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Abstract
Bangladesh was the scene for one of the developing world's great public health successes, the reduction of morbidity and mortality from water-borne disease by converting the drinking water source for 94 percent of the rural population to tubewells. Now, that success is being endangered by the discovery that 20 million people are in great danger and another 20 million in less danger of being poisoned by arsenic contamination from tubewell water. This article reports findings from the first national probability survey of the rural population and a census of tubewells aimed at looking at the social, demographic and epidemiological context of the crisis. The survey covered 3,780 households reporting on the water source and development of arsenicosis among over 20,000 people. The tubewell census covered 9,174 tubewells. The article presents data on the respondents' history of drinking tubewell water, knowledge of the arsenic problem, identification of arsenicosis, as well as the impact upon them of the national campaign, the testing of tubewells, and their subsequent sources of water. Suggestions are made for a more effective program.

Introduction
Demographers have long been concerned with the great mortality crises, but by the 1970s these were regarded as a matter for historical demography (see, for instance, Charbonneau 1979), at least in the sense that they gave rise to demographic crisis as evidenced by substantial declines in population. The belated realization of the scale of China's 1958-61 famine and of the continued march of the sub-Saharan AIDS epidemic may lead to a revised perspective, although Watkins and Menken (1985) have pointed out that in an era of high natural increase even the Chinese famine put only a temporary brake on population growth. This may be a short-term situation even in the developing world because the fertility transition is reducing the potential for population growth. Already projections are showing the possibility of the AIDS epidemic resulting in population decrease in such countries of advanced fertility decline as Zimbabwe, Botswana and Guyana (Stanecki and Way 1997: 23-24).

The next potential major mortality threat to emerge is that from arsenic in drinking water in Bangladesh and the eastern part of West Bengal, India. This article will focus on Bangladesh, where the potential for massive increases in mortality have been compared with the African AIDS epidemic. It reports a national survey, the first of its kind, designed to examine the impact of arsenic poisoning, and attempts to mitigate it, on the population; and to explain the apparent slowness of authorities and of the population to react to the problem.

Background
Arsenic poisoning (termed *arsenicosis* when symptoms are present) is confined to the Ganges - Brahmaputra - Meghna delta where a hydro-geological phenomenon as yet not fully understood has resulted in arsenic (much of it dangerously soluble inorganic arsenic) being present at fairly shallow depths in the soil. It is not present on the surface, and for millennia arsenic - free water was taken from rivers, ponds and hand-dug wells and tanks. Only a fraction of India's population, around 40 million, live on the alluvial land of the delta, but around 80 percent of Bangladesh's 130 million inhabitants do so.

The abundance of water on the alluvial soils of the delta accounts for one of the world's most intensive concentrations of population, but the same water, partly because of the population density, was a major carrier of waterborne disease. Cholera and dysentery were common and until the last few decades were the major killers of children with ten percent or more babies dying of diarrhea. In the deltaic conditions it was impossible to prevent fecal matter and accompanying pathogens from entering the water and the water table. Seemingly miraculously, it turned out that there was a fairly easy way of obtaining microbiologically pure water and that was through tubewells - tubes bored down 10-200 meters with water raised by hand pumps.. Some tubewells had been sunk in British India for agricultural purposes as early as the 1920s, but it was only in the late 1960s and early 1970s that governments and the international community saw them as an alternative to the frustrating attempts to purify ponds, discover means of immunizing against waterborne disease, and develop safe latrines. This new direction was astonishingly successful, and has undoubtedly prevented many deaths from diarrheal disease. It was not at first realized that this move would be so successful and the first tubewells were encouraged or provided by government initiatives, often with international assistance (especially from UNICEF). But the example was followed by individual farming families, many men learnt how to drill deeply and quickly, and the least costly materials were used. The soil was close to ideal for drilling. The situation was reached where most shallow tubewells could be installed in two days at a cost that nearly all farming families could afford. By the early 1990s there were 2.5 million tubewells and 95 percent of rural Bangladeshis were using water from this source: around half were drinking water from private tubewells, the majority of which were in the courtyards of their own *baris* (a group of buildings usually occupied by relatives) (Mitra and Associates 1992:14, 41-44). Most of the rest lived in places like the Chittagong Hill Tracts where there was no underlying aquifer, or on deltaic islands near the coast where the shallow aquifer had been penetrated by seawater. The mass conversion to tubewells was not propelled solely by a desire for hygiene but also by the convenience of having a nearby source of water often in the family's yard. Indeed, of those conveniences that affluent societies have brought right to the house, such as water, electricity, gas and telephones, it was, for most families, the first to arrive.

It took a long time to establish that there might be a major problem and it is taking longer still for those involved to be convinced of this. The presence of arsenic in West Bengal tubewell water was first suggested in 1978 but it did not become an important issue for a further decade (Chatterjee *et al.* 1995: 643). It was first detected in Bangladesh tubewells in 1993 and the first identification of persons with physical manifestations of arsenicosis occurred in 1994 (Ahmad *et al.* 1999: 187). The World Health Organisation (WHO) was in touch with the problem from 1994 and in 1997 declared it to be a "major public health issue" which should be dealt with on an "emergency basis" (United Nations 1999: 34; Yamamura 1999: 1,5). In 1998 the World Bank approved a credit of US $32.4 million for dealing with the problem. Even now, the central difficulty is the "poor availability of reliable information" (Yamamura 1999: 6).

