selected by donors. In Pakistan the implementation of mitigation options is based on feasibility studies.
What are the major problems encountered in implementation of the mitigation measures and what has functioned well?	It is difficult to operate the pond sand filter. It is difficult to make people change behavior and switch from tubewells to other water sources. The capital cost of the initial infrastructure for alternative water supply is a problem.

Health aspects of the mitigation measures

a) Which agencies are responsible for patient identification? b) Do they coordinate their work? c) If yes how is it done? If the coordination is not effective what are the reasons? d) Is the screening based on skin lesions or are there measurements (arsenic in hair, nail, and blood)?	In Bangladesh many agencies are responsible for arsenic identification, namely: Dhaka Community Hospital, upazila health complex at upazila level, and the Ministry of Health and Family Welfare. In Cambodia and Nepal it is the Ministry of Health. In Pakistan patient identification has not started yet. In Bangladesh the reported information is that there is no coordination among the agencies, while in Cambodia it seems to be coordinated. In Cambodia the coordination is through the Arsenic Interministerial Subcommittee and via UNICEF/WHO assistance. The screening is mainly based on skin lesions in Bangladesh, Cambodia, and Nepal. In Pakistan measurement is also based on arsenic in the nail.
How is medical management of arsenicosis patients organized? What is the procedure for monitoring patients?	In Bangladesh it is organized mainly through government hospitals, DCH, and UNICEF. In addition, through the financial assistance of BAMWSP, DCH trained doctors in the identification and management of arsenicosis patients. None of the countries reported any procedure for monitoring patients.
What is the current estimate of the number of patients with arsenicosis? What is the current estimate of the population at risk?	For Bangladesh the range is from 13,000 to more than 19,000 arsenicosis patients. In Pakistan, there are approximately 140 arsenicosis cases per 100,000 people in Punjab. It is reported that no patients have been identified as yet in Cambodia.

Research aspects of arsenic contamination

Is there any research done in your country/state/province on the origin of the arsenic in the sediment, its release to the groundwater, and the migration with the groundwater flow?	There seems to be a lot of research in both Bangladesh and Cambodia involving both local and foreign research institutions. Small-scale research in Nepal has been reported with involvement of the USGS. No research has been reported in Pakistan.
If yes, what institutions are involved: local universities, local research institutes, government agencies, foreign universities, foreign research institutes, NGOs, etc.?	
Is there any outcome of research on arsenic accumulation in the food chain?	While Bangladesh is the only country where research on arsenic accumulation has been reported, no conclusions as yet are available.

Research aspects of arsenic contamination

Is there national quality control of laboratories? If yes, how is it conducted (frequency, methodology, responsible institution, etc.)?	Nepal is the only country where there is national control of laboratories. In Nepal, the Department of Meteorology and Standards accredits the private laboratories; however, this is not mandatory and is done on a voluntary basis.

Economic aspects of the mitigation measures

What is the cost of each mitigation measure? How many people were served?	Bangladesh is the only country where most of the costs are available. These costs are summarized in the table at the end of this annex. In the case of Pakistan the following lump sum was provided: (Pitcher + awareness raising + testing & marking)/HH = Rs 1,500.

In general, in your opinion, what are the main lessons learned on the operational responses that have been conducted?

Social

It is possible to train female village volunteers to test the tubewells for arsenic.

Local women with limited educational background can also be trained on preliminary identification of arsenicosis patients, awareness education, alternative water supply, and monitoring of these options. Community needs to be mobilized in arsenic mitigation.

There is no unique solution because of technical limitations and cultural acceptance of mitigation options.

Communication of arsenic issues to private individuals installing tubewells is a challenge.

Technical

Local mason can be trained in the construction and manufacture of different mitigation options.

Monitoring of safe water options for arsenic and bacteria (when applied, e.g. for surface water) as well as for other potential contaminants.

Since there is so far no treatment for arsenicosis, there is a need to provide arsenic patients with safe water for drinking and cooking purposes.

