Environmental irony: summoning death in Bangladesh

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Abstract. The arsenic crisis that affects at least 30 million water consumers in Bangladesh has been called the world's greatest ever environmental health disaster. Although the problem and the potential solutions have been presented confidently in the various media, the argument of this paper is that, ironically, very little of the science or the technology is certain. From the spatial and depth variabilities of contamination, through safety thresholds, to the accuracy of field testing kits, we find indeterminacy. Rather than shying away from such uncertainty, however, our argument is that mitigation policies must acknowledge and embrace it if any real progress is to be made.

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> "Wake, foolish man! for Death stalks you. Here is pure water before you; drink it at every breath."
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> From a fifteenth century poem translated by Rabindranath Tagore (1915, page 65)

The irony of arsenic: an old poison with new victims

In the 1980s symptoms of what seemed at first to be a strange skin disease began to appear in the rural areas of Bangladesh and West Bengal (India). The numbers were small but by the 1990s there was a flood of cases of hyperpigmentation (dark spots), and also small hardened lumps (keratoses) on hands and feet, which were often disabling, as a result of proneness to fungal infections, and occasionally they became malignant. An epidemiological link was eventually made to water consumption because these symptoms were similar to those of arsenic poisoning in Taiwan, with its associated 'blackfoot disease'. The laboratory testing of Bengali patients' hair confirmed the diagnosis of arsenicosis and there is no longer any doubt that a major problem exists. By analogy with Taiwan, consumption of arsenic-contaminated water in Bangladesh over periods of 5-20 years will lead to cancers of the lung, bladder and kidney; hypertension; cardiovascular disease; and peripheral vascular disease, which is characterised by black skin discolouration, ulceration and possibly dry gangrene (WHO, 2001; IPCS, 2001; Chen and Ahsan, 2004).

Gradually, very gradually in the 1990s, it dawned on the Bangladeshi authorities that they had discovered perhaps 'the largest mass poisoning of a population in history' (Smith et al 2000, 1093). About 28-35 million people regularly consume ground water with levels of arsenic content that are considered unsafe (BGS and DPHE 2001). So far 38,380 sufferers have been registered (BAMWSP 2004a) but the true numbers are thought to be much higher. Yu et al (2003) estimate a future likelihood of 2 million cases of arsenicosis, including 125,000 cancers, and there are already roughly 9,000 arsenic-related deaths a year (Lokuge et al, 2004). Ahsan (2000) estimates a probable 3 million cases of arsenicosis over a thirty year period. In the most heavily contaminated areas, Smith et al (2000) speculate that long-term drinking of water containing 500 µg/l of arsenic may result in one in ten persons dying from arsenic-caused cancers, including those of the lung, bladder and skin. This raises issues about the ethical responsibility of the experts who recommended the use of groundwater, and also the question of possible compensation for arsenicosis victims (Atkins et al, 2006a).

The present paper contemplates the meanings of irony in an environmental context, concentrating on one, that of indeterminacy. This is used to show that there is very little by way of a stable understanding of the 'crisis' that has been identified so confidently in the media. First, we show that spatial and depth variabilities in arsenic content are extraordinary at the local scale, making analysis, interpolation and prediction highly problematic. Then we revisit the vexed issue of safety standards. The threshold of the level of arsenic that is safe to consume is by no means straightforward and shifting from the Bangladesh standard to that of the World Health Organization (WHO) nearly doubles the population estimated to be 'at risk'. Third, we turn to the issue of measurement and find that the field testing kits (FTKs), at least in the way they are used, do not provide a sufficiently accurate and reliable foundation for the dataset upon which much of the debate about arsenic in Bangladesh is based. This undermines the scientific credibility of some of the remedial measures taken so far in the field. Next the paper investigates the nature of lay and expert knowledges of arsenic. These are in a nascent state, with medical expertise being particularly thin on the ground. Until satisfactory programmes of diagnosis can be established, the prospects for arsenicosis patients are uncertain. Fifth, we argue that the debate about mitigation measures is in disarray and, finally, some comments are offered on policy-making with regard to arsenic in the light of the problems that we outline in the rest of the paper. A discussion of indeterminacy is not in our view a counsel of ignorance and failure but, rather, such a common feature of the sociology of scientific knowledge that it needs to be embraced if effective policies are to be formulated.

Environmental irony

There are many kinds of irony in common usage (Hutcheon, 1994). Probably the most popular is the irony of asymmetry: the antinomy between outcome and promise/ expectation/prediction/plan. This appears to highlight mismatches between society and environment or the shortcomings of environmental policies and it thereby reinforces divisions between the natural and the social.

