

## **Chapter 8**

### **Strategies to mitigate arsenic contamination of water supply**

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### **Chapter Summary**

The preceding chapters in this volume have presented the best available knowledge on the contamination of water sources by low concentrations of arsenic, and some of the technologies and tools available for its mitigation. The objective of this chapter is to apply this knowledge in the development of a strategic framework to help planners and policy makers design effective and sustainable mitigation programmes. The discussion in the chapter draws on the lessons learned over the years in the water supply sector, and introduces institutional and economic factors in the development of this framework. While presenting general information applicable to all instances of arsenic contamination world-wide, the discussion focuses on the specific constraints faced by the poor and isolated rural communities that are most severely affected.

The discussion in the chapter begins with a brief summary of the water supply and quality situation world-wide, a review of arsenic in relation to other water quality issues, including its consequences and global scope. It then presents the following key design principles to be considered in the development arsenic mitigation strategies: inform affected people and other stakeholders in a timely fashion; take immediate steps to determine the extent and seriousness of the problem through testing; prepare separate, but compatible, emergency and long-term programme phases; prioritise reductions in arsenic intake, even if standards are not met immediately; involve all relevant sectors in a coordinated mitigation programme; involve other stakeholders in a multi-partner effort; and recognize uncertainty by using flexible programme designs.

The chapter goes on to present a series of case studies on responses to arsenic contamination of water supplies in middle- and low-income countries. The objective of the case studies is to illustrate the application of design parameters in different geographic and socio-economic contexts. The discussion concludes with a brief review of the key design principals specific to arsenic mitigation programming.

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<sup>1</sup> The views expressed in this article are the authors' and do not necessarily represent those of the World Bank or its affiliated agencies.

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## **8.1 Introduction: water quality and arsenic**

The contamination of drinking water sources by low concentrations of naturally occurring arsenic presents governments, public and private utilities, and the development community with a significant new challenge. The design and implementation of arsenic mitigation programmes must be carried out under conditions of imperfect knowledge, especially in areas where arsenic contamination affects the rural poor.

As the preceding chapters in this volume show, much is already known about the geochemical, epidemiological, clinical and mitigation technology aspects of the problem and its solutions. However, as the same chapters point out, much more needs to be learned. The goal of this chapter is to integrate the various areas of arsenic contamination knowledge into a multi-sectoral strategic framework for intervention on the ground.

Global experience with successful mitigation is, however, limited and governments (in both developing and industrialized countries) have only recently taken up the challenge of addressing the problem of naturally occurring arsenic contamination. In the absence of well-tested “models” for the definition and implementation of arsenic mitigation strategies, this chapter presents (i) key physical and socio-economic aspects that define the arsenic problem and its mitigation strategy; (ii) examples of mitigation strategies in selected countries; and (iii) a framework of lessons learned to help to prioritise the components of comprehensive mitigation strategies at the community, national and global levels. Such a prioritisation is of key importance given the limited resources available, and the urgency of the problem.

This chapter is aimed at a broad audience of professionals involved in arsenic mitigation world-wide. However, its focus is clearly on those areas that present the greatest challenge for the development of effective and sustainable strategies: poorer isolated rural communities – whether in Bangladesh, Chile or the USA.

### **8.1.1 The nature, cost and consequences of unsafe water**

Safe water for domestic use is a priority in all countries and for all people. In industrialised countries, reliable and safe water supply at a reasonable cost is taken for granted by most. In developing countries, this is not the case. Despite significant expenditures on water supply in developing countries by government and external support agencies over the last ten years – from \$10 to \$25 billion a year (WHO/UNICEF 2000; WSSCC 1999) – almost 20 per cent of the world’s population, or about one billion people, still do not have access to a safe source of water. And, as shown in Table 8.1, progress over the last 10 years has been slow.

**Table 8.1 Global water supply coverage**  
(percent of world population with access to improved water supply)

	<b>1990</b>	<b>2000</b>
<b>Urban</b>	95 %	94 %
<b>Rural</b>	66 %	71 %
<b>Total</b>	79%	82 %

(WHO/UNICEF 2000)

People themselves recognize the importance of safe water and are willing to pay for it. Households routinely spend up to three percent of their income on water, and in situations of shortages or exploitation, people are often forced to pay much more. Against intuitive expectation, the poor tend to lose out: they are often not connected to the subsidized water distribution systems, and are forced to purchase expensive water from vendors at high prices, up to twenty times higher than what their neighbours are paying (WSSCC 1999).

The water supply challenge is as much one of quantity as of quality. The value of safe and adequate water supply resides in several factors. In many regions of the world, it means bringing water closer to the house, thus dispensing women and children from the (expensive) chore of hauling it from a distant well. As discussed in Chapter Six, some estimates put the cost of hauling water at 40 billion hours of labour a year in Africa alone. In addition to reducing drudgery, easy access to water of reasonable quality can stimulate an array of small-scale commercial activities such as vegetable growing and animal husbandry. If the water supply is of good quality and replaces old contaminated wells or supplies, it also contributes towards improvements in public health. Finally, water is increasingly seen by many to be a basic human right and thus the provision of water to all, at a reasonable cost, is an imperative that must be fulfilled by governments and other duty-bearers (see, for example, Article 24 of the Convention of the Rights of the Child - United Nations 1989).

However, if that water is of dubious quality or is easily contaminated during transportation or handling, it may actually increase health risks. For example, a persistent problem confronted by water supply authorities for many years is the presence of lead. This contaminant is absent from natural water but dissolves under certain circumstances from lead pipes that until recently were the material of choice for in-house plumbing. Two thousand years ago Romans used it even for longer-distance transport of drinking water, which caused widespread lead poisoning. Arguably, that was the worst case of water poisoning until arsenic was identified as a major concern.

Such chemical contamination of water supplies remains a very serious problem. However, the most serious water quality problem is contamination by pathogens (bacteria, viruses, amoebae, helminths, etc.) which remains the major cause of morbidity and mortality. Worldwide, there are 3-3.5 million deaths per year from gastro-intestinal diseases (WHO 1995, Murray and Lopez 1996, Van der Hoek *et al.* 1999). While some of these deaths are caused by poor quality water sources, more are caused by the

contamination of water during transportation and household storage, by poor hygiene, and by the lack of sanitary means for excreta disposal.

As discussed in Chapter Five, drinking water is never pure H<sub>2</sub>O – it always contains dissolved salts, some of which are of natural origin, and others introduced through pollution or contamination. Some of these constituents are innocuous or even necessary dietary supplements, while others, even when of natural origin, can be detrimental to health. Calcium, for example, originates from calcareous rock dissolving in the aquifer. Its presence in drinking water not only adds to one’s requisite daily intake of this element, but it also forms a thin calcium carbonate layer in distribution pipelines which helps prevent the contamination of water from undesirable pipe material such as lead or copper. Fluoride, on the other hand, also originates from dissolved minerals but has different health impacts. In large concentrations it stains teeth after a few months of ingestion and if taken over prolonged periods it will lead to painful and debilitating skeletal deformation. This occurs in rural water supply systems in several countries such as India and Ghana<sup>2</sup>.

Table 8.2 attempts to summarize and compare the magnitude, effects and responses to key water supply problems worldwide. Although figures are purely indicative, they illustrate the seriousness of water supply problems.

**Table 8.2 A tentative global comparison of water-related health problems**

Problem faced	People affected <sup>1</sup> (order of magnitude)	Health effect <sup>2</sup>	Remedies available <sup>3</sup>	
			Type	Technical complexity
Limited access to drinking water	<i>Only developing countries:</i> 1.1 billion	Various	Increase coverage by replicating water supply programmes	Moderate
Gastro-intestinal diseases due to water-carried pathogens (usually related to surface water)	<i>Only developing countries:</i> 1.5 billion cases/yr 3.0 million deaths/yr (burden: 120 million DALY/yr) <sup>4</sup>	Diarrhoea, cholera, worm infestation, etc; Often fatal	Improve hygiene behaviour, improve sanitation, apply disinfection of water	Low
Lead in water supply (related to distribution pipes)	1 million	Neural and cerebral disorders	Replace lead pipes and fixtures	Low

<sup>2</sup> In contrast, health authorities in some industrialized countries allow the deliberate addition of very small quantities of fluoride because it helps arrest tooth decay, and fluoride is added to toothpaste for the same reason. Whether or not this practice should continue is the subject of some debate.

Problem faced	People affected <sup>1</sup> (order of magnitude)	Health effect <sup>2</sup>	Remedies available <sup>3</sup>	
			Type	Technical complexity
Fluoride in water supply (groundwater)	<i>Mostly in developing countries:</i> Tens of millions	Tooth decay and debilitating skeletal deformation – irreversible	Remove fluoride, <u>or</u> provide water from alternative source	Moderate
Arsenic in water supply (groundwater)	<i>Mostly in developing countries:</i> Tens of millions	Skin diseases, intestinal cancers; often fatal	Remove arsenic, <u>or</u> provide water from alternative source	Moderate to high

Notes:

1. Various data sources: 1990-1995, 1999. People affected: people suffering from disease or great inconvenience.
2. In some cases there can be more than one causative agent, but water is always a major factor
3. The institutional complexity of remedy implementation is generally high in most developing countries
4. DALY = Disability-adjusted Life Years (WHO 1995, Murray and Lopez 1996, Van der Hoek *et al.* 1999)

Three developments in the past few decades have begun to change how governments and programme planners approach the issue of water supply and contamination. First, the capacity to analyse ever smaller amounts of constituents in water has advanced substantially. In the past, concentrations could typically only be measured in the mg/L (parts per million) range, while now measurements are routinely carried out for concentrations a thousand to a million times smaller. Second, the health status and life expectancy have risen substantially across most countries (with some noticeable exceptions in Africa due to AIDS). Third, health and epidemiological research have advanced: more information is available on the nature and treatment of longer-term health effects of prolonged ingestion of low-concentration contaminants. Taken together, these developments mean that more information is available on such contaminants and their public health repercussions, there is a greater need to confront these problems, and responses are within easier reach.

### 8.1.2 Arsenic: an emerging challenge

As shown above in Table 8.2, the potential global impact of arsenic contamination on public health makes it today's top priority water quality issue, second in importance only

to the microbiological contamination of water<sup>3</sup>. Arsenic's acute toxicity has been known for thousands of years, but the enhanced capability to detect very low concentrations in water (see Chapter Two for more information on arsenic analysis) has clarified the links between arsenic in low concentrations and the incidence of some types of cancer (see Chapter Three for more information on health effects). The disease symptoms caused by arsenic toxicity are now being termed *arsenicosis*. As field workers and scientists are discovering that arsenic, even at very low concentrations, seriously affects health *if ingested over prolonged periods*, we come to conclude that arsenic contamination is much more prevalent in the world than we thought a decade ago (see Chapter One and Table 8.3 below on the global incidence of arsenic contamination of water sources). This is especially worrisome because, in contrast to many other contaminants, there are no simple and inexpensive technologies to mitigate the problem, especially in the case of isolated rural households. In Chapter Six, currently available arsenic removal technologies are analysed and compared to technologies for tapping alternative arsenic-free water sources. The overall conclusion of the analysis is that in rural areas of developing countries, source substitution is more feasible than arsenic removal in most cases.