There is scant epidemiological information on the effect of chronic exposure to low levels of arsenic on morbidity or mortality. In 1958, WHO published *International Sanitary Regulations* which defined good drinking water, and revised versions appeared in 1965 and 1978, followed by *Guidelines for Drinking Water Quality* in 1984. In 1958 the suggested maximum level for arsenic in drinking water was placed at 0.2mg/liter, based on Latin American reported experience that this level appeared to give no problem and no rise in cancer deaths. In 1963 the level was, perhaps cautiously, lowered to 0.05mg/liter and is now 0.01mg/liter. WHO (1996: 162) justified the choice of a guideline of 0.01mg/liter by mathematically modelling the reported Taiwan experience from this and lower concentrations of arsenic in water, estimating that this concentration, when compared with arsenic-free water, would, over the first seventy years of life, yield one more case of cancer for every 1,667 persons. The assumptions underlying this estimate are somewhat controversial. With higher arsenic concentrations this rise in risk was likely to be curvilinear but there is little evidence of how great the increase would be. This risk is unlikely to be equally shared: It would be higher for the malnourished and those with Hepatitis B, and twice as great for men as for women (Mazumder *et al.* 1998:874; WHO 1999:1).

The number of arsenic-contaminated wells and the number of people at risk have been variously estimated by extrapolating from studies which tended to select sites reported to be arsenic-infected. Reports have suggested that over 50 million people are in danger (Dhar *et al.* 1997). But the long awaited report of the British Geological Survey and Mott McDonald (BGS&MM 2000) estimates that 21 million people are drinking water with more than 0.05mg/liter of arsenic and 42 million with over 0.01mg/liter (section S2.5): 15 and 30 percent respectively of the population. The arsenic is contained in a shallow aquifer and there is little danger in getting water from the first ten meters below the ground (surface wells) or below 200 meters (deep wells used primarily for agriculture). There is little risk for populations in the hills (where the water table is not deltaic) or on the seaward edges of the delta (where the only tubewells are deep ones), and limited danger in the northwest where the aquifer water is flowing faster. Elsewhere, the arsenic moves slowly and is not evenly spread with the result that even wells close by and of similar depths may exhibit very different levels of arsenic. BGS&MM (2000:S2.8) found that the older wells were more contaminated than the newer ones, and surmised that it was possible that the arsenic concentration around a functioning well increased over time. NAMIC, testing 43 affected *thanas* (districts), found 49 percent of tubewells arsenic-free, but 51 percent were contaminated with at least 0.01mg/liter (i.e. over the WHO guideline level), 35 percent with at least 0.05mg (i.e. over the Bangladesh guideline level) and 3 percent with over 0.5mg/liter (BAMWSP 1999:3).

The major unknown factor in the Bangladesh situation is less the concentration of arsenic in the tubewells than the epidemiology of arsenicosis. WHO (1999: 1-2) lists symptoms roughly in successive order as changes to the color of parts of the skin (either hyperpigmentation or depigmentation), a thickening of the skin particularly on the palms and soles (keratosis), skin lesions, skin and internal cancers, peripheral vascular disorders and neurological disorders. The liver and lung may also become affected (Mazumder *et al.* 1997; Abernathy *et al.* 1997). There is no clear relation in individuals between arsenicosis and arsenic intake as measured by the presence of keratosis (Mazumder *et al.* 1998: 875). But Mazumder *et al.* (1998) did find average keratosis levels rising from 0.1 percent among these drinking from wells with less than 0.05 mg/liter to 9.7 percent from wells with over 0.80mg/liter and keratosis climbing from 0.4 percent to 17.1 percent (p. 874). Progression is slow and is yet unpredictable. Tondel *et al.* (1999) studying 1481 subjects in four villages in West Bengal found the prevalence of hyper or hypo pigmentation or keratoses rfanging from about 18% in those exposed top levels of 0.15mg/liter to about 30% in those exposed to levels of 1.0 mg/liter. Note that these figures are for any or all of these independent clinical signs, which alone are unlikely to constitute arsenicosis. Ahmad *et al.* (1999), working in a badly affected Bangladesh village close to the Indian border, found 87 percent of the tubewells to have an arsenic presence of over 0.05mg/liter, with 10 percent of the population suffering from arsenicosis, mostly melanosis and keratosis, 0.6 percent evidencing pre-cancerous skin lesions and 0.08 percent with cancer (apparently visible skin cancer). To put the pre-cancerous and cancerous skin lesion prevalence estimates into perspective, the prevalence of skin cancer ikn Australia is estimated to be over 1%, with higher estimates for pre-cancerous skin lesions (Marks 1997). There is also an age effect, which is probably largely but not entirely a product of the period over which arsenic-contaminated water was drunk. Mazumder *et al.* (1998: 874) found keratosis rising from 0.4 percent among persons under 10 years to 1.7 percent among those 20-29 years of age and 4.2 percent for the 50-59 age range; for the same age groups hyperpigmentation climbed from 1.9 percent to 4.7 percent and then 9.1 percent.

There are few estimates of the prevalence of arsenic related symptoms. Smith et al. (2000: 1097) cites an estimate of at least 100,000 cases and suggests that there may be many more. He comments (p. 1095) that in West Bengal, India a much smaller population is at risk (1.5 million) but one estimate of those with arsenicosis exceeds 200,000. A Rapid Action Programme surveyed 200 villages with a combined population of 469,424 people and found only 1,802 cases. However, they also conducted an in-depth study in four villages with arsenic contaminated tubewells, involving the interviewing and physical examination of 1,481 adults found 430 with arsenic lesions (Tondel et al. 1999).