For instance, since its independence from Pakistan in 1971, Bangladesh has been portrayed as a hapless 'basket case' (by Henry Kissinger) beyond hope in the triage of development, or as a needy country requiring the support of the international aid industry

(Faaland and Parkinson, 1975). Material to this assassination of her self-esteem has been the proliferation of the environmental tropes of hazard, vulnerability and risk. Bangladesh is said to be annually challenged by riverine floods and cyclones, and in the longer term by sea-level rise and the shifting patterns of the monsoon that will come with global warming. Her environment is thought of as a cockpit of struggle between raw nature and a society enfeebled by dysfunctional governance. To misquote Giddens (1991), an ontological insecurity of identity in an unstable environment is surmised, along with an assumed dialectical relationship between risk and poverty that is emblematic of this, the most environmentally challenged, densely populated flood plain on earth.

Although excess water is the country's greatest hazard, ironically one of the most intractable development constraints currently is its surface water shortage, in the dry season. It is hardly surprising, therefore, that the people of Bangladesh should seek alternative sources underground. In 1972 the Department of Public Health Engineering (DPHE), with substantial financial support from the United Nations Children's Fund (UNICEF), started a rapid expansion of the number of hand-operated shallow tubewells in rural areas (Black 1990). The idea was not original - it was in fact citational of solutions that had worked elsewhere - but it seemed at the time to be appropriately low-tech, with small-bore metal pipes attached to easily maintained hand pumps. To what better use could aid money and expertise be put? After all, children were dying of diarrhoea and other water-borne diseases, such as cholera, by consuming heavily contaminated surface water, and a clean alternative was urgently needed. Yet it was these very tubewells that became responsible for the ready availability of poisonous water in almost every locality. The convenience, relatively low cost and high levels of water consumption locked villagers into a relationship with this life support system that has proved to be deadly for many of them.

A second version of irony is contingency of truth – the destabilized, slippery basis of knowledge and action that recognizes the constructed nature of belief and finds a space for indeterminacy even in scientific endeavour. Despite the playfulness of some postmodern interpretations, our version of this irony has serious intent. For neo-pragmatist Richard Rorty (1989, page xv), an ironist is someone 'who faces up to the contingency of his or her own most central beliefs and desires'. Ironists are 'never quite able to take themselves seriously because [they are] always aware that the terms in which they describe themselves are subject to change' (Rorty, 1989, pages 74-75). Irony is thus the opposite of common sense, which uses a closed vocabulary and lacks doubt. It is one of the most powerful of the discursive tropes, highlighting contradictions that can provide deeper insights. Schlegel described it as a form of (creative) astonishment (Behler, 1990) and Foucault understood irony to be 'revelatory of the counter-productivity and subversiveness of human intentionality, of the inevitable subversive relation of power to knowledge' (Fernandez, 2001, page 92). It is this, second, dimension of irony that will principally occupy our attention in the present paper.

The irony of indeterminacy

In this section we will discuss the uncertainty about almost all aspects underlying what has been portrayed boldly and confidently in the media as a major environmental health disaster. Despite the best efforts of a large risk academy, backed by interest from the insurance industry, not all hazards are known or are predictable within reasonable limits. Perhaps not very helpfully from this instrumental point of view, recent academic work has centred on the degree to which nature can ever be known to the satisfaction of all those concerned in environmental policy-making. Hinchliffe (2001), for instance, has written insightfully about this in the context of BSE in Britain, when a new cattle disease was allowed to spin out of control. The danger was known to exist in the 1990s but knowledge was limited as to its true nature and extent, a situation that has parallels with the arsenic issue in Bangladesh. The common feature here, latency, is a characteristic of environmental problems that has received too little attention in our view.

The precautionary principle, that a duty of care should motivate decision-makers to act early in the public interest, even when the science of a hazard remains unclear, seems not to have been followed either for BSE in Britain or for arsenic in Bangladesh. Hinchliffe argues that this is not at all surprising given the normative nature of the policy model and its continuing adherence to the view that realist science will eventually fill in any knowledge gap. For him it is the acknowledgement and knowing of indeterminacy that is crucial to successful policy.

For our present purposes, the major dimensions of uncertainty concern the spatial unpredictability of arsenic concentration; the nature of lay knowledges and capabilities; the definition of safety thresholds; the technology of field testing; and problems associated with diagnosis and treatment. We will discuss each of these in turn. Our other publications address additional issues such as patients' social situation (Hassan et al, 2005), mitigation options (Hassan et al, 2004), pragmatic perspectives on policy (Atkins et al, 2006b), and the legal implications of the arsenic crisis (Atkins et al, 2006a).