Much research is needed to find out effective treatment regimens for patients in different stages of arsenicosis.

Many treatment units, either home based or community based, produce sludge that contains a high concentration of arsenic. A countrywide proper management system for this sludge should be set up so that rural people can manage this sludge in a convenient way.

Economic

Need low-cost solutions.

Need for fee collection to cover ongoing maintenance issues.

Institutional

Set a priority to implement mitigation options in the most-affected villages.

There should be more coordination among different governmental and nongovernmental agencies working in the country.

The longer-term solutions must be based on a long-term vision. This may include the provision of piped water supply to its population and the optimum use of its surface water. The potential role that the local governments can play in this longer vision must be fully explored; towards this, experimentation and pilot projects should not wait.

Standardized field testing and data management are needed.

Government needs to be in the driver's seat in screening and implementing mitigation options.

Bangladesh: Costs of Mitigation Measures (Response to Questionnaire Item 32)

	Cost per unit (taka)	Number of people served
Screening with field test	Tk 30 (total cost Tk 3,000)	100 households
Screening with laboratory analysis	Tk 500 by AAS Tk 300 by spectrometer	
Awareness campaign	Tk 1,500 per village meeting	100 households
Dug well	New: Tk 40,000–50,000 (Renovation: Tk 10,000 average) Tk 35,000–40,000	40–50 households 20–30 families comprising 5 members
Pond sand filter	Tk 50,000–60,000 Tk 30,000–40,000	50–70 households 20–30 families comprising 5 members
Rainwater harvesting	Tk 10,000–12,000 (3,200 liters) Tk 8,000 (3,200 liters)	1 household 1 family comprising 5 members
Deep groundwater	Tk 40,000 average Tk 35,000–40,000	50–60 households 20–30 families comprising 5 members
Household treatment	Depends on the water treatment	
Community treatment	Depends on the water treatment	

Annex 4. Government, NGOs, International Organizations Involved in Operational Responses

Screening (field test)	Screening	Well switching/ awareness	Patient identification	Patient Management	Rainwater harvesting	Pond sand filter	Piped water supply	Dug well	Deep tubewell	Evaluating of removal technologies	Water treatment	Country arsenic policy	Regional/ country arsenic network/ database
Bangladesh	DPHE BUET UNICEF NIPSOM NGO-Forum BRAC WB JICA DANIDA SIDA SDC AAN IDE Grameen Bank VERC WVB WaterAid UNDP Rotary International	DPHE MOHFW NGO-Forum WB DANIDA UNICEF BRAC AUSAID JICA SIDA SDC AAN Grameen Bank IDE Proshika VERC DOEH WVB WaterAid UNDP Rotary International	DPHE (BAMWSP) MOHFW WB NGO-Forum DGHS UNICEF WHO NIPSOM DANIDA BRAC JICA SIDA SDC AAN DCH Grameen Bank VERC UNDP Rotary International	MOHFW WB UNICEF WHO DGHS BRAC ICDDR JICA SIDA SDC AAN CARE Grameen Bank DOEH	DPHE (BAMWSP) UNICEF JICA DCH SIDA SDC DANIDA CARE ICDDR IDE WVB WaterAid Rotary International	DPHE WB DANIDA UNICEF SIDA SDC AAN Grameen Bank ICDDR Rotary International	WB NGO-Forum DANIDA UNICEF SDC BRAC	DPHE WB NGO-Forum UNICEF SDC AAN Grameen Bank WVB WaterAid Rotary International	UNIICEF DPHE DANIDA WB JICA SDC AAN WaterAid Rotary International	DANIDA WHO CIDA DFID BRAC Grameen Bank OCETA UNICEF JICA	BRAC UNICEF SIDA AAN DANID ICDDR IDE Proshika WVB Rotary International	APSU (DFID)	NAMIC (BAMWSP) ACIC AAN NGO-Forum Harvard/MIT Project BUET-ITN
India	CIDA DFID Expert Comité GOW UNICEF	UNICEF West Bengal state	CIDA DFID Expert Comité GOW UNICEF West Bengal state	UNICEF West Bengal state			UNICEF West Bengal state		UNICEF West Bengal state		UNICEF West Bengal state		
Nepal	WHO UNICEF USGS DWSS NRCS JRCS FINNIDA		NRCS DWSS/ UNICEF RWSSSP/ DIDC										