Surface water remains arsenic-free but its threat of waterborne disease has almost certainly increased. Kränzlin (2000: 74ff) reports that most drinking water before 1947 was taken from special ponds owned by the *zamindars* (tax collectors who became, in effect, large landlords) who usually strove to keep them clean and free from fecal matter. Subsequently, with Partition and the breakdown of the *zamindar* system, these ponds were less protected. The pollution of most ponds became more marked still after most people switched to drinking tubewell water with the consequence that attempts to protect surface water largely ceased. For example, the use of potash alum (*phitkiri*) which reduced bacterial counts by promoting sedimentation has declined drastically (Kränzlin (2000: 69).

While there is reasonable evidence for increases in lung, bladder, kidney and skin cancers, cardiovascular disease and diabetes among those exposed to highly arsenic contaminated water (levels over 0.15-3mg/liter), there is no evidence for increased risk for mortality and morbidity attributable to chronic exposure to water contaminated with low concentrations of arsenic. There is also no evidence as yet for progression of the skin manifestations of arsenicosis to cancerous or other lesions likely to lead to premature death.

If there are to be rises in arsenic associated mortality they will be hard to detect unless a major mortality crisis develops. Bangladesh does not have a vital registration system. Only among the quarter of a million persons in the Matlab district covered by the Demographic Surveillance System of the International Centre for Diarrhoeal Disease Research is there a system for recording all deaths (ICDDR,B various years). It is not at present recording a rise in middle or old age mortality. The system attempts to record causes of death, but these are not professionally certified, and are not yet identifying arsenicosis mortality.

The studies

The frame of the studies reported here was a national probability sample of households involving collaboration between the National Centre for Epidemiology and Population Health, Australian National University, and Mitra and Associates, Bangladesh's foremost organization for conducting national surveys, including the country's demographic and health surveys.[1] The studies had three components. The first two, essentially social scientific and demographic, were completed between February and March 2000, and the third, biomedical and chemical, is continuing and will be reported later in epidemiological journals: (1) a national sample of households, (2) a tubewell census of the communities which formed the penultimate stage of the sample; and (3) a study of households' water, with arsenic testing, and the families' health with clinical examinations. The first two components aimed at exploring the relationship between families and their sources of water, the effect of the campaign to warn them about the danger of drinking arsenic-contaminated water, the extent to which their tubewells had been tested and their subsequent reactions, and finally their awareness of arsenicosis within their families and the treatments they had adopted.

(1) The household survey was a rural one, defined as being the 76 percent of the country's population living outside the four metropolitan areas (Dhaka, Chittagong, Khulna and Rajshahi) and the Municipalities where most water is not from tubewells or is taken from deep-wells that are not believed to be arsenic contaminated. The sample of households was a subsample of the 1996/97 Bangladesh Demographic and Health Survey (BDHS) (Mitra *et al* 1997: 153ff) which was drawn from the Integrated Multi-purpose Master Sample maintained by the Bangladesh Bureau of Statistics. In each of the country's six Divisions, a sample of 15 villages was drawn and in each of these, 42 households were selected from the BDHS household listings. This yielded 3,780 households, substitutions being made in the case of the small number of refusals. The total number of persons in the households, to which such questions as those on arsenicosis referred, was 20,260. In order to test sensitivity by gender to various questions, the respondents were alternated by sex from one household to the next, usually from household head to spouse. Finally, the responses were weighted by the rural population of each division.

(2) In each cluster forming the penultimate sampling unit a tubewell census was conducted. The 9,174 wells censused formed a universe from which households took water, and ensured that public as well as private wells were enumerated. The census also allowed a comparison with the tubewell data obtained from the household survey.

The tubewell census showed that 97 percent of tubewells are of the ordinary hand-pump type. Two percent were *tara* pumps, a more powerful hand-pump designed for deeper wells. The remaining one percent was comprised of wells with *dheki* (foot operated treadle) pumps or motor pumps. The great majority of the tubewells are private, 86 percent, compared with 12 percent installed by public authorities, one percent by non-government organizations, and one percent by some kind of communal arrangement. Private ownership was up from 71 percent in the 1991 survey (Mitra and Associates 1992: 13), a reflection of the tremendous increase in private tubewell construction in the 1990s and the withdrawal of government from the activity. This is supported by the household survey which showed over two-thirds of the tubewells in use in 2000 having been sunk since 1991. More surprisingly, 95 percent of all tubewells were functioning, a different situation than found in the 1980s in south India (Caldwell *et al.* 1988: 148-149) and probably a reflection both of the high level of private ownership and of the rather simple tubewells suited to the conditions of the delta.

The tubewell revolution

The household survey revealed that by 2000 over 87 percent of households were getting their water from ordinary tubewells, with the most potential for arsenic pollution; 7 percent were using relatively safe, but much more expensive, deep tubewells; and 0.6 percent had access to piped water, half at their own dwelling. Deep wells were a significant source of water only in two divisions bordering the Bay of Bengal where parts of the aquifer are salty, Barisal where 65% of water was supplied by deep wells and Khulna where 10% was. Throughout the 1990s the proportion of the rural population drinking surface water continued to decline, from 4.2 percent in 1991 (Mitra and Associates 1992: 41) to 2.5 percent by 2000, and the proportion drinking from hand-dug wells from 4.7 to 2.5 percent.

The proportion using tubewell water for cooking was much lower at 68 percent, thus lessening the arsenic danger, and dropped to even lower levels for dishwashing and bathing . Nearly 60 percent had their own tubewell or access to a tubewell in their bari, many relatively recently, one-fourth having been in this situation for at least 12 years, one-half for at least seven years and three-quarters for at least three years.