Origins and spatial pattern

Arsenic is an unusual metalloid in being highly mobile chemically in oxygen-free environments. The Holocene deltaic sediments of Bengal produce aquifers comprised of sands, silts and clays capped by layers of clay or silt and generate the highly reducing, anaerobic conditions that favour the mobilisation of arsenic, probably by its release from iron oxide as the result of microbiological reaction in sediments with an organic component (Nickson et al, 1998, 2000; McArthur et al. 2001; Ravenscroft et al. 2001; LGD, 2002). This is a simplified summary of a complex of processes that vary in importance in different parts of the aquifer according to geology and hydrology.

Although groundwater across large swathes of Bangladesh is affected, at the local level the spatial distribution of contaminated tubewells is very patchy and unpredictable (Hassan et al, 2003), with large differences over short distances, sometimes even between neighbouring wells a few metres apart. Van Geen et al (2003) investigate this astonishing and alarming micro-complexity, and in terms of depth they note that safe aquifers range from 30 to 120 metres, depending on where one is in the country. The observed spatial variability in arsenic concentration is presumed to be due to the characteristics of the sediments and the hydrogeological structure of the aquifers: upper shallow (0-40 m); lower shallow (40-130 m); and deep (130-400 m)(MLG, 2003). At depths greater than 150 metres, arsenic is less of a problem, perhaps because the older sediments were flushed during the Pleistocene at a time when sea levels were much lower or because they contain more stable minerals such as pyrite (Ravenscroft in DPHE, 1999; Ravenscroft et al 2001).

There is a regional moment to the spatial pattern. More than half of the upazilas (local authorities) have at least one well that is contaminated at the Bangladesh limit of 0.05 mg/l. The Chandpur district near the mouth of the River Ganges has the greatest problem, with 90 per cent of its wells exceeding that threshold and also having the largest number of patients presenting with symptoms of arsenicosis. Other badly affected districts include Munshiganj (83 per cent), Gopalganj (79 per cent), Madaripur and Noakhali (69 per cent), and Satkhira (67 per cent).

An issue that must be discussed in any interpretation of the spatial or depth patterns is that of the quality of the available data. The largest available database is compiled by the Bangladesh Arsenic Mitigation Water Supply Project (BMWSP). They have gathered together information supplied by various groups, official and unofficial, and the reliability and representativeness of these disparate sources are dependent upon the sampling methodologies employed and any operator error in the use of FTKs (Rahman et al, 2002). More reliable statistically but rather restricted in geographical coverage, is the stratified sample survey of 2,020 shallow tubewells undertaken by Mott MacDonald Ltd in 1998/99 as subcontractor to the BGS. This found 25 per cent of tubewells to be contaminated at the Bangladesh safety limit (DPHE, 1999).

Safety standards: 0.05 or 0.01 mg/l, that is the question

Demeritt (1998, page 176) has helpfully discussed artefactual constructivism and argued that it 'provides a way out of the dead end debate about scientific truth'. This approach sees social constructions of science and technological applications as joint achievements of society and non-humans: equipment, geological strata, pollutants. The results are interwoven, entangled and only decipherable if the pretence is dropped of clean divisions between the social and the natural. Thus we may reflect that the arsenic would have stayed underground and caused no alarm if it were not for the intervention of the GoB and the UNICEF, but that the socially constructed nature of the disaster depended upon the natural lineaments of the sediments. These components of the situation are inseparable (Irwin, 2001). To take the relationship one step further, one might also say that arsenic has changed Bangladesh because, in the words of Latour (2000, pages 113-14), artefacts have the capacity to construct social order: 'they are not "reflecting" it, as if the "reflected" society existed somewhere else and was made of some other stuff. They are in large part the stuff out of which socialness is made'.

We can progress an understanding of the arsenic pollution in terms of the means of testing and of the standards applied. Much of the literature accepts both as given, without discussing the crucial difference they make to estimates of the pollution and of its health impact. As Schiappa (1996) has ably demonstrated, experts and politicians are often at odds about definitions and about threshold standards of value or quality. At the stroke of a pen it is possible to manipulate the figures of the number of people identified as being at risk of arsenic poisoning. Leave aside the number of authors who uncritically cite the estimates of others, and there are many of these in the literature on Bangladesh; we are dependent, first, upon the screening technology used.[1] Second, the sampling methodology, crucial though it obviously is for estimates grossed up to the national level, is often ignored by commentators jostling for the most shocking headline. Third, Geographical Information Systems have been used to produce smoothed cartographic models but the astonishing micro-spatial variability of contamination means a strong component of indeterminacy and these models therefore do considerable violence to the data and are of questionable predictive value on the ground. Fourth, there is confusion in the international community, and in Bangladesh, about which water standards should be adopted in calculating the hazard. Should it be the 0.01 mg/l of the World Health Organization or the much laxer 0.05 mg/l of the GoB? Cynics might say that the latter standard is particularly convenient for the GoB because it is five times more lenient and therefore reduces the scale of the problem in the eyes of both domestic consumers and international commentators.