Until recently, most sectoral programmes were centred around the lack of access to water supplies, a problem could be addressed effectively by installing comparatively cheap handpumps, dug wells or through approaches such as the introduction of communal taps. Although this required a significant financial outlay as well as institutional capacity building, the strategy is in itself reasonably well established and risk-free if implemented properly.

The emerging importance of arsenic and other naturally-occurring toxicants places a new burden on water supply authorities and policy makers. Large cities in industrialized countries, which are connected to centralized water treatment and reticulation systems, can afford the added expense and technical knowledge necessary to implement arsenic removal programmes. However, in virtually all other situations, arsenic removal is much more problematic. Cities and towns in middle-income countries, and even smaller towns in industrialised countries, find it difficult to raise the technical and financial resources to set up arsenic removal systems. In rural areas of developing countries that rely almost exclusively on handpump-equipped tubewells, the situation is much more serious. The combined repercussions of the high prevalence of arsenic contamination, the isolation and poverty of rural households in developing countries, and the high costs and relative complexity of arsenic removal systems is creating a programmatic and policy challenge on a scale never before seen in the water sector. While Table 8.3 provides some perspective on the scale of the arsenic problem, too little is known currently about the full extent of the problem and the real costs of mitigation systems to attempt an estimate of the cost of global remediation. What is clear is that the poor, and especially the rural poor, are the most vulnerable.

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<sup>3</sup> Fluoride may affect as many or more people than does arsenic (although the lack of information makes it impossible to give reliable figures – especially for arsenic). However, arsenic will likely cause far more fatalities than fluoride, and thus it is seen as being more serious. What is clear is that both contaminants cause a great deal of human suffering, and thus both should be the subject of active mitigation programmes by governments and external support agencies.



While there are many unknowns, knowledge and tools are available to help to begin to meet the challenge. The preceding chapters in this volume represent a wealth of information that can immediately be applied to assist in the design and implementation of arsenic mitigation programmes. Another knowledge base that must be tapped is the lessons learned in over thirty years of working in the sector in rural and poor environments which emphasize that success can only be achieved if the approach is locally-based, relies on the participation of truly empowered communities, and is driven by an explicit and committed demand from the community (Sara and Katz 1998, WSSCC 1999).

### 8.1.3 Arsenic contamination world-wide

The extent of the arsenic problem world-wide is as yet unknown. Before arsenic was identified as the unambiguous cause of wide-scale health problems in Bangladesh, such occurrences were considered relatively isolated. However, since the 1990s, efforts by governments, external support agencies, and academic institutions to identify other potential contamination areas have dramatically increased. Although it is far too early to definitively outline the extent of the problem globally, it is possible to present a preliminary analysis. This has been attempted in Table 8.3.

The first case of a large-scale health problem caused by naturally-occurring arsenic to be identified and recorded was in Taiwan in 1968. Chile's contamination case became recognized as such in the seventies. In the eighties, the problems in West Bengal, India, as well as in Ghana, Mexico and several other countries were documented. The largest contamination case to date is clearly Bangladesh. In the early nineties patients from western districts in Bangladesh started to cross the border to visit hospitals in Calcutta, but it was not until 1995 before official exploration of the problem was initiated. After 1997 the number of studies and initiatives rapidly grew leading to the discovery that most of the country should be considered at serious risk.

**Table 8.3 Overview of major arsenic contamination situations in the world  
(all figures are estimates collected from a large number of sources)**

Country/Region	Number of people at risk	Spatial distribution and nature of the contamination
Taiwan <i>South west and north east coastal zones</i>	200,000	Rural and small townships depending on well water of which many are contaminated at medium to high levels, some up to 1,800µg/L
China <i>Inner Mongolia Shaanxi, Xinjiang</i>	600,000 1,100,000	Dispersed incidence of low and medium and occasionally high concentrations in wells. Some regions (e.g. Baotou, I-M): high incidence of contaminated wells at high concentration

Country/Region	Number of people at risk	Spatial distribution and nature of the contamination
USA >50µg/L ( <i>esp. in Western part</i> ) >25µg/L	200,000 2,500,000	Origin of arsenic varies. Arsenic occurs primarily in groundwater and in some rivers (California) fed by geothermal sources. In mid-west and eastern plains low concentrations and disperse incidence.
Mexico <i>Lagunera Region: towns of Torreón, Matamoros, Viesca, Francisco, Madero, San Pedro, Tlahualilo, Gomez Palacio, Mapimi, Lerdo, Nazas and Ceballos (Coahuila and Durango States)</i>	400,000	An enclosed basin with primarily calcareous formations, arsenic was first found in the east corner of the aquifer, but dissipated to other sides probably under suction of groundwater pumping. Low to medium concentrations in a large number of wells in the affected zone.
Chile <i>Loa and Salado regions (north Chile): cities of Antofagasta, Colama, Chuquicamato, Salar de Atacama; Arica Province</i>	400,000	Associated with quaternary volcanism in the sparsely populated and arid Central Andean Cordilleras. Many rivers and lakes contaminated by thermal springs or dissolution of salts.
Argentina <i>Salta Province: Puna and Chaco Salteño regions</i>	200,000	Many enclosed basins with evaporative lakes ( <i>salares</i> ). In some regions contaminated shallow wells. Low to high concentrations with sometimes well above 1,000µg/L in river water (Ch: Loa R.).
Bolivia <i>Southern Altiplano (Dept. Potosí)</i>	50,000	In north-western Argentinean plains also in sedimentary soils.
Greece <i>Thessaloniki</i>	150,000	In particular aquifers. Hydrothermal origin. Low to high concentration.
Hungary	400,000	Mostly artesian wells in peaty and sedimentary soils. Low to medium concentrations.
Ghana <i>Obuasi</i>	100,000	Some shallow wells and streams contain low to medium concentrations. Gold mining, and possibly some arsenopyrite oxidation.
India <i>West Bengal State (suspected occurrence in Bihar, Gangetic and Brahmaputra plains)</i>	In 8 Districts, out of total pop. of 40 million, 5 million “live close to contaminated well”	West Bengal: Out of 17 Districts, 8 have affected wells in various zones. Within these zones half of wells (medium depth) contain arsenic at low to medium levels. Origin not conclusively established but not likely due to arsenopyrite oxidation.

Country/Region	Number of people at risk	Spatial distribution and nature of the contamination
Bangladesh <i>In most Districts</i>	80-90 million people live in affected Districts, of which 20-30 million “live close to contaminated well”	Low to high concentration in groundwater wells of 5-150m deep. Some areas have 80-100% of wells contaminated, others much less; across the affected Districts 30-40% of wells affected (>50µg/L). Aquifers appear reductive alkaline environment, with arsenic displaced from clay adsorption sites by cations such as phosphate
Vietnam <i>Red River delta region, including Hanoi</i>	Arsenic confirmed in some wells. Number of people affected unknown.	Preliminary testing in Hanoi and Red River districts has indicated a significant arsenic problem in shallow tubewells used for drinking water. There are an estimated 150,000 shallow tubewells used for drinking in these regions.

Note: 1 Low/medium/high concentration: in order of magnitude of 10-50/ 50-250/ above 250µg/L.  
2 “People at risk”: living in direct vicinity and/or actually drinking water with 50µg/L.

Large epidemiological studies conducted first in Taiwan and later in Chile suggested that what was considered the safe level (standard) at 50µg/L may have to be revised downward. As described in Chapter Five, on the basis of such studies WHO set a provisional guideline value of 10µg/L, down from an earlier figure of 50µg/L. If such downward revisions are adopted as national standards, the number of people to be considered at risk will grow per country by a factor 2 to 10, depending on the local situation<sup>4</sup>.

An additional complication in this discussion, that will only be alluded to here, is the contention that arsenic (and possibly also other dissolved salts) are significantly correlated statistically at very low concentrations with an array of non-specific diseases, especially cancers, that develop only over a very long exposure time. If this were proved to be true, it would signal a fundamentally more complex approach to include these types of “third generation” issues in the relationship between water supply and public health, as it could mean that many micro-constituents that are normally present in groundwater pose serious health risks.

## 8.2 Developing a mitigation strategy: key factors

The development of a mitigation strategy in developing and industrialized countries is guided by similar considerations, although developing countries face additional constraints on financing and on technical and administrative capacity. In both cases, a

<sup>4</sup> Currently the countries of the European Union and seven other countries have adopted standards of 10µg/L or lower. Most other countries – including Bangladesh – maintain standards of 50µg/L. See Chapter Five, and Section 8.2.3 in this chapter, for further discussion on the setting of standards for arsenic.

wide range of multi-disciplinary factors must be considered in the development of sustainable strategies.

Although all relevant disciplines must be considered in strategy development, the focus of mitigation efforts must clearly be on water. In the current large-scale public health crises related to arsenic, water is the principal cause, and water is only the “cure”.

Currently there is no specific medical therapy for the prevention or treatment of arsenicosis. As detailed in Chapter Four of this volume, medical interventions are limited to alleviating the effects of symptoms and treating diseases, such as cancer, that can ultimately result from arsenic exposure. The only way to prevent arsenicosis in the first place is to ensure that arsenic ingestion does not occur. And the first and most important step in the treatment of arsenicosis when it does occur, is also to eliminate or reduce arsenic exposure.

As discussed in Chapter Three, exposure to arsenic occurs through a variety of environmental media, including food, soil and air. However, in cases – such as in Bangladesh – where arsenic is present in water in significant concentrations, water is the principle contributor to the daily intake of arsenic in humans (see Chapters Three and Four). Therefore, efforts to reduce arsenic intake should concentrate on the provision of arsenic-free water.

Arsenic mitigation strategies have to address the conflict between the need to fill a comparatively large knowledge gap (which calls for ample study prior to action) and the need to bring in immediate remedial action (which calls for early operational and investment decisions). Any strategy will have to be conceived in a sufficiently adaptable way and will inevitably have to determine a first course of action based on a preliminary classification of the nature of the local contamination case. A rough typology is summarized below, based on a number of differentiating factors.