What drove the overwhelming acceptance of tubewell water? Half the respondents said that the most compelling reason was the need for safe drinking water, while the remainder placed greater emphasis on convenience and no longer having to rely on neighbors through controlling their own water supply. Women were more likely to emphasize convenience and control, but this is readily understood when it is realized that they are the water carriers and also the negotiators with neighbors for access. For water beyond the *bari,* neighbors provide three-quarters compared with only one-quarter from public sources. No longer do governments or NGOs play a significant role in urging families to invest in tubewells. Every family wants its own tubewell and the limiting factor is solely resources – with the exception of a few areas where the water table is very deep. Nevertheless, even in poverty-stricken rural Bangladesh, 87 percent of those with wells (or 52 percent of all families) constructed the well with their own resources, while five percent obtained for the purpose an NGO loan, three percent a private loan, and one percent a government loan. Remittances from earnings in the Middle East apparently played a very minor role. The reason is that the cash outlay, over and above that of family labor, is modest, with a median level near Taka 1,900 – US$38 at the current exchange rate – around one-tenth of the per capita annual income, although a much higher proportion of disposable rural family income (first quartile = US$22, third quartile = US$55). Deep wells are in quite another category. They need machinery to install, heavy pipes, and often powerful pumps, and may cost many times as much as an ordinary tubewell. They are put in place either by the government or by the rich and landed for growing commercial crops. Some households have access to a small amount of this water for drinking.

Water is used for many other purposes than drinking, and arsenic derived from water can be ingested by such other routes as eating irrigated foodstuffs (being investigated in the ongoing work of the project). Table 1 explores the household sources and use of water.

Table 1 Use of water by source, Bangladesh rural households, 2000 (n=3,780)

Source	Use (%)			
	Drinking	**Cooking**	**Irrigating vegetables**	**Irrigating cereal crops[a]**
Ordinary tubewell	87	65	21	12
Deep tubewell	7	3	3	15
Surface well	3	4	0	0
Surface water[b]	2	26	39	16
Other[c]	1	2	0	
No irrigation[d]	-	-	2	24
No activity	-	-	35	33

Notes: [a] rice and wheat
[b] pond, tank, lake, river, stream
[c] piped water, rainwater from roof
[d] rainfall only
Source: NCEPH, ANU Household Survey 2000, weighted data.

Water when drunk is the major source of arsenic. Irrespective of the amounts of arsenic retained in ooked food, or irrigated vegetables and crops, ordinary tubewell water is used to a lesser extent in these activities. Deep well water is important for the seaward deltaic areas and more widely for irrigated crops because deep wells can produce very large flows of water. Only small areas of crops or vegetables can be irrigated by ordinary tubewells.

Two aspects of the tubewells are important for understanding and predicting Bangladesh's arsenic crisis: their depth and the period over which they have been available for drinking. Both are explored in Table 2.

Table 2 The nature of Bangladesh's tubewells

Measure	**Source of information**	**First quartile**	**Median**	**Third quartile**
Depth (meters)	Household survey	16.5	26.2	46.6
	Tubewell census	13.5	21.0	34.6
Age (years)	Household survey	2.5	6.5	12.5
Period household has used tubewell water for drinking (years)	Household survey (males)	10	20	30
		Less than 10 meters %	**Over 200 meters %**	
Extreme depths	Household survey	7.9	8.6	
	Tubewell census	11.4	1.2	

Source: NCEPH, ANU Household Survey 2000 and Tubewell Census 2000, weighted data.

Tubewells as measured by the tubewell survey are on average shallower than as measured by the household survey. This is an artefact of what is being measured in the two surveys. The tubewell survey measured all wells including many inexpensive shallow wells, particularly in northern Bangladesh, used by relatively few people. Deeper wells, more important in the lower water table areas of southern Bangladesh, are rarer but are used by more people on average and hence show up more prominently in the household survey, which measured household use.

The great majority of tubewells, 83-87 percent, are what we have called "ordinary tubewells", neither so shallow that they are in danger of surface microbial pollution nor so deep that there is little fear of arsenic contamination. Half lie in a 30-meter band between approximately 15 and 45 meters (or 50 to 150 feet as rural Bangladeshis still express it). There has been a steep rise in tubewell construction in the 1990s, but a much more moderate increase in the numbers drinking from tubewells. This is partly because old tubewells have been replaced, and partly, because more families have their own tubewells rather than getting water from other families' pumps or public pumps. One-quarter of the families have been drinking from tubewells for ten years and half for 20 years. Those in greatest danger are the 78.9 of the population at the beginning of 1992 who were drinking from ordinary tubewells: 62 percent of the current population. The remaining 38 percent either were drinking deep tubewell water or surface and near-surface water at that time, or they were not yet born.

The impact of the arsenic crisis

The threat of massive arsenicosis and of substantial increases in the death rate is still only a potential one. It seems unlikely that there have been to date substantial numbers of deaths as a result of the poisoning but there is no hard evidence on this. No one is quite sure what is going to happen. Very little is known of the epidemiology of arsenicosis. For the modestly high levels of arsenic found in many of the Bangladesh wells, we have no real knowledge at the population level of what this means in terms of evaluation of arsenic mortality levels or of other arsenic-related deaths over different periods. At the individual level we have even less knowledge. It does seem possible for persons to take in similar amounts of arsenic with very different arsenicosis outcomes. Certainly, the higher rates of keratosis and skin pigmentation changes among males than females is only partly explained by different body masses. We do not know in what proportion of cases skin changes will lead to skin lesions, skin cancers, other cancers, gangrene, or liver and vascular damage. This can be seen in the most comprehensive examination of the situation (Abernathy *et al.* 1997).