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Screening (field test)	Screening	Well switching/ awareness	Patient identification	Patient Management	Rainwater harvesting	Pond sand filter	Piped water supply	Dug well	Deep tubewell	Evaluating of removal technologies	Water treatment	Country arsenic policy	Regional/ country arsenic network/ database
	ENPHO RWSSSP/ DIDC NEWAH												
Pakistan	UNICEF												
Cambodia	WHO WB				RDI PFD						WB RDI		UNICEF/MRD
	UNICEF MRD RDI PFD										PFD UNICEF		
China	UNICEF												
Lao PDR	UNICEF ADRA												
Myanmar	WRUD UNICEF Save The Children Fund (UK)												
Taiwan													
Vietnam	EAWAG SDC HUS HUCE UNICEF								Central government	CEC CEETIA EAWAG	UNICEF-Hanoi		

Annex 5. Health Effects of Chronic Exposure to Arsenic in Drinking Water

Health effects	Symptoms	Exposure dose[a] mg kg^{-1} day^{-1}	Quantity of water drunk in 1 day (L day^{-1}); arsenic concentration in drinking water (µg L^{-1})	Reversibility of effects
Respiratory effects (ATSDR 2002)	Minor symptoms such as sore cough, sputum, rhinorrhea, and throat	0.03–0.05	2 L day^{-1} 900–1,500 µg L^{-1} 3 L day^{-1} 600–1,000 µg L^{-1} 5 L day^{-1} 360–600 µg L^{-1}	Reversible
Vascular effects (ATSDR 2002; InVS 2002; Engel and Smith 1994; Chiou and others 1997)	Blackfoot disease: progressive loss of circulation in the hands and feet leading ultimately to necrosis and gangrene	–	–	Nonreversible
	Cardiovascular arteries, arterioles, and capillarthe concentration	–	–	–
	Cerebrovascular disease	–	–	–
Gastrointestinal effects (ATSDR 2002; InVS 2002)	Clinical sign of gastrointestinal irritation are observed	0.01/0.04	2 L day^{-1} 300/1,200 µg L^{-1} 3 L day^{-1} 200/800 µg L^{-1} 5 L day^{-1} 120/480 µg L^{-1}	Reversible within short time after exposure ceases
Hematological effects (ATSDR 2002)	Anemia and leukopenia	0.05	2 L day^{-1} 1,500 µg L^{-1} 3 L day^{-1} 1,000 µg L^{-1} 5 L day^{-1} 600 µg L^{-1}	–
Hepatic effects (ATSDR 2002)	Clinical examination often reveals that the liver is swollen and tender and analysis of blood sometimes shows elevated levels of hepatic enzymes	0.01–0.1/0.06	2 L day^{-1} 300–3,000 µg L^{-1}/180 µg L^{-1} 3 L day^{-1} 200–2,000 µg L^{-1}/120 µg L^{-1} 5 L day^{-1} 120–1,200 µg L^{-1}/72 µg L^{-1}	–