### **8.2.1 The hydrogeological factor**

#### *Arsenic in natural waters*

Arsenic is found in low concentrations in rocks, soils and sediments throughout the world. Under certain conditions, arsenic is released into natural waters resulting in a wide range of concentration levels. As described in Chapter One, high arsenic concentration levels are principally restricted to groundwater, with some exceptions.

Cases of large scale naturally-occurring arsenic contamination of groundwater are mainly confined to hydrogeological environments characterised by young sediment deposits (often alluvium), and low-lying flat conditions with slow-moving groundwater such as in deltaic areas (such as in much of Bangladesh). High concentrations of arsenic in groundwater also occurs in regions where sulphide oxidation has occurred, in geothermal areas, and as a result of mining activity. Geothermal activity and mining can also result in serious – but usually localised – occurrences of surface water contamination.

See Chapter One for a more comprehensive discussion of the sources of arsenic in natural waters.

### *The variability of arsenic contamination*

Hard rock and calcareous formations carry groundwater in fissures and cracks. The available water, therefore, is unevenly distributed in the formation. Loamy or sandy sediments, on the other hand, tend to be more homogeneously porous to water, and water is more evenly distributed. These sediments, however, were not deposited in even layers one atop the other. As rivers eroded and silted up, sediment packets of varying composition and granulometry were deposited and shifted along. Therefore, their arsenic content and release potential may vary, even within distances as short as 10 m. This situation is encountered, for example, in Bangladesh, where handpumps draw water with very different arsenic levels even though they are located in each other's vicinity in a corner of a village (see also Chapter One). In other places, such as Inner Mongolia, China, most wells are arsenic-free, but some "hot spots" exist with very high concentrations.

In some areas arsenic contamination varies significantly, and more predictably, with depth. In Bangladesh, for example, almost all wells testing positive for arsenic are in aquifers shallower than 150m (see Figure 6.1 in Chapter Six). However, as discussed further below, deeper wells may become contaminated over time.

The implications of this high degree of variability in the context of mitigation strategy development is that all wells must be tested separately for arsenic. On the other hand, it also means that in a given area there is a good chance that some wells are uncontaminated and can be used as safe sources of drinking water.

### *Availability of an alternative water sources*

The mitigation strategy for arsenic contamination can entail arsenic removal, but because of the costs and operational complexity of the technologies involved, it is often preferable to seek an alternative water source of good quality. This is especially the case, as discussed earlier, for rural areas of developing countries. Options include surface water, harvested rain water, or arsenic-free groundwater. The latter, if available, is generally the preferable option. While appropriate in some cases, surface water generally requires extensive treatment and rainwater harvesting, while feasible, is usually technically difficult to achieve for the provision of year round water supplies. See Chapter Six for a comprehensive analysis of alternative sources of drinking water.

Arsenic-free groundwater is either transferred from a more distant source, or, as in the case of Bangladesh, may be abstracted from arsenic-free groundwater "pockets" or deeper aquifers in the neighbourhood of the contaminated well. In the latter case, where arsenic contamination is a widespread phenomenon, the arsenic concentration in the new wells should be checked at least annually because "safe" wells could gradually start aspirating contaminated layers. This has happened in Mexico (see below) and was also

reported in West Bengal, where deep wells, originally arsenic-free, over time started to draw from contaminated layers. In addition, if deep wells are improperly grouted (sealed), arsenic-contaminated water from shallow aquifers may directly enter the well.

### **8.2.2 The water supply technology factor**

As discussed earlier, two technical choices are available to planners of arsenic mitigation programmes: remove arsenic from existing contaminated sources of water, or develop and deliver alternative, arsenic-free water sources. The decision will be based on a variety of factors and will vary from case to case. In Section 6.4 of Chapter Six, a protocol for the selection of an arsenic-free water supply technology (both arsenic removal and source substitution technologies) is developed, based on a set of five technical criteria and six socio-economic criteria. The discussion below presents the key points to be considered in the development of mitigation strategies.

#### *The availability of feasible technical options for arsenic removal*

Arsenic is difficult to remove in simple, inexpensive ways, especially at concentrations above 100µg/L. Most technological research has been geared at either lowering the already low concentrations that are typically found in Western Europe (20-80µg/L) by optimising common treatment processes such as coagulation with iron or alum, or at more advanced and expensive processes that are typically destined for low flow rates, such as ion exchange and adsorption.

What is to be considered feasible depends on a variety of factors such as: (1) the existing basic water supply system, e.g. whether it is an “urban” piped system with centralized treatment, or one consisting of handpumps shared by a number of families as is typical in many rural environments; (2) the amount of arsenic in the water and the percentage that needs to be removed – the smaller the size of, and the more basic this system, the more unlikely it is that arsenic removal is feasible; (3) the level of technical and managerial capacity available to install and maintain the treatment units; and (4) the level of income and the willingness to contribute financially to operation and maintenance of the equipment – usually communities fail to maintain systems that are installed for free by the government. The importance of such considerations implies that any strategy for arsenic mitigation will need to be site-specific to avoid the seduction of looking for a “magic bullet” that will solve the problem in all instances.

#### *The availability of feasible alternative water sources*

Given that arsenic removal is prohibitively expensive in many circumstances, much will depend on the availability of feasible alternative water sources. Again, feasibility must be judged against several criteria, among which the capability and the willingness to pay of the households are critical. Also, the quality of these alternative sources must be thoroughly checked.

In Bangladesh, for instance, several regions have easy access to surface water ponds. It is argued that resorting to these ponds would be quite feasible, as Bangladeshis traditionally drew water from a protected pond before the general conversion to groundwater in the seventies. However, nowadays many of these ponds have been unprotected or derelict, collecting waste and sewage. Other ponds are doused with chemicals and used for fish cultivation, and are also unsuitable as a drinking water source. In addition, the population pressure in the rural areas has increased drastically thus rendering these ponds a much less obvious alternative. Re-introducing the protection of communal ponds will require a substantial change of attitude in the rural population. It runs the risk of reversing the recent progress in significantly reducing the mortality and morbidity caused by waterborne pathogens.

### 8.2.3 The health factor

#### *Uncertainties in the epidemiology of arsenicosis*

With only few incidences thoroughly investigated over longer time horizons (several decades) the chronic health effects of long-term exposure to small dosages seem adequately documented to confirm that health risks do exist, but there remains ample scope for debate on the risk calculation. Nonetheless, from the previously generally agreed 50µg/L, the standard for the maximum allowable arsenic concentration in water has been lowered to 10µg/L by a number of countries and, as a guideline, by WHO. In 2000, the US EPA lowered its standard from 50 to 10 µg/L, but it had contemplated 8 or even 5 µg/L (it has since revoked this new standard, see below). These lower standards, however, would have implied what some consider a prohibitively large increase in the cost of water treatment and/or abstraction of alternative safe water sources, and analysis showed that this burden would have affected primarily the smaller rural water supply systems. Physical chemical laws dictate that it is always much less expensive to remove the first 90% of the contamination (when at high concentrations) than the last 10% (which corresponds to very low concentrations). At the same time, the validity of extrapolating epidemiological data to effects at much lower concentration levels is contested notably by the American water utilities (Black et al., 1999). The fact that in 2001 the new US administration revoked the 10µg/L US standard only months after it was first announced illustrates—in part—the lack of consensus on what the safe level of arsenic in drinking water should ultimately be.

These point raise two issues:

- Rich countries that already have achieved near-100% coverage of their population with good water supply may find it expensive to meet the new standards, but for poorer countries the cost is prohibitive and they must therefore prioritise and phase their financial effort. For example, in Bangladesh the World Bank-supported Arsenic Mitigation – Water Supply programme recognizes the long-term goal of meeting the Bangladeshi standard (50µg/L) in each household, but in the intermediate emergency period aims at approaches to reduce by as much as

possible the excess intake of arsenic, even though this not always guarantees that the standard is achieved immediately.

- The levels of intake that are to be considered safe vary with, among others, body weight, average water ingestion, nutritional condition, and predisposition of individuals. For example, Bangladeshi agricultural labourers working under the sun drink 3-4L of water daily, against 1-2L for the average American. Equally important, the trajectory of arsenic from the underground water into the body varies a lot and can introduce physical chemical phenomena that neutralize or exacerbate the toxic effect. In Bangladesh, for instance, which witnesses almost country-wide poisoning of groundwater, there is not always a correlation between the typical level of the arsenic concentration as measured in the groundwater and the incidence of disease. Preliminary observation suggests that areas south-east of Dhaka (such as Laksmipur and Chandpur, see Fig. 8.2) experience among the highest concentrations (well into the 100s and even 1,000 $\mu$ g/L) yet few casualties are reported. Areas north-west of Dhaka, on the other hand, such as Ruppur and Bagga, face concentrations 5-10 times lower, yet morbidity and mortality are higher. This discrepancy has not been explained so far. Differences in nutrition, or different water source use patterns (some people may make more use of surface water for drinking or cooking), may also play a role. This region also has groundwater with high dissolved iron levels, which spurs women to always let pitchers with water stand for a night after which the iron precipitate is decanted – precipitate that is known to effectively bind arsenic (see also Box 8.2, below). Epidemiological results, therefore, need to account for such effects, for these can help target the strategy significantly better.

#### *Arsenicosis as priority in the local health picture*

The image and reputation of arsenicosis as a slow poison may distort a candid assessment of the burden the disease imposes on a population. As discussed above and detailed in Chapter Four, the best treatment strategy when symptoms start emerging is the provision of arsenic-free water. Planners and affected populations should be made aware of the fact that introducing arsenic-free drinking and cooking water is the first and most important single step to be taken: this will reduce the chances of escalating health problems amongst affected people, and may, in some cases, reverse the symptoms and some of the clinical manifestations of arsenic toxicity. The fact that there is some symptomatic reversibility in the disease, at least in the early stages, may allow more time for appropriate preventive action than acute emergencies, such as, diarrhoeal diseases. Nonetheless, in most cases arsenic poisoning is a localized phenomenon which makes the larger population vulnerable to slow recognition of the problem, and inadequate response by national health authorities.

At the same time, mitigation strategies should be careful to not overemphasize the arsenic burden, because it risks a possible neglect of other important health threats. For instance, substituting arsenic contaminated groundwater with water from ponds or shallow dug



wells in poor rural areas may actually *reduce* the quality of health in that region because of the potential to increase the incidence of gastro-intestinal diseases<sup>5</sup>.

