The largest identified man-made environmental catastrophe

Richard Wilson, D Phil., Harvard University

Presented at the Royal Geographical Society
9 am Wednesday August 29th 2007
plus corrections and clarifications

Abstract:

The problem of arsenic in South East Asia, particularly Bangladesh is the largest identified man made environmental catastrophe. The catastrophe demands three simultaneous actions.
(1) Understanding the causes of the catastrophe;
(a) why was arsenic present;
(b) why was it made available in drinking water?; and
(c) why did no one recognize what was happening in time to avert the catastrophe?

(2) What exactly is the effect on humans of arsenic in the amounts present in the drinking water?

(3) How can one rapidly bring pure water to the population to avoid further damage? and a fourth question which is less urgent but crucially important.

(4) How can the world avoid such catastrophes in the future whether from arsenic or from some presently unknown cause?

The first three were posed at an International meeting in Dhaka in 1998. I will review the appalling lack of progress in these, especially in item (3) with which I am most familiar.

Introduction

In Bangladesh at the turn of the century there were 60 million people who were drinking water at levels higher than the US EPA standard, and that in a tropical country where water intake is large. As a result many people developed dyspigmentation, (figure 1), keratoses (figure 2) , and skin cancers (Bowen's disease in figure 3). If villagers walk on feet with keratoses they develop gangrene (figure 4) and a foot has to be removed. Internal cancers, bladder, kidney and lung are anticipated in due course. These will be discussed by Alan Smith latter in this session. Estimates vary, but over a million people will have adverse health symptoms before the problem is solved, and between 100,000 and 1,000,000 will die. This exceeds by over tenfold the Chernobyl catastrophe, where less than 100 died outright and 1,200 children developed thyroid cancer, of which only 20 have proven fatal. Calculations predict that there will be 5,000 fatal cancers from Chernobyl in Belarus, Ukraine and Russia and perhaps 20,000 world wide. When other regions, West Bengal, Bihar, and Nepal etc are added in the comparison is even more dramatic.

The Bangladesh catastrophe need not have happened and can therefore be called man-made as much as Chernobyl. Traditionally most Bangladeshis used surface waters. It was world agencies, World Bank, UNICEF and British Geological Survey that encouraged a switch to ground water, and 10 million tube wells had been dug before there were serious searches for arsenic. There was a lawsuit, being discussed later in this meeting, against the parent of British Geological Survey. I am not a proponent of lawsuits in these situations, largely because the blame, if blame is indeed appropriate, should be assigned wider than the above three organizations. The world toxicological community was silent while the wells were being dug. I include myself in that category. To their credit, the World Bank, UNICEF and the British Government have reacted positively to help. I call upon the whole world scientific community to help also.

The prior information

Arsenic has been known to be acutely poisonous for 3 millenia, but it was not realized to be dangerous at chronic (low repeated) doses. Following the Paracelsus' maxim that "the dose makes the poison". Dr Fowler of Edinburgh recommended low doses for stomach upsets about 1788. Fowler's solution is in the British Pharmocopeia. At intermediate doeses, arsenic has been used as a cure for syphilis before peniciin was produced, and as a cure for leukemia. Before chlorinated hydrocarbos were used, 1970, the USA sprayed 20,000 tons of arsenic a year on our crops and forgot about it. But warnings began to appear. Hutchinson in 1888 reported, in a prestigious British Journal, dyspigmentation, keratoses and cancers from continuous doses of Fowler's solution. One such is shown in Figure 5. The famous epidemiologist Sir Richard Doll informed me that many years ago his father got cancer from continued use of Fowler's solution. Then in 1895 arsenic was sprayed on vineyards in France and vineyard workers developed lung cancer. About 1903 there was the Manchester beer epidemic where beer had been made from arsenic contaminated water near Manchester and many ailments resulted. Notably, a Royal Commission reported on this, chaired by one of the brightest scientists of the 19th century, Lord Kelvin. In the 1920s arsenic was found in air pollution from smelters, and was shown to cause lung cancer. Also in the 1960s, a rare liver tumor, angiosarcoma was found in farmers. There were also reports of an incident in Japan where some cancers were found more than background but the number was small. In 1966 C.J.Chen showed that in an area of Taiwan NE of Tainan, that death rates from internal cancers were 100 times more probable than the US EPA calculation. All of these were IGNORED or attributed to lung ingestion, and/or a threshold process. Indeed the US EPA only proposed a modification in the arsenic standard 14 years later! But I suggest a fourth (unstated) reason they were ignored is that rats and mice did not get cancer at appropriate doses. For most of the 20th century toxicologists had depended on rats and mice to give them warning of impending human problems. Moreover dogs, a species closer to man than rats and mice thrived on arsenic. It gave a sheen to theiir coats. Chickens are still fed arsenic as a growth enhancer in their feed. . But this time the comparison method method failed. We did not notice.