Arsenic-induced mortality appears to be associated with a long lead-time except with such concentrations of arsenic as are rarely found in aquifers. Smith (2000: 1095) reports that skin lesions typically have a latency period of about 10 years depending on the volume of arsenic ingested. Skin cancers have a typical latency period of over 20 years (Smith 2000: 1096). Over half the population are under 20 years of age and so are limited in the period they have been ingesting arsenic. Another one-tenth of the population were over 50 years of age when they began drinking tubewell water and accordingly were at increasingly high risks of mortality from all causes. The causes of rural deaths can be estimated only in very broad categories and postmortems with pathology testing are extremely rare. Changes in skin color and the thickening of skin on the palms and soles do not usually result in distress but are merely markers of the progress of arsenicosis. Most villagers find them hard to recognize. They do not examine each other's bodies very much (except for mothers with young children who rarely exhibit these symptoms), and, in any case, even before arsenicosis many people had blotchy skin, and hardworking, barefooted farmers and agriculture laborers did not lack horny soles and palms. These factors mean that we remain unsure of the impact of arsenic exposure in Bangladesh.

Nevertheless it should be possible to move beyond pure guesswork. Half the population has been drinking tubewell water for 20 years and one-quarter for 30 years. Amongst this population there should be a fairly strong indication as to likely size of the potential problem – at least as measured through the occurrence of skin lesions.

It is argued here that the rural population has been slow to notice arsenicosis or to heed the warnings about it for several reasons. The first reason is that the resort of nearly all the population to tubewell water for drinking is still relatively recent and the appearance of individuals with the symptoms of arsenicosis even more recent. The second is that there has been a tremendous psychic investment by both individuals and government in turning to bacteriologically pure tubewell water, and a suspicion that it may be years if ever before the dangers from arsenic eclipse those from surface-waterborne diseases. This is aggravated by a realisation that most of the rural population cannot afford the fuel to boil surface water. The third reason is the lack of hard evidence about the impact on populations of high levels of inorganic arsenic in water either in Bangladesh or elsewhere: On the local scene, most people have not seen arsenicosis symptoms and very few have known of arsenic-induced deaths. The fourth is that the Bangladesh situation is full of anomalies: One well is safe and the next is not, and one member of a family has symptoms while others are free of them. The British Geological Survey identified 20 million as taking in more than 0.05mg of arsenic per liter of water, which means that much of the present rather diffuse effort is probably aimed at people in little danger. The fifth reason is the lack of mortality or cause-of-death data. This is aggravated by a situation where those most likely to be attended by a doctor or to die in a hospital are the metropolitan populations drinking relatively safe water. The sixth is that adequate experience and epidemiological data are unlikely to come from elsewhere because the Bangladesh-West Bengal region is almost unique in having a large population – perhaps 200 million – living on an active delta, and one which receives huge quantities of minerals from nearby mountains in monsoonal floods. This tardiness in heeding warnings and acting has also been apparent with the government, which was also influenced by the same range of reasons. The position was rendered more complex by some involved groups, mainly NGOs, pinpointing atypically affected villages, sometimes misreading arsenicosis symptoms, and over-interpreting weak epidemiological evidence.

Meeting the challenge

The household survey sought to explore the effect on the rural population of efforts to increase awareness, and to change behavior so that the arsenic danger can be contained. The campaign has two main parts. The first is an informational effort using the media and the administrative system. The second is the testing of wells to ascertain arsenic levels so that the users can be warned when dangerous amounts of contaminant have been detected.

The informational campaign has been moderately successful, as is shown in Table 3, and will almost certainly eventually reach the whole rural population just as did the warnings about drinking untreated surface water. Nearly half the population has heard the arsenic warnings, more men than women as might be anticipated in a *purdah* society.

Significantly, the information is reaching the people more from the media, especially radio, than through direct contact with officials or NGOs. Almost twice as many men as women receive the media messages, a reflection of higher educational levels and greater access to radio and television. In 1996-97 national levels for listening daily to radio were 64 percent for men and 40 percent for women, and for watching television at least once a week 53 percent and 27 percent. Rural levels were around three-quarters of national ones for radio and half for television. Women's exposure to the radio rose with education (Mitra *et al.* 1997: 20-21). Women partly made up for their lower media exposure by hearing from others including husbands.

Table 3: The impact of the informational campaign

Question	Responses	Male respondents (n=1,890) %	Female respondents (n=1,890) %
Has heard that something may be wrong with tubewell water	Yes	47.5	39.6
First source of Information:	Administration	3.8	2.5
	NGOs	2.4	3.3
	Media	17.0	8.7
	Relatives, friends, neighbors	15.5	20.0
	Other, not certain	8.8	5.1
		47.5	39.6
Message received:	Water contains poison called arsenic	20.6	11.3
	Water is bad or will cause sickness	18.1	17.9
	Water can eventually cause death	0.8	0.9
	Other	8.0	9.5
		47.5	39.6
Resulting behavioural change:	No change	41.4	34.6
	Stopped using tubewell water for drinking	1.5	1.2
	Stopped using tubewell water for both drinking and cooking	0.3	0.3
	Filtered the water	0.2	0.3
	Boiled the water	1.2	1.1
	Other	2.9	2.1
		47.5	39.6
Subsequent specific question on the worst outcome of the Contaminated water	Death	9.9	10.3
	Permanent sickness	4.7	4.7
	Bouts of sickness	15.3	13.1
		29.9	28.1