#### *Need for parallel health/curative efforts*

Although arsenic-free water is in many respects the best “antidote” for the majority of people at risk or even for those in the first stages of intoxication, in some of the population arsenic may have already damaged their health irreversibly. For these people a separate strategy for adequate curative effort should be developed, comprising at least identification and diagnostic capabilities at the local level, referral systems, and provision of treatment, possibly at more centralized locations. In addition, programmes to enhance the health and nutritional situation of the local population are likely to render people more resilient and may lower the incidence or seriousness of the health impact. However, as described in Chapter Four, the treatment of advanced stages of arsenicosis is still in its infancy. Nonetheless, the very fact that a diagnostic system is in place already helps to restore confidence, and, importantly, it is the only way to provide an accurate assessment of the health impact, which in turn is essential to develop an effective strategy. Until now, the problem assessment is very often founded on arsenic concentration levels in the water, or on the number of patients with visible (skin) defects. Yet, the most serious health impacts concern internal tumours that are not easily detected or are not recognizable as related to arsenic.

### **8.2.4 The economic and institutional factor**

#### *Capacities and institutional strengths required at the levels of households, local governments and utilities, and national governments*

Industrialized countries dispose of elaborate institutional capacities, and finance and cost recovery mechanisms, that allow them to (1) identify and assess arsenic poisoning cases at an early stage; (2) set up a working health support system; (3) conduct high-quality research to come up with technically feasible solutions for arsenic removal or provision of alternative sources for water; (4) involve both local government in proper local planning, and national government in policy making, standard setting, monitoring and providing financial stimulus; (5) depend on water supply utilities to construct, operate and maintain all requisite infrastructure, and recover all costs; (6) rely on a private sector capable of delivering a wide array of quality services and goods; and (7) depend on households that are generally well educated about environment and water quality issues, and about the necessity to pay the utility fees and taxes to sustain operations. Developing countries, on the other hand, though perhaps stronger on the institutional “quality” of

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<sup>5</sup> Although reliable data is scarce, in Bangladesh the mortality rate due to diarrhoeal diseases is estimated at 120,000-200,000 per annum, of which possibly half can be attributed to drinking of pathogen-contaminated water (Dewier and Islam 1997). The best estimates so far for arsenicosis mortality suggest an order of magnitude of 20,000-40,000. These figures are by themselves insufficient to warrant a definitive prioritization, but they do highlight the need for careful consideration of priorities.

family and community cohesion, commonly experience serious weaknesses in one or more of the above institutional characteristics.

### *Mitigation costs and affordability*

The provision of “safe” drinking water close to home has been and still is a major policy priority in most developing countries (see above). Bangladesh, like many other developing countries, has made great progress towards achieving the goal of full water supply coverage over the past three decades, drastically lowering the incidence of diarrhoeal diseases and contributing to economic growth. The cost of providing the basic service level of one handpump per 10-20 households is high (at US\$100-300), but over the past decade income has risen enough to allow families to pay for the pump installation themselves. A vigorous private sector of manufacturers, drillers and pump mechanics has sprung up to meet this demand. Clearly, the financial and technical-institutional capacity of the Bangladeshi society has grown commensurate to this type of technology. Arsenic-removal systems, and alternative water supply, however, are options that pose new constraints for either rural or urban settings: they are decidedly more costly than regular water supply; and they require higher levels of technical-managerial capacity. As discussed earlier, even in the United States—a rich country with strong institutions—a debate was sparked during the revision review process of the arsenic standard. Although larger cities would be able to afford and operate the required technologies, smaller towns and rural communities would face serious financial and operational problems in conforming to a standard of 10µg/L or below

### *The “rural” and “urban” agendas*

From the above discussion it is clear that small and rural communities are at particular risk. They tend to be less wealthy than urban ones, and typically cannot benefit from large economies of scale to finance water treatment processes. Rural households, especially in developing countries, commonly rely on their own handpump-fitted private well, or a shared local well. Installing arsenic removal filters on such handpumps present a number of technical and institutional problems, and this has yet to be attempted on any significant scale. Bringing in alternative water, by piping, tanker or by walking to a more distant source, adds considerably to the economic cost. In addition, rural communities in developing countries have less developed local institutions such as local governments or water utilities, and transaction costs are higher to have the private sector involved as service provider. Mitigation strategies must allow for this difference in the environment.

Another factor to consider is the disposal of spent arsenic-laden filter media (or sludge water) from arsenic removal systems. In centralized systems this media can be relatively easily collected and stored in protected landfill sites. It becomes significantly more difficult when dealing with a large number of scattered household or community systems in rural areas, especially in countries with poor transportation networks<sup>6</sup>.

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<sup>6</sup> There is some debate on whether the disposal of spent media in rural areas constitutes a potential threat to public health or not. See Box 6.8 in Chapter Six for more information.

## **8.3 Mitigation Strategies**

Arsenic contamination of drinking water supplies occurs in high, middle and low-income countries. Wherever it arises, the technical parameters which form the basis for developing mitigation strategies remain the same. Thus, there are general facets of mitigation programme design which will be common in all programmes and countries. However, the social, economic, geographic and cultural differences between affected countries dictate differences in approaches and strategic choices in the final shape of the programme design. To best illustrate both the similarities and differences in mitigation programming, this section is divided into three parts: a description of a general approach to programming design, and case studies of specific approaches from middle and lower income countries.

Readers with an interest in more information on how socio-economic factors specifically influence technology choice in the development of arsenic mitigation strategies should also read Section 6.4 of Chapter Six.

### **8.3.1 A general approach to developing a mitigation strategy**

Arsenic contamination occurs in a wide variety of forms, as so does the societal context in which the contamination must be addressed. A check-list of strategic issues to consider in developing site-specific interventions is suggested in Table 8.4 below. If recent experience gained from arsenic mitigation efforts to date is combined with the experience obtained from addressing related sectoral problems and other “crisis” situations (water supply, health emergencies, disaster relief, etc.), a set of general principles for the design of arsenic mitigation strategy can be devised, as outlined below.

#### *Inform affected people and other stakeholders in a timely fashion*

In most cases the arsenic problem was recognized first by health officials alerted by the unusual high incidence of skin diseases. In many of these situations little remedial action ensued and often the local affected communities were not informed about these developments. This may seem inappropriate in hindsight, but a lack of understanding of the problem’s significance and of the underlying phenomena, and a traditional reluctance to work across government sectors commonly contributed to the inertia. In some countries this even led to a period where government officials denied the existence of a problem.

A transparency policy engenders its own set of difficulties. A risk exists that people will panic, although prolonged absence of information is even more certain to stir panic. Also, government and other officials may feel vulnerable due to accountability issues. However, wide consensus exists that only informed people can make proper choices, and that successful strategies critically depend on the fact that the affected people and other stakeholders “buy into” the proposed programmes. This cooperation is especially

important in the arsenic case because a successful strategy depends on a series of actions regarding water use and hygiene, and many of them are of a strictly behavioural nature within the affected communities and households and well out of control of government.

Therefore, any strategy must include, on a priority basis, a comprehensive and participatory information programme stressing immediate actions that can be taken by affected communities and that allows feedback from these communities to programme managers in government and civil society organizations. Such programmes typically include radio and TV broadcasts, contributions to newspapers and other publications, public hearings, activities geared at schools and youth organizations, involvement of religious institutions, staging of plays, facilitation of interpersonal communication, and other methodologies. Box 8.4 in this chapter briefly outlines the communication strategy employed by the government and UNICEF in Bangladesh as an example. Detailed recommendations for understanding, developing and implementing communication programmes for arsenic mitigation are covered in Chapter Seven.

### **Box 8.1** **The Right to Information**

The provision of comprehensive information about arsenic to affected communities is not just a good programming strategy. Access to information is a basic human right that governments and other duty-bearers are obligated to fulfil.

This right has been stated and reaffirmed in different ways in several widely ratified international conventions and charters beginning with Article 19 of the Universal Declaration of Human Rights, and including Article 17 of the Convention of the Rights of the Child and Article 15 of the Declaration on Social Progress and Development (United Nations, 1948, 1969 and 1989).

### **End Box**

*Testing: take immediate steps to determine the extent and seriousness of the problem*

Due to the high degree of spatial variability of arsenic contamination of groundwater (as described earlier), the field testing of wells for arsenic is a programming priority. This is especially true in countries – such as Bangladesh – where people rely on individual handpump-equipped tubewells for their drinking and cooking needs. Without testing it is difficult to judge the real scale of the problem at the national level and thus it is difficult to design a rational programme strategy. At the community level, it is impossible for people to make informed choices about how to use and share existing sources of water – or to construct new systems – if the extent of the problem is not known.

In reality, field testing in low income countries has proven to be extremely problematic. The development of the inexpensive, robust and user-friendly arsenic test kits that are essential for a successful field testing programme has been slower than expected. This means that programmes have been designed and launched – necessarily due to the urgency of the confronting the problem – without the benefit of the key data that a field

test programme could provide. See Chapter Two for more information about arsenic measurement and analysis and the field and laboratory levels.

After wells have been tested once, they will have to be re-tested again on a periodic basis due to the possibility of migration of arsenic across aquifers as described in Chapter One and elsewhere. Periodic arsenic testing as part of a national groundwater surveillance programme (also see Section 5.6 of Chapter Five) should be an integral component in long-term national arsenic and groundwater quality programmes.

*Prepare separate, but compatible, emergency and long-term programme phases*

The very fact that the contamination is detected by the presence of patients suggests that rapid action is required. However, the characteristics of emergency and sustainable programmes differ considerably, and both phases must be clearly distinguished. Rapid action programmes can rely on extensive subsidies and on executive agencies that are good at effective fast delivery of a service or product (such as identification of contaminated wells, and emergency relief and distribution of safe water or medicine). Longer term programmes that seek to establish a sustainable system to address the problem require a more time-consuming process of institutional capacity building with a focus on local authorities and organizations. The process includes the development and definition of financial and managerial commitments on the part of these institutions and the full participation of all stakeholders in the final programmatic framework. It is now widely recognized that emergency relief is most effective when it is not in contradiction with the sustainability requirements of long-term mitigation strategies. Local conditions should be the predominant determining factor on how the emergency and the longer-term programmes are made to co-exist.

*Prioritise reductions in arsenic intake, even if standards are not met immediately*

All other factors being equal, people drinking water with higher concentrations of arsenic will more likely contract arsenicosis. It is thus an imperative, from both a strategic and ethical perspective, to focus immediate relief efforts on those communities with higher levels of arsenic concentrations in their domestic water supplies. Such efforts, given time and resource constraints, may focus on reducing arsenic levels to some interim standard above the national standard, but far below the elevated levels found in many sources. Such a strategy, by seeking out communities in arsenic “hot spots” and providing immediate solutions, will ensure that resources are used to help the greatest number of affected people.

As emergency interventions develop into longer-term programmes, and as additional financial resources are raised to fund such programmes, arsenic mitigation efforts can be re-directed towards ensuring that national standards are met for all domestic water sources.