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Health effects	Symptoms	Exposure dose[a] mg kg^{-1} day^{-1}	Quantity of water drunk in 1 day (L day^{-1}); arsenic concentration in drinking water (µg L^{-1})	Reversibility of effects
Renal effects (ATSDR 2002)	The kidney is relatively less sensitive to arsenic than most other organ systems	n.a.	n.a.	n.a.
Endocrinal effects (ATSDR 2002)	Diabetes	–	–	Nonreversible
Dermal effects (noncancer effects) (ATSDR 2002; InVS 2002)	Skin changes that include generalized hyperkeratosis and hyperpigmentation interspersed with small areas of hypopigmentation on the face, neck, and back	0.04 6 months to 3 years	2 L day^{-1} 1,200 µg L^{-1} 3 L day^{-1} 800 µg L^{-1} 5 L day^{-1} 480 µg L^{-1}	Nonreversible
	Skin changes that include generalized hyperkeratosis and hyperpigmentation interspersed with small areas of hypopigmentation on the face, neck, and back	0.01 5 to 15 years	2 L day^{-1} 300 µg L^{-1} 3 L day^{-1} 200 µg L^{-1} 5 L day^{-1} 120 µg L^{-1}	Nonreversible
	Skin changes that include generalized hyperkeratosis and hyperpigmentation interspersed with small areas of hypopigmentation on the face, neck, and back	–	<100 µg L^{-1}	Nonreversible
Ocular effects (ATSDR 2002)	Facial edema, generally involving the eyelids, was prominent feature of arsenic poisoning among 220 cases associated with an episode of arsenic contamination of soy sauce in Japan	0.05 2–3 weeks	2 L day^{-1} 1,500 µg L^{-1} 3 L day^{-1} 1,000 µg L^{-1} 5 L day^{-1} 600 µg L^{-1}	-

Health effects	Symptoms	Exposure dose[a] mg kg^{-1} day^{-1}	Quantity of water drunk in 1 day (L day^{-1}); arsenic concentration in drinking water (µg L^{-1})	Reversibility of effects
	Periorbital swelling was reported in people drinking contaminated well water at an approximate dose of 0.2 mg kg^{-1} for 1 week	0.2 1 week	2 L day^{-1} 6,000 µg L^{-1} 3 L day^{-1} 4,000 µg L^{-1} 5 L day^{-1} 2,400 µg L^{-1}	–
	Corneal ulceration from arsenic keratosis	–	–	Nonreversible
Body weight effects (ATSDR 2002)	Weight loss: dose and time exposure reported for one person losing 40 pounds (18 kg)	0.06 4 months	2 L day^{-1} 1,800 µg L^{-1} 3 L day^{-1} 1,200 µg L^{-1} 5 L day^{-1} 720 µg L^{-1}	–
Immunological and lymphoreticular effects (ATSDR 2002)	No study available on this issue	–	–	–
Neurological effects (ATSDR 2002)	Symmetrical peripheral neuropathy. Histological examination of nerves from affected individuals reveals a dying-back axonopathy with demelination	0.03-0.1	2 L day^{-1} 900–3,000 µg L^{-1} 3 L day^{-1} 600–2,000 µg L^{-1} 5 L day^{-1} 360–1,200 µg L^{-1}	Some recovery may occur following cessation of exposure, but this is a slow process and recovery is usually incomplete
	Fatigue, headache, dizziness, insomnia, nightmare, and numbness of the extremities	0.005	2 L day^{-1} 150 µg L^{-1}	–

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Health effects	Symptoms	Exposure dose[a] mg kg^{-1} day^{-1}	Quantity of water drunk in 1 day (L day^{-1}); arsenic concentration in drinking water (µg L^{-1})	Reversibility of effects
	were among the symptoms reported		3 L day^{-1} 100 µg L^{-1} 5 L day^{-1} 60 µg L^{-1}	
Reproductive effects	No study available on this issue	–	–	–
Development effects (ATSDR 200)	Spontaneous abortion	–	–	–
Genooxic effects (ATSDR 2002)	Chromosomal effects	–	–	–
Cancer (ATSDR 2002)	Skin cancer: multiple squamous cell carcinoma as well as multiple basal cell carcinoma	Some cases for an exposure of less than 1 year	Observed exposure in different locations that induced skin cancer: in Taiwan: 500 µg L^{-1} for 10–20 years (Smith, Lingas, and Rahman 2000)	Both types of skin cancer can be removed surgically; however, they may develop into painful lesions that may be fatal if untreated
	Internal cancer: bladder, kidney, liver, lung, and prostate		Observed exposure in different locations that induced internal cancer: in Chile: 500 µg L^{-1} for 10–20 years (Smith, Lingas, and Rahman 2000); in Cordoba: 178 µg L^{-1}	Long latency, and in Chile an increase in mortality due to internal cancer continued for 40 years after the highest exposure began