Source: NCEPH, ANU Household Survey 2000, weighted

Seven-eighths of those who have heard of the danger are doing nothing about changing their water supply. Around 1.4 percent have stopped drinking tubewell water, 0.3 percent are trying mitigate the danger by using filters, and 1.2 percent are futilely boiling the water. Part of the explanation is a low level of awareness of what is involved. Only about one tenth of the population is aware that the possibility that death is threatened. In addition, there is a certain skepticism about the magnitude of the problem, frustration at having no easy solution, and a concern that any alternatives may be more harmful than current practice. The skepticism, or a decision to wait and see, arises, as we will show below, from not seeing people afflicted in the way that the campaign suggests. The delayed response also is explained by a lack of well testing and a suspicion that the lack of poisoning in the family is probably evidence that their well is all right.

The tubewell testing program appears to be proceeding slowly. Table 4 shows the situation reported in the Household Survey and Tubewell Census.

Table 4: Tubewell testing and the aftermath
(n=3,780)

	%
Household Survey 2000	
Family drinks water from ordinary tubewell	87
This tubewell has been tested	5.2
Tubewell marked: red	1.7
green	1.9
not marked, other	1.6
Family has stopped drinking from tubewell as a result of marking	0.3
Family previously drank from a/another tubewell	71
This tubewell was tested	2.3
Tubewell marked: red	1.6
green	0.2
not marked, other	0.5
Tubewell Census 2000	
Tubewell tested	2.7
Tubewell marked: red	1.9
green	0.3
not marked, other	0.6

Source: NCEPH, ANU Household Survey 2000, Tubewell Census 2000, weighted data.

Only around three percent of all tubewells (Tubewell Census 2000) or five percent of wells currently being used at the household level (Household Survey 2000) have been tested (the difference between the estimates of the Tubewell Census and the Household Survey is due to a high concentration of tubewell numbers in the north of the country where arsenic is believed to be a relatively smaller risk and hence fewer tubewells have been tested). The Tubewell Census indicated that around 70 percent were marked red, ten percent green and 20 percent were either not marked or were ambiguous. Probably most of the latter were tested as safe though it is unclear. The proportion marked green is very low given estimates that only 35% of wells in the 43 most affected districts exceeded the Bangladesh Government's recommended level of no more than 0.05mg of arsenic per liter of water (BGS&MM 2000). However, the inaccuracy of portable measuring equipment has led UNICEF to recommend that all wells recording more than 0.02 mg of arsenic be marked red (UNICEF 2000). This procedure will clearly have major economic and potentially adverse health consequences if users of wells with low levels of contamination resort to surface water. Combining currently used wells with previously used wells in the Household Survey suggested a lower percentage of tested wells as marked red, below half, but still higher than national estimates of the proportion of wells over 0.05mg/liter of arsenic.

The data indicate that most people whose wells were marked red stopped using water from those wells. It may be noted, however, that they were often changing either to other tubewells that had not been tested or to other sources that had their own risks. Among those who had ceased drinking from a marked tubewell, 45 percent returned to surface water, 34 percent moved to an ordinary tubewell not marked as dangerous, and 21 percent found a deep well source. Those who continued to drink from a well marked as contaminated mostly believed that they had little choice except to return to surface sources and that such a move would be premature unless there was some sign that their continued drinking of tubewell water was proving deleterious to family health.

The proof provided by family symptoms of physical illness has been slow in coming. The respondents were asked a series of questions on possible arsenic related illnesses. The first was whether there were any household members over the age of 18 years suffering from an illness caused by tubewell water: 0.2% of respondents said there were – this question was restricted to those over 18 years as arsenicosis is believed to be most prevalent amongst the adult population. In answer to a more specific question on whether anyone in the household of any age was suffering from the effects of arsenic only 0.2% of respondents reported household members of any age suffering – 13 cases in all were identified. Given that many in the population were unaware of arsenic-related illness and an even higher proportion of its manifestations as the symptoms of arsenicosis, changes in skin pigmentation, thickening of the skin of the soles and palms, and skin lesions were explained by the survey interviewers to the respondents and the latter were asked about their presence. The results are shown in Table 5.

These findings are national and are not directly comparable with individual villages identified as having acute problems. When Ahmad *et al.* (1999) reported on their examination of Samta in Jessore District, 12 kilometers from the Indian border and in the area where high arsenic contamination was first detected in Bangladesh in 1993, they found 87 percent of the tubewells with over 0.05mg/liter of arsenic, 10 percent of the population with some degree of melanosis or keratosis, but only 0.6 percent with precancerous skin lesions, while a mere 0.08 percent were identified with cancer. Where people were drinking from wells with less than 0.05mg/liter, not a single person with arsenicosis was found. Arsenicosis takes a long time to develop and may be very capricious in how it strikes. Given BGS' estimate that 35% of wells in 43 high prevalence districts exceed 0.05 mg/litre Ahmed's figures if extrapolated imply substantially higher levels of arsenicosis than reported here. It is interesting to note, however, that 31 (54%) of the reported cases of respondents identified as presenting arsenic symptoms were in Khulna (which includes Jessore District and Samta) and Barisal Divisions, which represent 19% of the country's population.