*Involve all relevant sectors in a coordinated mitigation programme*

Effective strategies that relate to health and behavioural habits require, by definition, a multi-sectoral approach. Such an approach necessitates the coordinated participation of government agencies from different sectors and different levels of government, as well as other institutions and stakeholders from civil society:

- Typically, health agencies are the first to be confronted with the effects of contamination. When the public health problem is water-related, normally the agencies responsible for water supply and/or for water resources management should play a leadership role given their mandate and their access to expertise and finance. These agencies are also most familiar with the administrative procedures for commissioning of works. Although local conditions may impose specific constraints, a typical distribution of roles among key stakeholders in an arsenic contamination strategy is as follows. At the local level, the urban or rural municipality or district is the prime actor in the provision of water supply and similar services. It is also the most appropriate level from which to coordinate the activities in different sectors (water supply, health, information, etc.). In the rural context, sufficiently strong technical and financial capacities are often still absent at this local-government level, and little experience may exist regarding sustained provision of such services. In such cases, strong village- or community-based water organizations may better represent the community, and may have more success in successfully implementing cost sharing programmes. Whether at the level of local government, or in the form of a village based organization or water committee, it is essential that a “water utility” in whatever form can operate in close reciprocal relationship with its “customers”. This implies that the utility can operate in a financially and managerially autonomous fashion, that it derives at least the operation and maintenance costs from local tariffs, and that it is seen as fully accountable to its community, with all major decisions transparent and subject to scrutiny. Where there are potential gains in economies of scale, local utilities should cooperate.
- At the central level, leadership roles need to be fulfilled with respect to development of overall policy and priority-setting, conflict resolution among regions and main stakeholders, initiation, coordination and supervision of the national arsenic mitigation programmes, development of scientific support mechanisms of high quality, and provision of financial support. Such support can take the form, for example, of a partial subsidy of the capital costs of arsenic treatment works, or for offsetting those additional costs to water supply that are caused by the arsenic.
- The Ministry of Health and regional health authorities are commonly the first to be informed about an arsenic contamination case, for the simple reason that until now arsenic is not one of the key contaminants for which water utilities monitor water supply and wells routinely (despite the fact that arsenic has been a listed toxic substance in WHO literature and guidelines since the 1950s – see Chapter Five). The health sectors, therefore, need to be better equipped and prepared to identify and diagnose arsenicosis. This information should be channelled into a national steering or coordination committee that would allow other sectoral agencies to take action. Similarly, health agencies need to keep full records on incidence and possible causation of the arsenicosis to detect trends over time, as the contamination may spread and as populations may become more or less vulnerable, and to ensure detailed

follow-up of the nation's mitigation programmes (see Chapter Two for a more detailed discussion on public health surveillance for arsenicosis). In coordination with the medical system, curative approaches for arsenicosis must be put in place as well as systems to minimize any secondary effects (such as skin infections – see also Chapter Four). Finally, the Ministry (or the environmental regulatory agency) usually retains the critical task of setting and monitoring drinking water quality standards, as described more fully in Chapter Five.

- Typically the Ministry of Water Resources, Public Works or Local Government is the national agency responsible for supervising and assisting the water supply utilities. In most countries, therefore, these ministries commonly take the lead in establishing an arsenic mitigation strategy where it concerns water supply.
- The Ministry of Agriculture plays the key role in the activities geared at the agricultural impact of the presence of arsenic in irrigation water. This relates to essentially three issues: (1) arsenic may enter the food chain; (2) arsenic may inhibit proper crop growth<sup>7</sup>; and (3) heavy groundwater abstraction discharges large quantities of arsenic on irrigated fields and may change the hydrochemistry of the aquifer<sup>8</sup>. Typically the agricultural agencies have a strong stake in accurate understanding of groundwater flow and availability.
- The geological services, and the academic research establishment must play a key role in a development effort with such a high science and technology input requirements. Geological services are needed to evaluate the extent and progress of the contamination problem, develop and test hypotheses on the source of the arsenic, conduct research and modelling on feasible mitigation interventions, and provide reliable information to private citizens and entities. Many of these knowledge-based responsibilities are also shared by universities and research centres. An important element is the role that the scientific community plays in a country's policy-making or day-to-day life. Where strong academic and scientific societies exist, there is openness in sharing of information and more confident confrontation of new and emerging problems such as the arsenic contamination. As detailed in Chapter One, outstanding questions on the hydrogeology and geochemistry of arsenic mobilisation and contamination may very well outnumber known facts, underscoring the need for such organizations and for information sharing.
- As full partners, the international community can share its knowledge, technology, funding and technical assistance. However, past mistakes have to be addressed squarely and national and local stakeholders have to be in control of the design and implementation of development efforts such as for arsenic mitigation.

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<sup>7</sup> Arsenic, for example, substantially lowers the productivity of rice plants at concentrations above 50µg/L (causing "straight-stem" disease due to small rice grains).

<sup>8</sup> Likely much of the arsenic will be adsorbed onto oxidized iron particles when discharged under aerobic conditions. However, as biomass is collected on the ground and starts rotting in the topsoil during subsequent seasons, the arsenic may be released again.

*Involve other stakeholders (communities, NGOs, private sector) in a multi-partner effort*

As described above, the nature of arsenic contamination necessitates well-coordinated contributions from different partners both in and outside of government. Especially when dealing with dispersed and poorly informed rural communities, the success of a strategy depends on the cooperation of civil society organizations, the willingness of stakeholders to participate in an effective way, and on the role of the private sector to provide a wide array of services to the communities.

*Recognize the uncertainty: design for flexibility*

Few water supply programmes present so many uncertainties up-front, yet maintain such a high sense of urgency. The uncertainties pertain to the hydrogeology, the epidemiology, the water supply and treatment options, and the behavioural and institutional aspects at the national and community level. The latter is especially of concern in countries, such as Bangladesh, where rural communities have not had a history of dealing with complex and expensive water supply systems. Will these communities be willing and able to organize themselves and provide finance to properly and sustainably manage new water systems? Clearly, any mitigation strategy will have to rely on high-quality studies – thereby avoiding delays – but still be able to drastically improve the focus and effectiveness of the next phases in the implementation programme. Any programme should minimize up-front costs to contain expenses in case the strategy must be amended. Strong links must be built with a scientific advisory committee, or equivalent, to attract the best analytical and research capacity, and develop a high-quality data base of all relevant parameters, that will be maintained as long as the arsenic problem exists, and that will be able to detect changes in the situation.

**Table 8.4 Check-list on key issues in the development of an integrated strategy for arsenic mitigation**

<b>Determinants of the gravity of arsenic contamination</b>	<b>Possible strategic intervention</b>
<i>Measurable, physical symptoms of arsenic contamination:</i> Extent and intensity of contamination, sources and valences of As, etc.	<ul style="list-style-type: none"> <li>▪ National data collection;</li> <li>▪ Improvement of field and laboratory protocols for As measurement.</li> </ul>
<i>Economic impact of As contamination:</i> Health, environment, agriculture, etc.	<ul style="list-style-type: none"> <li>▪ Integration of information on the impact of As on key economic/social sectors to establish priorities and appraise solutions.</li> </ul>
<i>On-site actions that promote As ingestion directly or through bio-accumulation:</i> This is especially important where large numbers of affected rural people rely on contaminated water for themselves, their animals and their crops.	<ul style="list-style-type: none"> <li>▪ Provision of on-demand testing of individual wells;</li> <li>▪ Provision of information on health and emergency alternative sources of water;</li> <li>▪ Long term technical assistance to decrease reliance on As contaminated sources.</li> </ul>



<b>Determinants of the gravity of arsenic contamination</b>	<b>Possible strategic intervention</b>
<i>Off-site actions that promote As contamination:</i> Rates of pumping and overall flows of groundwater in one place could be affecting the quality of water of individual farmers in another place.	<ul style="list-style-type: none"> <li>▪ Research on and modelling of groundwater dynamics; disseminate data;</li> <li>▪ Include As (and overall water quality parameters) in the routine environmental impact evaluation of water development projects.</li> </ul>
<i>Level of knowledge of people and institutions:</i> In many cases, there are simple on-site solutions that can be introduced, in others, more research is needed. (see, for example, Box 8.2)	<ul style="list-style-type: none"> <li>▪ With information on the extent of the problem, disseminate existing technologies;</li> <li>▪ Prioritise research and dissemination themes for capacity building of key actors in an As situation.</li> </ul>
<i>Legal, institutional, policy framework:</i> In most cases, groundwater management is left to individual users, with government maintaining overall stewardship.	<ul style="list-style-type: none"> <li>▪ Clarify the roles and empower institutions that can address groundwater quality issues, starting with local-level institutions;</li> <li>▪ Integrate As mitigation in overall water supply, water management, health, agriculture and environmental strategies.</li> </ul>
<i>International considerations:</i> For developing countries, external assistance often constitutes the bulk of investment into specific sectors, such as water supply.	<ul style="list-style-type: none"> <li>▪ Include As in routine environmental impact assessment of water-related investments;</li> <li>▪ Promote local ownership of interventions by keeping the national and local stakeholders in the “driver’s seat” at all time in planning, designing, implementing and monitoring of As mitigation.</li> <li>▪ Promote international networking in support of As mitigation.</li> </ul>

## **Box 8.2**

### **Dug wells: Traditional knowledge for arsenic mitigation in West Bengal, India**

Dr. Dipankar Chakraborti (Jadavpur University, Calcutta, India) has been one of the earliest voices around the world for recognizing the epidemic nature of arsenic as a naturally occurring contaminant. His teams have now more than 13 years of field experience in West Bengal and Bangladesh. One of their observations was initially puzzling but arguably points to one of the more cost-effective water treatment methods for the millions living in rural areas with arsenic in their groundwater.

In West Bengali villages known to have arsenic in the groundwater, virtually no *arsenicosis* incidences were found where people drank mainly from the common dug wells, which are shallow hand-excavated wells. However, *arsenicosis* was found in people who drank from deeper tubewell water in the same areas, although dug well water was often as rich in arsenic as tubewell water. Field and lab work suggested a correlation between the iron content of dug well water and the lower levels of arsenic in the water that got eventually consumed. It could be surmised that dug wells, with their higher exposure to air, allow iron and arsenic to co-precipitate out of the water.

Dr. Chakraborti thinks this is consistent with traditional behaviour in rural West Bengal: Bengalis say “*Jal basi kore khabi*” which translates into “drink water after letting it settle overnight”. Such a simple

procedure, accepted as local wisdom, would indeed allow to lower arsenic levels in water (if iron is present at significant levels) and have it settle out at the bottom of the water jar. Filtration of the supernatant water with a simple home strainer, readily available in rural households, would further enhance separation of the settled arsenic from the drinking water (see Chapter Six for a comprehensive analysis on the pros and cons of all arsenic removal techniques, including the one described here).