- Not available.
n.a. Not applicable.
[a.] Exposure dose: $ED = \frac{C \times DI}{BW}$

Where:
ED = exposure dose (mg kg^{-1} day^{-1})
C = exposure concentration (mg L^{-1})
DI = daily intake of water (L day^{-1})
BW = body weight (kg)

References

Ahmed, M. F. 2003. *Arsenic Contamination: Bangladesh Perspective*. Bangladesh University of Engineering & Technology. ITN-Bangladesh.

Alaerts, G. J. and N. Khouri. 2004. "Arsenic Contamination of Groundwater: Mitigation Strategies and Policies." *Hydrogeology Journal* 12:103–114.

Alam, M. G. M., E. T. Snow, and A. Tanaka. 2003. "Arsenic and Heavy Metal Contamination of Vegetables Grown in Samta Village, Bangladesh." *The Science of the Total Environment* 308:83–96.

APSU (Arsenic Policy Support Unit). 2004. *Risk Assessment of Arsenic Mitigation Options – Phase I*. Dhaka, Government of Bangladesh.

ATSDR (Agency for Toxic Substances and Disease Registry). 2002. *Toxicological Profile for Arsenic*. www.atsdr.cdc.gov/toxprofiles/tp2.html and www.atsdr.cdc.gov/toxprofiles/tp2-c2.pdf.

Bae, M., C. Watanabe, T. Inaoka, M. Sekiyama, N. Sudo, M. H. Bokul, and R. Ohtsuka. 2002. "Arsenic in Cooked Rice in Bangladesh." *The Lancet* 360.

Bates, M. N., A. H. Smith, and K. P. Cantor. 1995. "Case-Control Study of Bladder Cancer and Arsenic in Drinking Water." *Am. J. Epidemiol.* 141:523–30.

Berg, M., H. C. Tran, T. C. Nguyen, H. V. Pham, R. Schertenleib, and W. Giger. 2001. "Arsenic Contamination of Groundwater and Drinking Water in Vietnam: A Human Health Threat." *Environmental Science & Technology* 35:2621–2626.

Bhattacharya, P. 2002. "Arsenic Contaminated Groundwater from the Sedimentary Aquifers of South-East Asia." In: D. Bocanegra, H. Martinez, and E. Massones, eds., *Groundwater and Human Development* 357–363. Proc. XXXII IAH and VI ALHSUD Congress, Mar del Plata, Argentina, 2002. www.lwr.kth.se/Personal/personer/bhattacharya.prosun/Mardelplata.pdf.

BRAC (Bangladesh Rural Action Committee). 2000. *Combating a Deadly Menace, Early Experience with a Community-Based Arsenic Mitigation Project in Bangladesh*. Research Monograph Series No. 16. BRAC, Research and Evaluation Division, Dhaka, Bangladesh.

Chaudhury, N. and J. S. Hammer. 2003. *Absenteeism in Bangladesh Health Facilities*. Policy Research Working Paper WSP 3065. Water and Sanitation Program.

Chiou, H. Y., W. I. Huang, C. L. Su, S. F. Chang, Y. H. Hsu, and C. J. Chen. 1997. "Dose-Response Relationship between Prevalence of Cerebrovascular Disease and Ingested Inorganic Arsenic." *Stroke* 28:1717–23.

Das, H. K., A. K. Mitra, P. K. Sengupta, A. Hossain, F. Islam, and G. H. Rabbani. 2004. "Arsenic Concentration in Rice, Vegetables, and Fish in Bangladesh: A Preliminary Study." *Environment International* 30:383–387.