Table 5: Responses to questions on the presence of arsenicosis

	Male respondents n=1,890 %	**Female respondents** n=1,890 %
Is anyone in your family over the age of 18 years suffering from an illness caused by tubewell water? YES	0.2	0.2
(Question asked before arsenicosis symptoms explained) Do you think anyone (any age) in your family is suffering from the effects of arsenic? YES	0.2	0.2
(Question asked after arsenicosis symptoms were explained) Has anyone in your family any of the symptoms? YES	0.9	1.5
Proportion of all persons in survey identified as presenting arsenic symptoms	0.2	0.4
Proportion of respondents identified as presenting arsenic symptoms	0.5	0.4

Source: NCEPH, ANU Household Survey 2000, weighted data.

Three points should be noted. First, in the Household Survey females everywhere reported more arsenicosis symptoms than males. This may demonstrate either greater sensitivity or greater suggestibility, or it may mean that women see a larger proportion of the family's bodies than do men. Certainly they are expected to be more sensitive to illness and to symptoms than are men. The second possibility receives some support from the fact that women were more likely to identify symptoms among female family members. Given that many respondents, especially males, may not have been aware of the symptoms of other family members the figures on the proportion of respondents reporting their own symptoms should be more accurate. Self-reported prevalence was higher, especially for male respondents but this may partly reflect the fact that the respondents are on average older than their family members and hence more likely to suffer from rashes whether caused by arsenic or not. The second point is that these are informed but self-reported arsenicosis status figures. Doubtless some cases have been missed, but there is also the possibility that other skin conditions have been mistaken for arsenicosis. Clinical examination may result in a higher rate of diagnosis. The authors are intending to undertake a follow-up survey involving the clinical examination of all reported cases of arsenicosis and a sample of cases reporting no symptoms to verify the findings reported here. The third point is that the arsenic message from the government is not managing to get over the information about arsenicosis symptoms.

The level of arsenicosis is at present low, except in specific villages with long use of tubewells and high levels of groundwater arsenic spread unusually evenly throughout all parts of the area. Even if we take the upper-level estimate provided by the proportion of respondents reported to be afflicted, noticeable symptoms affect only 0.5 percent of the entire rural population, or around half a million people. While 500,000 people is a very sizeable population these figures raise important questions as to the priority of arsenicosis in a list of Bangladesh's public health challenges, and the most appropriate means to tackle it. As noted above, half the population has been drinking tubewell water for twenty years, so, while the number affected will increase, the increase is unlikely to be exponential. Furthermore as reported above Ahmed et al. Found that only six percent of those with any degree of melanosis or keratosis evidenced pre-cancerous skin lesions and only 0.8 percent had cancer, and as noted above, this is fewer than would be measured in a such a study in Australia.

In terms of the success of government programs it is significant that no more than 1.5 percent of females and 0.9 percent of males could identify afflicted family members even with trained advice. Without that advice the proportion was 0.2 percent. This is why families are reluctant to give up drinking tubewell water, and probably why the government was at first somewhat slow to react. This reluctance would be reduced if there were obvious alternative easily accessible sources of good water, but there are not.

Overview

Probably about 20 million Bangladeshis are drinking water above the Bangladesh Government's recommended maximum acceptable level of arsenic, 0.05mg/litre of water and many more above the level recommended by World Health Organization of 0.01mg and hence may be said to be in danger of arsenicosis. It is doubtful whether more than half a million yet have symptoms of arsenicosis. Too little is yet known about the effect of long-term exposure to modestly high levels of arsenic to be able to predict with any accuracy what proportion of the 20 million will develop arsenicosis, let alone die of it. But on the findings of the survey and what is known of arsenic poisoning it is probably safe to say that the considerable majority of these people will not develop arsenicosis, and that most of the rest will not die of it but eventually of some other unrelated condition. The reasons include the following. Most of this population have been drinking tubewell water for at least two decades and many considerably longer and are yet to develop symptoms. Many of this group are drinking water in the 0.05-0.10mg/liter range and it seems likely that a significant proportion of people can tolerate this level for many years. This includes a disproportionate number of females, better-nourished persons, and those not suffering from Hepatitis B. Many people were middle-aged when they first started to drink tubewell water and, in a country with a life expectancy still under 60 years, are at risk of dying from other causes.

These qualifications are needed to place the crisis in perspective, to modify some of the more extreme scenarios, and to explain the relative passivity of the population to the situation. They do not suggest that there is no crisis. In terms of absolute numbers affected and the potential number of victims it may well be the biggest poisoning in history. Hundreds of thousands and possibly millions are at risk of suffering and in many cases dying from arsenic poisoning unless the situation can be changed. In particular, arsenic poisoning may becaome a significant cause of adult mortality. It will act to slow rises in adult life-expectancy. Its overall impact of mortality and life-expectancy will, however, be much less as it has such a long latency period rarely affecting people in less than 20 years and usually much longer, in a country where few people live to old age. In the demographic sense it will not be a mortality crisis in that population numbers will not fall. This is because the rate of natural increase is still almost two percent annually in spite of over one million deaths from all causes per year.

The Bangladesh program to improve the situation is still feeling its way and there are no clear solutions to the difficulties. The first reactions were sensible: Not to reduce the concentration of arsenic in water as recommended as reasonably safe in the Bangladesh situation below 0.05mg/liter, and to place an emphasis on testing tubewell water. There have been problems with the design and provision of adequate testing equipment and the program is by no means in top gear yet. By early 2000 probably no more than five percent of tubewells had been tested and the same results were often not achieved when two different groups did the tests.

There are some hopeful aspects to the crisis. The population does react to public health promotion, as is evidenced by the almost universal suspicion of drinking untreated surface water, and by child vaccination rates around 80 percent in rural areas (Mitra *et al.* 1997:118). In one sense the present program is working: Almost half the population has heard that there may be problems with drinking tubewell water. Most families whose wells were marked red did stop using them for drinking. Many, however, had changed to other tubewells that had not been tested or to other sources of water, which may be affected by bacterial contamination.