## **End Box**

### **8.3.2 Arsenic mitigation strategy in middle-income countries: Mexico and Chile**

#### *Background*

Local health authorities were the first to detect arsenicosis in both countries in the sixties and seventies. However, it took several years before recognition grew that this was indeed arsenic-induced, that it was related to water contamination, and that many more casualties would be caused if no rapid remedial action was taken.

In Mexico, one of the principal areas where the contamination was found to be occurring was the Lagunera Region in the country's mountainous centre, north of the capital and straddling the Coahuila and Durango States. The Region is a large enclosed basin with a small population of approximately 400,000 (Table 8.2; Fig. 8.1) and intensive agricultural activity, notably grain production. Crops are irrigated from groundwater wells and from water reservoirs on rivers on the outskirts of the region.

In Chile, contamination was reported in the northern provinces of the sparsely populated central Cordilleras and the nearby coastal plain. This region has a few larger towns and cities (notably Antofagasta) in the coastal plain. In addition, several dozen small hamlets, each with a population of approximately one hundred, are located more inland. The region has numerous local depressions that collect the scarce run-off and from where the water evaporates leaving salt layers (*salares*). The rural communities are very poor and remote in relation to the towns.

#### *Mitigation strategies*

Although local health authorities had been aware since 1964 of the arsenicosis incidence in the Lagunera Region (Mexico), little action was taken. In 1986-87 the (then) Ministry of Agriculture and Water Resources took the lead in drafting a mitigation strategy together with the Ministries of Health and of Urban Construction (the latter typically being responsible for water supply). A three-phase strategy was developed:

1. Emergency response of a temporary nature:
  - Make the situation public and explain to the local communities the implications of the contamination and the government's actions;
  - Provide rapid health response to identify patients, provide information, and offer medical assistance where feasible;

- Bring in reverse osmosis treatment plants mounted on trucks to treat local well water and distribute free of cost at selected locations in the towns;
  - Initiate studies regarding the origin and possible dissipation of arsenic contamination in the groundwater.
2. Sustainable mid-term solution: Finance a pipeline (*acuaducto*) to convey safe groundwater from distant wells to the affected towns, from where it can be tapped by the local utilities. (Early studies had shown that the arsenic originated from one corner of the aquifer and was dissipating to other zones under the influence of water abstraction. The continuing groundwater use would after several years cause these safe wells to become contaminated as well.)
  3. Longer-term sustainable solution: If the *acuaducto* starts to yield contaminated groundwater, the initial pipeline design would allow an extension to tap water from surface water reservoirs in the mountains.

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**Insert Figure 8.1 Map of the Lagunera Region in Mexico**

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The *acuaducto*'s length is approximately 100km and involved substantial expenditure. Over negotiations with the local governments that normally are responsible for water supply, the national government agreed to finance the construction of the new wells, pumping stations and pipeline given the exceptional nature of the water supply situation. The local authorities agreed to (1) set up a joint regional corporation (owned by the two States involved and the municipalities) to operate and maintain the *acuaducto*, and to ensure local cost recovery for this through tariffs; and (2) assume the responsibility for investment, operation and maintenance for the distribution of the water starting from the respective abstraction points on the *acuaducto*. The national government transferred ownership of the infrastructure to this new corporation. The main operational cost of the *acuaducto* is for pumping. Isolated farms that were not connected to the local distribution networks would have to purchase drinking water from the utility by container or tanker.

In Chile, the affected region is arid and sparsely populated. The water supply task rests solely with local governments. The major affected city of Antofagasta (population: 200,000) draws water from the Toconce River via a 300km pipeline. Most rivers in this region, as well as in the Arica Province, have elevated arsenic concentrations. Some six conventional treatment plants for surface water are operational in the region serving a total population of approximately 330,000 and have been upgraded to remove arsenic to the threshold of 50µg/L. Although originally this goal proved difficult to achieve, optimised operation has recently allowed the production of water at this quality level in the larger plants. However, performance remains variable. Treatment typically consists of oxidation with chlorine followed by direct filtration or flocculation with alum, and final filtration. However, the small rural communities of *atacameño* settlements of 100-400 people are too dispersed and too poor to be easily reached. Experiments with small-scale on-site treatment have been initiated using iron sponges as adsorbent and double sand filters, but no satisfactory solution has been achieved so far. Interestingly, mummified

bodies of native Indians have been discovered in the mountain range, dating back several centuries, and many of these show high arsenic levels in their tissue.

### **8.3.3 Arsenic mitigation strategy in low-income countries: case studies from Bangladesh**

The characteristics of the arsenic contamination in Bangladesh differ substantially from those in the two Latin American countries described above. Bangladesh is decidedly poorer, with a GNP per capita of US\$270 compared to US\$3,700-5,000 for Chile and Mexico. Its population density is very high, and most people live in small to medium sized villages, with populations generally ranging from 500-3,000.

Most of the country is a flat deltaic area with soft soils and high water table. This allowed the successful introduction of shallow and medium-deep handpump-equipped tubewells since the seventies. Current estimates indicate that there are now between 2.5 and 5 million such wells used for domestic water supply and an additional 5 to 6 million wells drilled for irrigation purposes but also used, at least in part, for drinking water (DCH/Uposhon 2000; UNICEF 2000a; WHO 1999). The majority of the tubewells were drilled by the private sector, and a vigorous market exists of part suppliers, well drill crews and mechanics.

Bangladesh's government structure is still very centralized. However, since 1997, new legislation is gradually promoting the devolution of power to local levels, although it is unclear to what extent the lowest administrative unit (the Gram Parishad, which is an association of one to three villages) will be enabled to assume decision-making powers. Local authorities are very weak and many have no prior experience with infrastructure and with water service delivery.

The contamination is nearly country-wide (Fig. 8.2) with up to four-fifths of the territory sitting atop contaminated aquifers. The size of the affected area, the very large numbers of people "at risk", and the often very high arsenic concentrations (well above 500µg/L) make it decidedly a priority concern at the national scale. An important complicating factor is that the contamination degree varies widely from one spot to another, and one well may be contaminated whilst another one at 10m distance yields good quality water (although it is reported that good wells can turn bad over time, as discussed earlier in this chapter).

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#### **Insert Figure 8.2      Map of Bangladesh**

Caption: "Map of Bangladesh indicating the distribution and intensity of contamination. The data are compiled from a variety of reliable well studies conducted by the Government, NGOs and others. The map reflects the status of the understanding in 1998; new information broadly confirms this pattern (World Bank 1998)."

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Preliminary reports of arsenicosis emerged in the early nineties in the western Districts bordering West Bengal in India (where widespread arsenic contamination of groundwater was just being recognised). First field tests on randomly sampled wells, notably by the Dhaka Community Hospital and Jadavpur University's School of Environmental Studies, and later by the Department of Public Health Engineering, confirmed an unexpectedly large incidence of arsenic contamination. In 1996 the Minister of Health and Family Welfare took the initiative to set up an inter-ministerial committee to review the situation. WHO fielded a number of individual experts to help assess the situation but it soon transpired that the dimension and complexity of the problem necessitated a broader effort.

The two case studies presented below describe some of the programmes currently being implemented in Bangladesh. The first case study is on the Bangladesh Arsenic Mitigation – Water Supply Program (BAMWSP), a large national-level programme implemented by the government of Bangladesh and financed primarily through a World Bank loan. The second case-study describes a smaller “action research” initiative supported by WHO and UNICEF in Bangladesh, financed by the United Nations Foundation.

The case studies presented here describe only a portion of ongoing activities in Bangladesh. There are many external support agencies, local and international NGOs, academic institutions, and branches of government active in arsenic mitigation activities in the country. A recent WaterAid report lists 35 such organizations (Jones 2000).

It should also be noted that this plethora of agencies and initiatives, while welcomed and necessary, can create its own set of problems. The coordination of mitigation strategy development and implementation in Bangladesh has been problematic. One of the purposes of the BAMWSP programme as described below was to assist the Government of Bangladesh in developing the capacity and institutional infrastructure to effectively coordinate all mitigation activities in the country. This has been more difficult than originally envisaged and, to date, efforts are still ongoing by governments and a number of agencies (including WHO) to set-up effective coordination mechanisms.

### **Case Study: The World Bank-supported Bangladesh Arsenic Mitigation –Water Supply Program (BAMWSP)**

In 1997 the government requested the World Bank to assist in working out a national strategy and in assisting in the coordination of the international cooperation effort.

When the programme was being designed, the degree of urgency was inversely proportional to the amount of information on hand. Very limited insight existed into the extent, cause, and impact of the contamination; no simple technological answers were available nor did the country have much experience with low-cost water supply systems beyond shallow handpumps. Millions of measurements of arsenic would have to be conducted in the field, yet world-wide only the first steps were being taken to develop a

cheap and reliable field test kit. In 1997, not even a reliable estimate of the number of wells existed. Most difficult of all, the local nature of the contamination would force the teams to work closely with the local affected communities, yet there was no proven methodology in Bangladesh to develop sustainable service delivery at the grass-roots level. Under such challenging circumstances, a phased approach was opted for, with plenty of room for “learning-by-doing”.

In 1998 the government adopted a national strategy for implementing the programme, for which support was provided through a soft credit from the World Bank complemented with a grant from the Swiss Development Corporation. Various coherent support and complementary activities, all as grants, from the British, Danish, Dutch and Japanese Governments, as well as from UNDP, WHO, UNICEF, IAEA (and others) were also taken into account in the programme development process. A number of major NGOs, both international and national, were also active preparing their own responses, and some participated in the strategy development and implementation of the World Bank-supported programme.

Partly to start understanding the precise nature of the problem at field level, and partly to provide field assistance, a preliminary emergency initiative was conducted in 1997-1998 to complement the planned World Bank-supported programme. With UNDP funding, a national health agency, the Dhaka Community Hospital and NGOs held one-week-per village extensive visits, first in 200 and thereafter in 600 villages that were carefully selected. The local health situation and all wells were analysed and recorded, and basic information and medicine given. This field study confirmed earlier hypotheses about the high incidence of contamination, and the commitment of villagers to deal with it.