Peter Atkins has recently (Atkins, 2006) shown that our understanding and appreciation of the natural qualities of our food and drink depends very much upon an historical ontology of the 'coming into being' of materialities. The evolution of policy and regulation with regard to adulteration and contamination is often complex and is inevitably the result of compromise between competing interests, with legal standards set in the light of technical and legal considerations. Public trust in these standards, if sufficiently embedded, may in time be naturalized to the extent that the long and complex history of negotiation is forgotten and expectation starts to rise again. So it is with water, as much as any other commodity in public consumption. Hamlin's (1990) excellent account of the history of water analysis in Britain is proof of this, and we may extend his style of curiosity to the case of ground water in Bangladesh.

Bruce Braun (2000, page 20) refers to the 'cycles of accumulation' which allow for the emergence of an ordered system of knowledge. He is referring to a temporal ordering of knowledge construction and we may add that the science of arsenic has in recent years gone

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(1) We are well aware of the 'irony' that the indeterminate and incomplete nature of our critical reflections in this paper lays it open in turn to further critical scrutiny by others.

through a rapid evolution of technical expertise and theory building. One of the most interesting aspects of this has been how regulators have interpreted the science in terms of safety standards for drinking water. Smith et al (2000) and Smith and Smith (2004) show that there is a long and complex story about this internationally. In the USA a 0.05 mg/l limit was established in 1942 that lasted until 2001, but as early as 1962 there was advice from the US Public Health Service that this was too high, and that 0.01 mg/l was a safer limit. In 1986 the Congress instructed the US Environmental Protection Agency to revise standards but there were further delays. Similarly, the WHO safety threshold was 0.05 mg/l for 30 years until 1993, but this was apparently dictated more by the pragmatic consideration of what was possible in the field in terms of testing than by any clinical factors.[2] In that year the WHO reduced their limit to 0.01 mg/l (reaffirmed 2004) but that in Bangladesh (since 1989) and many other countries has remained at the previous figure (BGS and DPHE, 2001).[3] In ethical terms, we should consider whether technical expediency has gained the upper hand over the precautionary principle.

Interestingly, Allan Smith, one of the scientists most responsible for bringing the arsenic crisis in Bangladesh to the attention of the international community, espouses a solution of classic utilitarian logic when he argues that increasing the threshold from 0.05 to 0.01 mg/l may well in theory reduce the long term cancer risk from one in 100 to one in 500, but in practice such a policy would be self-defeating because action is likely to be postponed until such a time that the technical and administrative capacity is in place to achieve that limit (Smith and Smith, 2004). Meanwhile, many people would be exposed in the absence of a credible standard. The implication of this style of argument is that policy should be incremental and that it should be derived from the real world of practical implementability. Such a conclusion seems likely to appeal to many local people, some of whom are already

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(2) The first recommended limit was 0.20 mg/l, set in 1958. Note that three metrics are commonly quoted in the literature. 50 micrograms per litre (μg/l) = 50 parts per billion = 0.05 milligrams per litre (mg/l).

(3) The 0.01 milligram limit was reaffirmed in 2004, although it remains provisional (WHO 2004).

ignoring the red paint warnings on their tubewells and continue to consume contaminated water (Caldwell et al, 2003; Quamruzzaman et al, 2003).[4]

The opinion of things: field testing kits

When, in the 1990s, it became apparent that there was a problem with arsenic poisoning, the wheels of scientific realism began to turn.[5] A method of testing was needed that could be used under field conditions in all parts of Bangladesh. It had to be chemically sensitive to a range of possible levels of arsenic concentration, physically robust, simple and safe to use, and affordable (Deshpande and Pande, 2005). This was an epistemological dilemma, a trade-off between precision and practicability: in other words, what version of the truth was knowable within certain constraints? The alternative of laboratory analysis simply was not available at that time and it is only now, ten years later, that capital investment is being made to enhance indigenous laboratory capacity.