Del Razo, L. M., G. G. Garcia-Vargas, J. Garcia-Saicedo, M. F. Sanmiguel, M. Rivera, M. C. Hernandez, and M. E. Cebrian. 2002. "Arsenic Levels in Cooked Food and Assessment of Adult Dietary Intake of Arsenic in the Region of Lagunera, Mexico." *Food and Chemical Toxicology* 40:1423–1431.

Devesa, V., A. Martinez, M. A. Suner, V. Benito, D. Velez, and R. Montoro. 2001. "Kinetic Study of Transformation of Arsenic Species during Heat Treatment." *Journal of Agricultural and Food Chemistry* 49:2267–2271.

Engel, R. R. and A. H. Smith. 1994. "Arsenic in Drinking Water and Mortality from Vascular Disease: An Ecological Analysis in 30 Counties in the United States." *Arch. Environ. Health* 49:418–427.

EPA (Environmental Protection Agency, United States). 1988. *Special Report on Ingested Inorganic Arsenic. Skin Cancer; Nutritional Essentiality*. EPA, Washington, D.C.

Ferreccio, C., C. Gonzalez, V. Milosavjlevic, G. Marshall, A. M. Sancha, and A. H. Smith. 2000. "Lung Cancer and Arsenic Concentrations in Drinking Water in Chile." *Epidemiology* 11:673–679.

Friberg, L., G. F. Nordberg, and V. B. Vouk. 1986. *Handbook on the Toxicology of Metals* Volume II.

Hadi, A. 2003. "Fighting Arsenic at the Grassroots: Experience of BRAC's Community Awareness Initiative in Bangladesh." *Health Policy and Planning* 18(1):93–100.

Hanchett, S., Q. Nahar, A. Van Agthoven, C. Geers, and F. J. Revzi. 2002. "Increasing Awareness of Arsenic in Bangladesh: Lessons from a Public Education Programme." *Health Policy and Planning* 17(4):393–401.

Hoque, B.A., A. A. Mahmood, M. Quadiruzzaman, F. Khan, S. A. Ahmed, S. Shafique, M. Rahman, G. Morshed, T. Chowdhury, M. M. Rahman, F. H. Khan, M. Shahjahan, M. Begum, and M. M. Hoque. 2000. "Recommendation for Water Supply in Arsenic Mitigation: A Case Study from Bangladesh." *Public Health* 114:488–494.

Hossain, Z., M. Rahman, and M. Jakariya. *In Search of Safe Water: People's Responses to Various Safe Water Devices in Arsenic Affected Bangladesh*. Abstract. www.brac.net/red_abs_env.html.

International Water Resources Association. 2001. "Extent and Severity of Groundwater Arsenic Contamination in Bangladesh." *Water International* 26(3):370–379.

InVS (Institut de veille sanitaire). 2002. *Exposition chronique à l'arsenic hydrique en Auvergne: évaluation des risques sanitaires*. Institut de veille sanitaire et Ministère de la santé, de la famille et des personnes handicapées.

Jakaria, M. 2003. *The Use of Alternative Safe Water Options to Mitigate the Arsenic Problem in Bangladesh: Community Perspective*. Research Monograph Series No. 24. BRAC, Research and Evaluation Division, Dhaka, Bangladesh.

Kaufmann, R. B., B. H. Sorensen, M. Rahman, K. Streatfield, and L. A. Persson. 2001. *Addressing the Public Health Crisis Caused by Arsenic Contamination of Drinking Water in Bangladesh*. World Bank.

Kinniburgh, D. G. and W. Kosmus. 2002. "Arsenic Contamination in Groundwater: Some Analytical Considerations." *Talanta* 58:165–180.

Mandal, B. K. and K. T. Suzuki. 2002. "Arsenic Round the World: A Review." *Talanta* 58:201–235.

Masud, K. 2000. "Arsenic in Groundwater and Health Problems in Bangladesh." *Water Resources* 34(1):304–310.