The main principles and components of the strategy developed are as follows (programme policies and illustrative technical, institutional and financial details of project implementation are compiled in a manual; BAMWSP 1998):

1. The consensus among experts is that it is priority to provide arsenic-free drinking water, partly because it is a *preventive* measure, and partly because in many arsenicosis patients clean water flushes out excess arsenic from the body and may reverse disease symptoms, to a certain extent (see e.g. WHO 1997). Therefore, the strategy concentrates in the first instance on water service delivery rather than strictly on health care. The main initiative, thus, is placed with the Ministry of Local Government, Rural Development and Cooperatives, as well as with local authorities, village communities and NGOs to the extent that they play a role in water supply. Nonetheless, a second separate activity concerns health care and curative action and falls under the purview of the health authorities and medical colleges. The Minister of Health remains the Chair of the overarching policy coordinating committee.
2. With most Bangladeshi households fully depending on their handpump-equipped well for water, these households have, at least, the right to be informed about (1) the current status of their own well, (2) the availability of an alternative safe water source in their immediate vicinity, (3) basic rules to minimize the exposure and the health impact, and (4) the quality of their well water in the further future through the provision of an arrangement that would allow annual re-testing. Providing this

information can be done in a reasonably expedient way, and it would arguably be a very cost-effective first approach to reduce the net intake of arsenic. Similarly, such transparency would help prevent panic given that rumours on the contamination were spreading quickly.

3. The most appropriate strategy would be to lower as quickly as possible the net arsenic intake by applying low-cost, simple approaches, even if these do not immediately meet the drinking water standard. Such a strategy is justified by the fact that the sheer scale of the contamination and the intrinsic cost of mitigation technologies pose an excessive financial burden on households and government, and because the arsenicosis risk is reduced more or less proportionally to arsenic intake. For example, a backyard flocculation-and-filtration double bucket system costs less than US\$5 and can be reliably operated in households; removing only 80% of the arsenic, it would lower the concentration of well water with 300 to 60 $\mu$ g/L – still above the standard of 50, but now with much reduced health risk.
4. The first four-year implementation phase includes a nation-wide rapid emergency component that comprises (1) the testing of all wells (at the same time recording these wells in a GIS data base), (2) a rapid health survey with referral for diagnosis and treatment, (3) the provision of short-term relief where feasible, and (4) nation-wide as well as village-based information (see the second Bangladesh case study below, and Box 8.4 for a description of national information campaigns). A second, parallel component aims at providing more sustainable alternative water supply options, which may imply some construction and procurement. This component will progress more slowly as it has to build community demand and participation at village level. Possibly 10-15 years may be necessary to cover all affected villages, and identification of the “hot spots” (in terms of local health impact) would be eminently important.
5. In towns, the programme helps local authorities (that normally would already exist but may have limited experience with utility functions) to set up water quality monitoring, and design and finance remedial actions. Utilities will be supported and trained to improve service delivery and cost recovery to ensure sustainable operation.
6. In the rural areas as well as in the urban fringes, community-based organizations will be set up. In close coordination with the local official administrations, these will decide on their local strategies, select their alternative water supply technology, have a design formulated, conduct local procurement, and carry out and/or supervise construction. They will take charge and finance the operation and maintenance of any infrastructure and, importantly, finance part of the investment as well. The programme finances the other part of the investment. Water supply alternatives include rainwater harvesting, ponds, dug wells and shrouded wells, deep groundwater, and where feasible, arsenic removal techniques. Many of these options will also require sanitation to prevent recurrence of diarrhoeal diseases, since the alternative water source would be again surface or pond water that are very liable to bacterial contamination. An uncommon partnership between local and national government, and NGOs, has been forged to implement the programme. Local NGOs

act as the direct partners for the local authorities and for the communities when these form their community-based organizations and devise and implement their strategy.

7. One of the unknowns in the strategy is whether communities and local authorities will be strong and accountable enough to assume the task of sustaining the delivery of water services within the community. These doubts notwithstanding, the programme design assumes that greater effectiveness and sustainability will be achieved by keeping management and implementation at the local level as much as possible. Compelling arguments that support working directly through the communities are (1) positive experiences with service delivery in projects in neighbouring countries; (2) the demonstrated ability of Bangladeshi communities and private entrepreneurs to develop a vigorous handpump market without government support; and (3) the unusually high awareness and concern among the population, at least in some parts of the country, that arsenic is dangerous to health. Nonetheless, the programme's strategy is flexible enough to allow simultaneous piloting and implementation of different institutional approaches and then replication of what works best.
8. A major constraint in optimising the strategy is the lack of information on the epidemiology (see, for example, Chapter Three), the extent and causes of the arsenic release and the related hydrogeology (see Chapter One for details of outstanding questions and further research needs), the institutional arrangements and behavioural aspects of the water service, and the appropriate low-cost water supply technologies<sup>9</sup>. To address this, two supportive entities are being set up. The National Arsenic Mitigation Information Centre to collect, interpret and disseminate all relevant hydrogeological, water quality, health and socio-economic data. Secondly, a Technology Assessment Group of experts was established to review technology options, allocate funds to local researchers to undertake specified studies, and provide academic input in the policy development. Several bilateral donors fund specific fundamental studies, such as on the geochemistry of the problem, the development of a cheap and reliable field test kit, and on the epidemiological dimension.
9. The strategy provides substantial capacity building efforts, especially to assist communities and local authorities in developing their skills as well as their internal administrative procedures. In addition, training for medical colleges on arsenic diagnosis and referral is included. Finally, a substantial effort is made to inform and educate the population at large through a variety of the media channels about appropriate ways of dealing with arsenic.

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<sup>9</sup> As described in Chapter Six, there is no shortage of information on alternative water supply technologies in general, but there are questions about applying the technologies in Bangladesh. In addition, there are many outstanding questions on arsenic removal technologies.



## Case Study: WHO- and UNICEF-supported Programmes in Bangladesh<sup>10</sup>

UNICEF and WHO have been key partners with the Government of Bangladesh in the area of rural water supply and sanitation for several decades. As such, these two agencies have been at the forefront of national arsenic research and response programmes since the crisis emerged. Both agencies are supporting a number of ongoing initiatives in the area of arsenic in Bangladesh with a variety of partners<sup>11</sup>.

For the purposes of this case study, a new WHO/UNICEF joint project will be described. The fact that it has recently been developed (2000/2001), has allowed it to capitalize on lessons learned from other arsenic mitigation projects in Bangladesh, and can thus be considered to be a kind of state-of-the-art project design for arsenic research and mitigation in the context of Bangladesh. The most important input to the design of the WHO/UNICEF joint project are the lessons learned from previous initiative, notably from the DPHE/UNICEF Action Research Project described below.

### *DPHE/UNICEF Action Research Project: Lessons Learned*

The DPHE/UNICEF arsenic mitigation Action Research Project was implemented in 1999 and 2000 in five upazillas<sup>12</sup>. The project's achievements at the field level included the testing of over 100,000 tubewells, the construction of over 500 alternative water systems (deep tubewells, pond sand filters, rainwater harvesters and dug wells), the distribution of 14,000 home arsenic removal filters (four different household filter designs were used in the project) and the construction of 3 community filter plants. The project also identified more than 900 arsenic patients and provided palliative care for symptom relief.

The DPHE/UNICEF project provided a valuable set of information and data on the effectiveness, real costs and sustainability of technology choices for arsenic mitigation under actual field conditions. Several technologies—notably household arsenic filters—were modified as the project progressed in response to field-level conditions. The project also reinforced expectations of planners that there is no single “best” technology for arsenic removal or alternative water supply in Bangladesh – rather it helped to narrow and improve the set of effective, acceptable and inexpensive technologies available for application by local authorities to respond to local conditions.

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<sup>10</sup> Information sources for this case study include UNF 2000, WHO/UNICEF 2001 and other WHO and UNICEF sources.

<sup>11</sup> UNICEF, for example, is working with the Department of Public Health Engineering (DPHE) in the area of water supply at the national level, and has supported DPHE's large-scale arsenic testing programme (UNICEF 2000). UNICEF has also helped to develop a national arsenic communication campaign (see Box 8.2). WHO has supported the Government of Bangladesh's response to the arsenic situation since 1994, primarily through the provision of technical expertise. WHO is also active, with a variety of local partners, in the area of research and development of alternative water supply systems. WHO's global role as the focal point for water quality issues within the UN system, and the publisher of the Guidelines for Drinking-water Quality, has allowed it to act as a kind of knowledge base for all agencies working in the area of arsenic in Bangladesh (WHO 1999).

<sup>12</sup> Sub-district administrative divisions, previously known as thanas.

Perhaps the most important lessons learned from the UNICEF/DPHE Action Research project were at the institutional level. Like the World Bank-funded BAMWSP project described in the case study above, the design of this project emphasized the importance of working at the local level. However, instead of attempting to work directly with a large number of small, local NGOs as was envisaged by the BAMWSP project, the Action Research project designers instead opted for forging partnerships with four large national NGOs. Each of the NGOs chosen (BRAC, Grameen Bank, Dhaka Community Hospital and Rotary) had extensive country-wide networks of extension workers with well-established systems of supervision and feedback. This proved to be a successful model, allowing the project to immediately concentrate on pursuing objectives rather than spending time establishing new institutional infrastructures necessary for working with larger numbers of scattered NGOs.

On the other hand, the project did not go far enough to establish and formalize links with local government authorities at the upazilla and village levels. This is now seen to be potentially detrimental to long-term sustainability. In addition, no system of community contribution towards the construction, maintenance and operation of the new water supply systems was put in place. This, also, would impede the eventual expansion of the model to the national level.

*Building Community-based arsenic mitigation response capacity in three sub-districts: an outline of the WHO/UNICEF joint project*

The United Nations Foundation has funded the two-year project, which will be implemented by DPHE, the Directorate General of Health Services (DGHS), WHO and UNICEF in cooperation with the World Bank-funded BAMWSP project, local governments in the sub-districts (upazillas), and six national NGOs and research institutions.<sup>13</sup> In terms of funding and size, the project is an order of magnitude smaller than the World Bank-supported project (roughly \$2.5 million versus \$42 million) and is restricted to a small area of the country. As such, the project's key objective is not to mitigate the arsenic problem on a national scale, but to develop an approach to arsenic mitigation at the local level that can ultimately be used by larger government and external support agency initiatives. However, the project is not a study, it is "action research" that will, as it develops strategic approaches, also help communities provide solutions to the arsenic public health problem in the project area.

A key concept behind the project is the promotion of empowerment for local action for arsenic mitigation. As such, it builds on recent Government of Bangladesh movements in this direction as described, in part, in the above case study. It also is in accordance with government's 1998 National Policy for Safe Water and Sanitation which emphasizes greater user participation through local governments. As described earlier in this chapter and elsewhere in this volume (notably in Chapters One and Six), there is a high degree of spatial variability of arsenic contamination of tubewells in Bangladesh and technological

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<sup>13</sup> National Institute for Preventive and Social Medicine (NIPSOM), Bangladesh Rural Advancement Committee (BRAC), Grameen Bank, Dhaka Community Hospital, NGO Forum for Drinking Water Supply and Sanitation, ICDDR,B – Centre for Health and Population Research.

and institutional solutions must also differ from area to area. Thus, an approach that emphasizes local solutions to local problems is highly suited to this issue.