The FTKs that were introduced in the 1990s have been heavily criticized. First, technically, they have been shown to give unreliable and varying results. This is due to a design problem of miniaturising the chemistry to a portable size, combined with the difficulty of developing a test outside the laboratory that is accurate to below 0.10 mg/l. By comparison, Atomic Absorption Spectrophotometry, the main laboratory method, yields accuracy to 0.003 mg/l. Second, there has been, apparently, significant operator variability in the field, probably due to inadequacies of training (Pearce and Hecht, 2002; Kabir, [2006]) and to the perverse incentive of completing a maximum number of tests in a day, which leads to skimping on demanding aspects of the process, such as leaving the test paper for a standard period to develop its full colour, and to 'phantom wells' entering the database (Rosenboom, 2004). Most of the FTKs currently in use are based on the Gutzeit method, which involves the reduction of arsenite and arsenate by zinc to give arsine gas. This gas then produces a coloured stain on mercuric bromide paper (Pande et al, 2001). The colour

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(4) Besides arsenic, there are worries also about manganese, boron and uranium.

(5) The analysis of arsenic (especially in the late 1980s and early 1990s) has never really been routine. Even today it is quite a specialized analysis.

(yellow, brown, black) is interpreted using a standard reference chart in order to gauge the amount of arsenic present but it seems that this is not a straightforward procedure.

Rahman et al (2002) have written a particularly damning assessment of the four most commonly used FTKs. When calibrated against laboratory-based flow injection hydride generation atomic absorption spectrometry (FIHGAAS), they were reliable only at high concentrations (>0.10 mg/l) and correctly identified the binary status (acceptable or contaminated) of the water in only 49.3 per cent of the 2,866 tubewells tested. If true, this totally unacceptable result throws the whole status of the nationwide testing programme into disarray and deracinates the GoB's policy.[6] Unless new FTKs can be found immediately that are more accurate by an order of magnitude, the only credible solution seems to be to replace FTKs altogether with a large-scale laboratory testing programme. Certainly a short-term goal must be to establish sustainable testing regimes to re-test every tubewell in Bangladesh on a regular basis, but by mid-2004 only 4.6 million tubewells had been tested for the first time, less than half of the total number (BAMWSP, 2004a).

The alternative of using laboratories is now realistic. World Bank funding has enabled the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) to establish or upgrade ten laboratories and bench testing is regarded by most authorities as being more accurate, assuming a staff of competent and well-trained technicians. Using the FIGHAAS method, for instance, the accuracy premium is potentially ten fold over most FTK. However, the availability of trained local staff is limited for employment in these laboratories and there are issues of sustainability in the long term given the expense of consumables and the amortization of the capital cost of equipment. Most alarming of all is the operational variability of results that has been found between laboratories (Kinniburgh and Kosmus, 2002; Foster and Tuinhof, 2004).

Lay knowledges and capabilities

Variations in theories of knowledge and in the methodologies used to acquire and validate

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(6) It is important to note here that van Geen et al. (2005) have recently published a more reassuring account of the accuracy of the Hach kit, one of the FTK most widely used at present. They found a 12 per cent discrepancy between field and laboratory tests.

data can make substantial differences to conclusions drawn and action taken. The underlying assumptions and the technical aspects of data analysis, along with the positionality of the observer, are also crucial, if the sociology of scientific knowledge has taught us anything. It is worth spending some time reflecting upon epistemological considerations of the arsenic crisis in order to understand the role of lay and expert knowledges.

Lay knowledge of arsenic in Bangladesh is, so far, weakly developed. Awareness seems to be greatest in heavily contaminated regions, where the sources of information are the media, family and NGO workers (Paul, 2004). Thus 87 per cent of respondents in one arsenic-affected region surveyed had heard of the problem as against 53 per cent in an area not affected, but only 35 per cent knew the symptoms of arsenicosis, compared with 4 per cent in the control area (Ahmad et al, 2002).

Taking demotic understandings of risk into account is vital for any campaign of public awareness to be successful and for policy implementation to work. Our fieldwork in Satkhira district found that many saw arsenic as a 'curse of nature' (Hassan et al, 2005). As a result, people with visible symptoms of arsenicosis are often ostracised because it is thought of as a contagious disease (Hanchett et al, 2002; Hanchett, 2004). Especially vulnerable are young women, who as a result may be unable to marry, and children, some of whom are excluded from school. Patients face rejection, even by their immediate family members (Nasreen, 2001) and they occupy liminal spaces on the margins of social life, often afraid to leave their own homes. In the terms of Mary Douglas (1992), these people have transgressed a social boundary and now appear to be polluted. Ingestion of contaminated material produces the most threatening kind of such social danger (Bickerstaff and Walker, 2003). There is a sinister focus in society upon the bodily stigmata of arsenicosis and those with the characteristic dark spots (*zengoo* in Begali) try to hide them. Some employers even check the palms of casual labourers and refuse work to those with skin lesions (Hassan, 2003).