The ways in which the program is not working are the following: (1) not enough people know just what the arsenic danger is; (2) too few can recognize arsenicosis symptoms; (3) far too few tubewells have been tested; and (4) many people do not know what their alternatives are. The first three problems can be overcome by effort, expenditure and time. The real problem is the fourth and the difficulty here is that there are no clear or simple solutions.

The easiest and perhaps eventual solution may be to concentrate all drinking on safe wells. Nearly every village contains at least some safe wells: Perhaps two out of three even in the most arsenic-contaminated Divisions, and one in four even in the worst-affected local areas. But this depends on universal well testing, unambiguous marking, and continued retesting of the wells being used. This may place an excessive load on the safe wells and the households owning them, and may have to be supplemented with the drilling and testing of new wells, and the use of contaminated wells for bathing and even dishwashing. There is some danger that, if too much emphasis is placed on the dangers of tubewell drinking, in the absence of appropriate testing people may turn to sources of water which are much more dangerous, at least in terms of microbiological infection.

The use of water from deep tubewells may seem an obvious solution until it is realized that such wells may require mechanical pumps and cost many times as much as ordinary tubewells. There is the possibility of public investment in community deep wells and of diverting some water from existing agricultural pump wells. In the latter case the water would have to be collected near the pump rather than allowing microbial infection as water passes along earthen surface channels. Almost seven percent of households already get their water from deep wells and the figure rises to over 60 percent near the coast.

Another alternative, although one that most of the rural population now reacts against, is to return to surface water. This would mean a return to the old system of protected tanks, perhaps the treatment of tank water with chemicals, and more boiling of drinking water than in the past. It may also involve the revival of practices such as adding alum (*phitkiri*) that declined after the widespread adoption of tubewell water. This approach could work given that the population is more hygiene-conscious than in the past. Indeed, the tubewell revolution may be responsible for a smaller fraction of the infant and child mortality decline than is usually attributed to it. Levine et al. (1976) found no evidence that tubewell users had fewer cholera attacks or a lower incidence of diarrheal disease than non-tubewell users. However, given the decline in the maintenance of surface water sources this situation almost certainly no longer holds.

There are possibly more technical fixes but all have problems and some are expensive. Water can be collected off galvanized iron roofs or with cheap plastic sheets off straw roofs, as has been done with some success in the salt-water areas bordering the Bay of Bengal, but the limited area of house roof per person in small crowded houses and the length of the dry season would incur considerable storage expenses and the volume of stored water might prove to be insufficient. Small sand-filter treatment systems for surface water can be constructed for populations of 200-500 people, but there are problems of both cost and contamination (Ahmed 1999: 4.4-4.5). Filtering systems employing cheap chemicals such as alum or ferric salts for precipitation or adsorption can be used on individual pumps to reduce the level of arsenic by as much as two-thirds, but their use has not yet proceeded far beyond the experimental stage (Ahmed 1999: 4.7-4.8). The 2000 Household Survey found over one percent of households attempting this approach. Ahmed (1999: 4.11-4.12) pointed to problems of quality assurance and dose control, as well and chemical residues, and concluded: "The use of unknown chemicals and patented processes without adequate information should be totally discouraged". Most of these approaches also suffer from imposing high financial and labor costs on households and reduce the control that the households have over their water supply.

The arsenic crisis is a major public health challenge for Bangladesh and potentially the biggest mass poisoning the world has seen. Much yet remains to be learnt about it. The 2000 Arsenic Household Survey and the Tubewell Census were efforts to provide a balanced national picture. The study has sought to provide some tentative estimates of the public health size of the problem. The data is by no means conclusive, being based on self-assessment, and many of the people at risk in the long-term are yet to show symptoms. Nevertheless the findings do provide a basis for a national assessment of the likely size of the problem. The studies have also shown how little the rural population know at present about arsenicosis. Hesitation at both the family and governmental level to adopt effective policies lies less in lack of will than in a justified uncertainty at the household level about what to do in the absence of water testing; and what to do at the household and government levels about what to do once arsenic is detected.

The problem will be on its way to solution only when highly professional government and NGO teams arrive in villages with an agreed-upon program for combating arsenic. This must include locating and testing all tubewells, informing local officials, and educating the people. At present tubewell testing is likely to proceed faster than knowledge of arsenicosis symptoms and outcomes. But the decisive part of the program will be a high degree of certainty in advice on what to do next, and some help in moving in that direction. Until the more technical solutions are really practicable at an affordable cost, these decisions may be in some areas to use only the safe tubewells, in others to depend more on deep tubewells, and, in places where it can be afforded, to boil surface water from protected ponds. Programs suited to each village will have to be agreed upon and implemented, even if they are replaced by different programs in subsequent years. The solutions, however, will have to be balanced. There will be no benefit to the people of Bangladesh if a program is undertaken which is unrealistic and overly difficult or costly to implement – in a country that is currently struggling to meet other health priorities such as reducing maternal mortality. It is particularly important that any proposed interventions should not detract from other health priorities such as control of diarrheal disease among infants.

The answer to the question posed in this article's title is that Bangladesh is the potential scene for a mass poisoning of unprecedented size. A relatively small proportion of the population yet show signs of arsenicosis and few are aware of the problem. The crisis is in no sense a myth but is important that relevant data be collected and interpreted sensibly and that Bangladesh is able to address the challenges facing it in a sober and practical manner.

Notes

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