The project will promote an integrated approach including awareness raising, water supply testing, choosing and constructing alternative safe water sources, and patient identification. Capacity-building efforts will be focussed on the upazilla and sub-upazilla government authorities for the provision of communication, advice and action in arsenic-affected villages.

At the institutional level, the project's design reflects the lessons learned from the DPHE/UNICEF Action Research Project described above. Planning and implementation of activities at the upazilla and sub-upazilla level will be the responsibility of local government authorities supported by DPHE, UNICEF's field-based staff, and national NGOs. Technology choice will be made on the basis of local conditions and preferences out of a changing pool of acceptable technologies defined by DPHE, WHO and UNICEF based on the results of the Action Research Project, ongoing research and information from other agencies active in the sector.

Activities implemented at the upazilla-level range from awareness-creation and tubewell testing to monitoring and evaluation (see Box 8.3). The roles and responsibilities of all implementing partners differ from activity to activity and are pre-determined in the project design. The focus of the project on capacity building is reflected in the number of activities that include training and the development of institutional infrastructure. The design of upazilla-level activities also stress the need to monitor, evaluate and document lessons learned during the implementation period.

### **Box 8.3**

#### **Joint WHO/UNICEF Project: List of Upazilla-level activities**

1. Training / awareness creation for NGO, DPHE, Local govt., Health complex staff, communication campaign counterparts
2. Carry out baseline survey / study
3. Formation of upazilla arsenic mitigation committee
4. Training on use of communication materials and implementation of communication campaign
5. Training for tube well testing
6. Blanket tubewell testing
7. Arsenicosis patient identification and management
8. Formation of Village Arsenic Mitigation Committees
9. Provision of technical advice on alternative water supply technologies (with emphasis on gender considerations) and community selection of appropriate technologies
10. Training on construction of alternative safe water technologies
11. Construction or distribution of alternative water supply technologies
12. Training for caretakers on alternative water supply technology maintenance
13. Monitoring of alternative water supply technologies
14. Evaluation: changes in baseline data, assessment of effectiveness
15. Consolidation and dissemination of knowledge generated and lessons learnt

(source: WHO/UNICEF 2001)

### **End Box**

The multi-faceted nature of the arsenic crisis as described earlier in this chapter was a key factor in the design of the joint project. The design was careful to include implementing partners and cooperating institutions that could bring a variety of skills and experience to project implementation. NGO partners were chosen not only for their field presence, but for the mix of skills and experience they offer which include: primary health care, grass-roots mobilisation, micro-credit, epidemiological research, and rural water supply. Similarly, both the public health engineering (DPHE) and health (DGHS) wings of government are participating in the project. On the same note, the implementing partners (WHO and UNICEF) will operate within their comparative competencies in the management of the project: UNICEF will use its water supply and communication experience, and its field presence in Bangladesh, to take the lead on managing the upazilla-level project activities, while WHO will take primary responsibility for the management and implementation of the research component of the project described below.

The project's research component has two objectives: one, to support and inform implementation of the project itself, and two, to expand the general knowledge base on arsenic and mitigation, for the use in other projects in Bangladesh and elsewhere. The project will sponsor studies and research on the causes and effects of arsenicosis. Topics to be studied will include case detection and management, and suspected associated co-factors such as nutrition and dose-response relationships. The research activities will be undertaken in collaboration with national institutions (notably, the Centre for Health and Population Research) and in cooperation with complementary research activities at the national and global levels.

#### **Box 8.4: Information, education and communication in addressing Bangladesh's arsenic crisis**

*Community involvement* is a fundamental aspect of arsenic mitigation in Bangladesh. The population is largely rural and supplied with water through community or private tubewells. Lessons in Bangladesh and elsewhere had already shown that these conditions dictate a community-based approach—in planning, design and implementation—for the success and long-term sustainability of overall interventions in water supply and sanitation.

*Mass awareness* techniques that had already proven successful in dramatically reducing the incidence of water-borne microbial diseases are being re-introduced; this time to confront a “new”, chemical, contaminant: dissolved arsenic in groundwater.

*Historically unique challenges* are, however, constraining the effectiveness of mass awareness campaigns targeting arsenic contamination. Previous water-quality related campaigns such as during the Water Decade have targeted well-understood human-induced water degradation processes (e.g. faecal contamination) with the use of readily available mitigation interventions (oral re-hydration saline, low-cost tubewells). In the case of arsenic, however, the source of contamination is natural and continuous--arsenic is colour-, odour- and taste-less-- and the technology for field testing and treating of arsenic is still under development. Under these circumstances, incomplete or erroneous information could lead to panic, misinformation, and a worsening of the situation, such as, for example, rural people reverting to highly microbially-contaminated surface water once they know that their underground water source is contaminated with arsenic.

**Communication initiatives:** Arsenic contamination in Bangladesh has triggered an unprecedented level of mobilization of local NGOs, government organizations and external support agencies. Among the early and most active organizations in Bangladesh that focused on the preparation and evaluation of community-level communication strategies were the Dhaka Community Hospital, the Bangladesh Rural Advancement Committee, and Integrated Services for Childhood. With external support from UNICEF and in collaboration with central and local government agencies (Directorate of Public Health Engineering, the Ministry of Health and others) communication packages have been prepared and are being widely disseminated to communities. In particular, in December 1999 a the UNICEF-designed National Communication Campaign on Arsenic Mitigation was launched, aiming at the dissemination of available material on key aspects of the problem. Because of the gravity and geographical extent of the problem, the communication campaign has to rely on the widest range possible of NGO participation in collaboration with 5 levels of decentralized government entities. As in other aspects of arsenic mitigation, coordination among such a large number of institutions is a major challenge. See the case study in Chapter Seven for a complete description of the development of the national communication campaign.

**Technical Parameters:** Given the knowledge gaps and degree of uncertainty in the area of arsenic, it is of key importance to ensure that the technical information that form the basis for communication messages are clearly defined. In Bangladesh, a small group of international experts was convened to define and come to a consensus on a set of basic technical information that was then used as the technical underpinning for the development of the national campaign. See the annex of Chapter Seven for the full text of these technical parameters.

**Vital Information** that is being disseminated through pamphlets, site visits and mass media outlets, include the following:

- Test water for arsenic;
- Do not drink from contaminated wells (usually marked with red paint);
- Improve diet to include protein, vitamin supplement etc.;
- Collect rain water for drinking and cooking;
- Explanation/demonstration of currently available low-cost technologies for: household and community-level arsenic removal, surface water filters for microbial/sediment treatment, and rain water harvesting;
- Explanation of external symptoms of arsenicosis;
- Information on options for referral of affected people to health personnel.

**From Development to Dissemination:** As new research refines technical knowledge about arsenic, and as arsenic mitigation strategies evolve, it is important that messages disseminated through communication campaigns to communities be updated on a regular basis. It is therefore essential to revise technical parameters for communication through networks of researchers, planners and field workers. Such networks are being established in Bangladesh and will require concerted and long-term support to ensure their effectiveness in changing the situation on the ground.

(From Chapter Seven of this volume and various reports by UNICEF-Dhaka, e.g. UNICEF 2000b, and other agencies)

## **End Box**

## **8.4 Conclusions**

It is now clear that the chronic effects of low concentrations of arsenic in drinking water have been underestimated. Large populations in various parts of the world are exposed to levels of arsenic above safe limits. The full epidemiological implications of arsenic contamination are only now emerging, and it is likely that over the coming decade more arsenicosis cases will be identified.

This adds substantially to the complexity of water service provision. Arsenic removal is – in general – expensive and technically difficult, and alternative water sources may either be unavailable or can pose their own serious health risks (such as increased diarrhoeal disease incidence). Such complexity in the provision of safe water supply is especially acute in rural and poor urban areas, and also in regions where arsenic levels are relatively high (above 200µg/L).

Importantly, the degree of complexity and the commensurate expenditure greatly depend on what is considered to be a “safe” standard for drinking water. Technological and financial complexity of arsenic mitigation skyrocket once standards are lowered below 50µg/L. It is doubtful that setting standards at the safest possible level is an effective health policy for developing countries because the resulting costly arsenic mitigation is likely to divert funds from other health related programmes that may have a greater impact on public health. Whatever national standards are, it is of key importance that priority be given to measures that reduce the absolute intake of arsenic as much as possible, even if the standard is not met immediately.

Arsenic contamination can occur in a wide variety of geographic and socio-economic contexts. Therefore, any mitigation strategy will have to be tailored to suit the local hydrogeological, institutional and financial situation. That said, it is also important to not develop national or sub-national arsenic mitigation programmes in isolation. Many of the lessons learned over the years in water supply programme implementation are highly applicable in situations where arsenic is a factor. One of the most important of these lessons is that to achieve effectiveness and sustainability communities must be fully involved in the planning and development of water supply systems, and they must be fully committed to take an appropriate level of managerial and financial responsibility for the construction, operation and maintenance of those systems. Often, such institutional and social factors are a greater determinant of the ultimate success of water supply programmes than are technological factors. Similarly, real, long-term health benefits do not automatically flow from new water supply systems, they must be accompanied by communication and education programmes that promote behavioural change.

The government plays a critical role. It must develop national plans of action, and ensure that mitigation efforts by external support agencies and civil society organisations are implemented in a coordinated fashion. Governments must also ensure that the affected population is fully and properly informed about the situation, so that people themselves can immediately initiate precautionary measures. Governments should work with academic and research institutions to improve the understanding of the causes, extent and impact of arsenic contamination. Most importantly, governments should immediately provide emergency relief as far as is feasible, and, in many cases, provide financial support for the construction of mitigation facilities if these prove beyond the means the communities.

It is now abundantly clear that groundwater should be carefully analysed for arsenic before it is used as a source for domestic water supply systems – or even for irrigation. Although the ultimate global impact of arsenic contamination on public health is as yet

unknown, there is little doubt that it constitutes a serious threat and arsenic analysis should thus be included in water quality monitoring surveillance programmes. Perhaps more importantly, the arsenic crisis in Bangladesh and elsewhere has highlighted the need for including comprehensive water quality surveys as integral components of all water supply programmes. Finally, the experience from arsenic has indicated that additional research is necessary on the potential health effects of other inorganic elements present in low concentrations in water sources.

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