An example of ignoring lay mis/understandings is given by Hanchett (2004). She notes that the authorities paint red any tubewell that gives water with arsenic above the safety limit but this well-meaning health warning is taken in some communities as a denunciation of the tubewell owner. It conveys the same message as bodily evidence of arsenicosis and marginalises the unlucky family, irrespective of the reality of disease within the household.

Hermeneutic accounts of risk are in short supply in Bangladesh, which is highly regrettable given their importance for a full phenomenological understanding of present and likely future behaviours under stress. Lay knowledges of environmental health, elicited through qualitative research methods are a key to policy implementation and it is our contention that they should also have a part to play in policy-making. There is little evidence of either in Bangladesh at the time of writing.

Brian Wynne (1996, page 74) has laid a foundation of understanding responses to risk in terms of a thoroughly hermeneutic analysis of situated experience and of the 'intrinsically local nature of scientific knowledge construction'. He rejects any superiority of expert knowledge over lay knowledge and doesn't admit any difference in their epistemological status. He is highly critical of science for its 'optimistic fantasies about behaviour in the real world' (Wynne 1989, page 39). Wynne's contention is that grass roots capabilities are often overlooked, and this is certainly true in discussions of development in rural Bangladesh. An exception is Duyne's (2004) thorough presentation of case studies showing that appropriate water management is already widespread. To build on this independent and entrepreneurial spirit in certain areas, Hanchett (2004) suggests that a participatory approach is best for both the communication of messages about arsenic and the planning of mitigation options. Similarly, Hoque et al (2000) speak highly of the results from social mobilization for the improvement of sanitation in the 1990s in their survey area, Singair, and they regard the local Village Water and Sanitation Committees as possible nodal points for a similar campaign with regard to arsenic. Community cohesion is a necessary condition for success, however, and this cannot be met in the many villages in Bangladesh where there are serious social or political tensions. It is by no means uncommon, for instance, for both participatory discussions and the benefits that flow from them to be dominated by local elites, with social pressure and sometimes violent persuasion undermining any chance of a truly democratic outcome. In our opinion it is therefore essential for the state to play a continuing role in both facilitating and regulating a participatory element for solving the arsenic crisis.

Expert knowledges

In the field of arsenic poisoning, expert knowledges are far from settled it seems. The science is evolving rapidly and there is currently an impressive amount of important new work being published .The bibliography at the Harvard University arsenic project website (Wilson 2004) indicates that this scientific literature is dominated by writers from the global North. However, there is a considerable depth of local knowledge and some of the loudest voices of advocacy with regard to suitable policies of mitigation are from Bangladesh and India. Professor Dipankar Chakraborti, for instance, is Director of the School of Environmental Sciences at Jadavpur University, Kolkata, and he has made a major contribution to debates about testing water to determine the extent of the pollution, and also on the remedial technologies that could be used either to remove the poison or provide safe surface water supplies. He and his team (Chakraborti et al, 2002; 2003; 2004) are pessimistic in their assessment of the health effects, suggesting that the number of patients identified so far is just 'the tip of the iceberg'. They report over 300,000 cases of visible skin lesions in the Indian state of West Bengal alone, and suggest that there are likely to be many more in neighbouring Bangladesh.

Professor Chakraborti is a leading advocate of switching from contaminated tubewells to dug wells. The latter would have an improved design from those available in the 1970s and 1980s when they had a bad press with regard to bacterial contamination. Some progress has already been made in West Bengal (Smith et al, 2003) but, like most other aspects of the arsenic story, this solution is controversial (Ahmed et al, 2005). Dug wells are probably appropriate only in those areas where, by trial end error over many centuries, the local people have found them to be convenient.