NAISU (NGOs Arsenic Information and Support Unit). 2002. *An Overview of Arsenic Issues and Mitigation Initiatives in Bangladesh*. NGO Forum for Drinking Water Supply and Sanitation.

Ng, J. C., J. Wang, and A. Shraim. 2003. "A Global Health Problem Caused by Arsenic from Natural Sources." *Chemosphere* 52:1353–1359.

NRC (National Research Council, United States). 1999. *Arsenic in Drinking Water*. NRC.

Rahman, M. M., D. Mukherjee, M. K. Sengupta, U. K. Chowdhury, D. Lodh, C. R. Chanda, S. Roy, Q. Quamruzzaman, A. H. Milton, S. M. Shahidullah, T. Rahman, and D. Chakraboti. 2002. "Effectiveness and Reliability of Arsenic Field Testing Kits: Are the Million Dollar Screening Projects Effective or Not?" *Environ. Scien. & Technol.* 36(24):5385–94.

Roychowdhury, T., H. Tokunaga, and M. Ando. 2003. "Survey of Arsenic and Other Heavy Metals in Food Composites and Drinking Water and Estimating of Dietary Intake by the Villagers from the Arsenic-Affected Area of West Bengal, India." *The Science of the Total Environment* 308:15–35.

Roychowdhury, T., T. Uchino, H. Tokunaga, and M. Ando. 2002. "Survey of Arsenic in Food Composites from an Arsenic-Affected Area of West Bengal, India." *Food and Chemical Toxicology* 40:1611–1621.

Smedley, P. L. and D. G. Kinniburgh. 2002. "A Review of the Source, Behaviour and Distribution of Arsenic in Natural Waters." *Applied Geochemistry* 17:517–568.

Smith, A. H., E. O. Lingas, and M. Rahman. 2000. "Contamination of Drinking-Water by Arsenic in Bangladesh: A Public Health Emergency." *Bulletin of the World Health Organization* 78:9.

Smith, A. H., P. A. Lopipero, M. N. Bates, and C. M. Steinmaus. 2002. "Arsenic Epidemiology and Drinking Water Standards." *Science* 296:2145–2146. ehs.sph.berkeley.edu/superfund/publications/02_smith_1.pdf.

UNICEF (United Nations Children's Fund). 2002. *Mitigation of Arsenic Contamination in Drinking Water Sources of Myanmar: A Proposed Plan of Action*. UNICEF.

Warren, G. P., B. J. Alloway, N. W. Lepp, B. Singh, F. J. M. Bochereau, and C. Penny. 2003. "Field Trials to Assess the Uptake of Arsenic by Vegetables from Contaminated Soils and Soil Remediation with Iron Oxides." *The Science of the Total Environment* 311:19–33.

WHO (World Health Organization). 2001a. *Arsenic Contamination in Groundwater Affecting Some Countries in South-East Asia Region*. WHO Regional Committee, South-East Asia Region.

WHO (World Health Organization). 2001b. *Environmental Health Criteria 224, Arsenic and Arsenic Compounds*. Second Edition. WHO, Geneva.

World Bank. 2003a. *World Development Indicators*. www.worldbank.org/data/.

World Bank. 2003b. *Technical Support to World Bank Urban and Water Supply Unit, Hanoi, Vietnam.* Water Supply Project CR N-26-VN-ID 4830.

WSP (Water and Sanitation Program). 2000. *The West Bengal Pilot Project: Responding to Community Demands for Safe Drinking Water in an Arsenic Affected Area.* Field note. WSP.

WSP (Water and Sanitation Program). 2003. *Fighting Arsenic, Listening to Rural Communities*. Field note presenting findings from a study on willingness to pay for arsenic-free, safe drinking water in rural Bangladesh.

Yu, W., C. M. Harvey, and C. F. Harvey. 2003. "Arsenic in Groundwater in Bangladesh: A Geostatistical and Epidemiological Framework for Evaluating Health Effect and Potential Remedies." *Water Resources Research* 39:6.