Another problem is that the thinness of medical expertise on arsenic outside the universities and research institutes in the region means that diagnosis has been problematic. Hassan (2003) showed that, in Satkhira district, physicians often know as little as their patients about the consequences of arsenic consumption. They frequently treat zengoo and keratoses as within the normal ambit of the skin diseases that they see regularly and they prescribe ointments accordingly. Few are willing openly to admit their ignorance because that might destabilise the doctor-patient relationship, and a minority cynically manipulate sufferers for the cash that comes from writing a prescription, even when there is presently no known cure. At the level of the village health worker, an audit of their diagnoses has shown a 75 per cent false positive identification rate, so there is obviously room for improvement (Rosenboom, 2004). A number of NGOs are now engaged in training medical staff and new pathways are being opened up, in a very small way, for diagnoses via the laboratory testing of hair, urine or nail clippings. This is an expensive procedure but its use is at last beginning to assist with compiling a list of registered sufferers, for whom some remediation may be possible through better nutrition and a switch to the consumption of safe water. The irony here is that the best treatment for arsenic would be to cure poverty since it is people in the lowest income quartile and the malnourished who are most susceptible to arsenicosis and to the accompanying socio-economic fallout (WHO, 2000; Milton et al, 2004; Hadi and Parveen, 2004).

Finally, legal expertise is an area of knowledge that has had little attention so far in the literature on arsenic. Atkins et al. (2006a) have investigated this in the context of a case that is working its way through the British courts. Sutradhar v NERC addresses the claim of a Bangladeshi water consumer that his health has been damaged due to the failure of the BGS, a subsidiary of the Natural Environment Research Council, to test for arsenic in a screening project (Davies and Exley, 1992). We don't have the space to comment further here, other than to say that technical legal arguments have dominated the proceedings so far and that the deployment of the law of torts has demonstrated yet another perspective that may undermine the deployment of science without responsibility in the globalized system of aid giving. The law, because it comes to definitive decisions, gives the appearance of certainty but Atkins et al. (2006a) argue that present definitions of the 'proximity' between international donors and their clients require a fundamental rethink if we are to achieve what Michael Mason (2005) has called the new accountability of environmental responsibility across borders.

Arguments about mitigation

Is it possible to mitigate the impact of the mass arsenic poisoning in Bangladesh? So far the response has been slow, bearing out Mythen's (2004, page 110) view that, in the 'maelstrom of modernity', risks will invariably be dealt with on a 'first-come, first-served' basis.

Bold action has been discouraged by uncertainty about the most suitable approach (Hanchett, 2004). The key debate is between those who want hi-tech and those who prefer low-tech solutions. In the former camp are many water treatment specialists, who wish to resolve a problem generated by technology with a further layer of technology. Their recommendation is to remove the arsenic by chemical reaction. Possibilities include coagulation and filtration, ion exchange resins, activated alumina, and reverse osmosis, all expensive and, in LDCs such as Bangladesh, likely to be restricted to urban situations. Advocates of low-cost technologies are trialling, amongst other ideas, the three kolshi filter, three earthenware jars stacked on top of each other. Unfortunately this and many of the other low-tech systems seem to have substantial disadvantages. Johnston et al (2001) review them and conclude that the delays caused by batch processing often outweigh the attractions of low cost. Perhaps more likely to succeed are techniques that avoid arsenic contaminated water altogether and seek alternatives, such as the filtration or solar disinfection of pond or dug well water, and rainwater collection from metal roofs or plastic sheeting.

The third mitigation method, and the one of choice for most rural people, is switching to the use of water from deep tubewells (van Geen et al, 2002; 2003). Ahmad et al (2002) found that 72 per cent of their sample of 1,331 arsenic-affected households preferred this solution. To a large extent this is backed by the evidence that the lower aquifers are safer, with minimal arsenic content, although so far their testing has been largely limited to the south coast and the Sylhet regions. Dunn et al. (2006) find that many deep tubewells in Satkhira District are contaminated and knowledge of the deep aquifer in the rest of the country is certainly incomplete. Deep drilling might prove not to be the panacea hoped for by many. With poorly drilled and maintained wells, 'shunting' may take place, allowing water from the higher aquifer to trickle down and contaminate the lower level.

Fourth, in 2004 a decision was made by the BAMWSP to pilot piped water supplies for 30 villages (BAMWSP, 2004b). These schemes will be demand-driven, with a 50 per cent capital grant from the GoB, up to 20 per cent from users and the balance from local sponsorship. This policy direction follows the conclusion drawn by a World Bank mission in September 2003 that, in villages over 250 households, the cost of piping water was less than alternatives such as pond sand filters, domestic chemical treatment or dug wells (BAMWSP, 2003).

Conclusion

There is very little that is certain about the arsenic crisis in Bangladesh and the time has come to admit this indeterminacy. We can perhaps agree that it is a classic example of a human-made crisis, but the first uncertainty is whether there was at root any culpable incompetence. The UNICEF funded some of the drilling work but it cannot been sued by the people of Bangladesh because of the legal immunity conferred by the United Nations system. Rather, it is the NERC that has been tackled, not in Bangladesh but in London. This case opens out fundamental issues concerning the global reach of responsibility for environmental problems in the LDCs (Atkins et al, 2006a).

Second, scientific indeterminacy is shot through most aspects of arsenic poisoning in Bangladesh. Although its geochemical origins are now known, there is a complex relationship between arsenic concentration and the geology, demonstrated in the extraordinary spatial variability of contamination at the local scale. In addition, there seem to be inconsistencies in the depth at which poisoned aquifers are found (Ravenscroft et al, 2001).

Third, there is debate about the threshold level of arsenic that is safe. This is not just a dry technical and administrative argument but a vital one for policy-making. The Bangladesh figure of 0.05 mg/l is respectable internationally but it is one that has been abandoned by the WHO and the USA. The new figure recommended globally is now 0.01 mg/l and adopting this stricter limit in Bangladesh would increase the number of people thought to be at risk from 28-35 million to 46-57 million (BGS and DPHE, 2001). In truth, we are uncertain even about these broad estimates because no satisfactory nationwide testing programme has yet been completed.

Our fourth conclusion is that it is only recently that the scientific capacity for laboratory testing of arsenic has been boosted in Bangladesh and West Bengal. As a result, there has been reliance upon FTKs, which have been shown to be unsatisfactory in a number of ways. It may be that some consumers will have been given incorrect information about whether their tubewells are safe or polluted. The system of painting wells red or green as a safety measure is also under suspicion.

Fifth, a campaign of public awareness-raising has begun but it seems that there are vast areas of Bangladesh where this has so far had no effect. Even many local experts, in the shape of doctors and public health officials, are so ill-informed that diagnosis is woefully inadequate. We are certainly not denigrating the contribution that has been made by Bengali scientists. Nor are we ignoring the potential role of water consumers in deliberative democracy (Atkins et al, 2006b). This conclusion is partly the obvious one of the need for training programmes that must be expedited if the true extent of arsenicosis is to be delineated; but it is partly also about the nature of expertise itself. As Harry Collins has demonstrated, it is time to investigate the distribution of expertise in society at large (Collins and Evans, 2002), which in our case should draw in a range of local knowledges.

Finally, there is much debate about the best approach to mitigation. The argument hinges around the level of technology that should be deployed, but the evidence suggests that neither the hi-tech chemical treatments nor the low-tech use of filters are satisfactory. Both have been extensively trialled and their expense and impracticability for poor rural people make them unattractive. Other alternatives, such as the piping of safe water to each village, seem to be better options. The use of surface water may also be an option.

< Table 1 here >

Overall, it seems to us to be essential to admit what we don't know and to incorporate a discussion of this uncertainty into future policy prescriptions. In Table 1, the arsenic crisis is high in uncertainty and its political salience has risen in recent years. Part of the problem with all six issues has been the purification, in the minds of both scientists and policy-makers, of the arsenic problem into separate environmental and social strands: epistemic communities that have too little dialogue. In looking for clear-cut solutions to this vast and unexpected problem, both groups have either ignored or underestimated its mixed, hybrid profile. As Hinchliffe (2001, page 183) has observed in a different context, 'the contested politics and geographies of human-nonhuman relations continue to be downplayed', with the result that remedial actions tend to exhibit only partial success because of a failure to address the problems of knowability.

In terms of scale, it is essential that policy-making should engage with water consumers at the local level. This is because appropriate solutions and technologies will be place-specific. At the local and regional scales, an integrated consideration of all types of water provision would be the counsel of perfection, rather than addressing each source in turn. An example of this would be solving the drinking water problem by the use of deep tubewells, while continuing with the shallow tubewells for irrigation purposes. Recent evidence suggests that arsenic can be absorbed by a variety of vegetables and cereals and cause health risks quite separate from those associated with drinking water (Das et al, 2004). At the national scale, the problems shared by West Bengal and the areas of Bangladesh south of the Ganges and Brahmaputra, suggest that a consideration of the issues in an international context would be helpful, especially since India, as the upper riparian of most of the rivers that flow into the delta, has geopolitical power over this vital resource. Joint discussions and sharing of technologies would help to ease the tensions that have built up over the water politics of this part of South Asia.

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Table 1. Uncertainty in policy-making

		Uncertainty	
		Low	High
Salience	Low	Bureaucratic politics	Technocratic logic
	High	Politicization	Epistemic communities

Source: after Radaelli (1999, page 763)