The realization

It is convenient to consider the first of three International Conferences and subsequent smaller ones, on Arsenic, held jointly by the Dhaka Community Hospital (DCH) and SOES, Jadavpur University, Kolkata, in February 1998, as a turning point in public attention to the arsenic problem. The 200 participants saw over 165 victims of chronic arsenic poisoning which number is more than most US dermatologists see in a lifetime. Most of the participants added a strong emotional reaction "we must do something" to their intellectual curiosity.

The following general observations were made in a "Dhaka Declaration" at the end of the 1998 conference:

1.) The groundwater of a significantly large area in Bangladesh is contaminated with high concentration of arsenic;
2.) The cause of this arsenic contamination is geological
3.) Supply of arsenic free water is the only solution;
4.) This could also happen in other parts of world ; and
5.) Coordinated and concerted efforts are needed from National and International organizations

and individuals to overcome this severe problem.
6.) The arsenic contamination of groundwater in Bangladesh needs to be addressed on an emergency basis;
7.) We shall direct our research for the benefit of all people;
8.) We shall use our knowledge and expertise and unite resources available to us to determine appropriate community based, affordable and sustainable water supply solution;
9.) We shall work in a concerted manner to protect and save people from the arsenic problem, ensure treatment of all patients and identify those at risk;
10.) We agree to share information amongst ourselves, make our findings freely accessible and allow others to use them for the interest of all people
11.) We shall assist in the setting up of organizations/ canters for research, training, storage and dissemination and all over the world.

The second meeting from December 13-15th 1998 at DCH discussed several specific ideas although these were not specifically recorded..
(a) It is important to have a national survey of all wells
(b) to encourage “well-switching”; that is to encourage all villagers to switch their use of water from unsafe wells to safe wells without arsenic;
(c) as a "rapid" but (temporary) measure install temporary (household scale) arsenic-removal devices; and
(d) use deep wells (deep enough to penetrate a clay layer) while studying in detail the hydrological effects .
(e) explore a return to surface waters.

These and subsequent meetings emphasized a sense of urgency:
“Act immediately! Remember: a day lost is a few lives lost!” (Dhaka declaration in 2000)
“Less words and more deeds, please!” (Dhaka declaration in 2002).

Now 9 years later progress has been mostly discouraging. It is appropriate to consider the progress, the obstacles, and suggestions for the future.

How does the arsenic get into the water?

There has been considerable progress. In 1998 two alternate hypotheses were being suggested - the oxidation hypothesis and the reduction hypothesis. In the first of these lowering of the water in the relevant aquifer by continuous pumping was presumed to lay bare iron arsenide, and allow the iron to be oxidized and release the arsenic. A modified proposal was that the lowering was caused by the barrage across the Ganges river (has particular difficulty because the relevant aquifer is fed by rainfall not by the river level. The reduction hypothesis is now considered to be the correct one. As MacArthur states It becomes increasingly clear that severe arsenic pollution of ground water in most alluvial aquifers worldwide is driven by the microbially-mediated metabolism of organic matter, with FeOOH acting as the source of oxygen: the oxide is reduced during the process and its sorbed arsenic is released to ground water. Despite the widespread acceptance of this mechanism, much about it remains obscure." We will hear more from John MacArthur about this later today. Peter Ravenscroft also has a world map showing which explanation is applicable to which region.

What are the effects? Is there a cure?

Progress in the epidemiological studies about the effects is inherently slow, but nonetheless progress is being made. Prior information suggested that by eating a good diet, with fresh fruit and vegetables, cancer rates can be cut in half, even for lung cancer which is known to be caused by cigarette smoking. In addition the effects of chronic arsenic poisoning have been made much clearer by epidemiological studies and analyses of other situations: m Argentine, Chile, Inner Mongolia and Taiwan .

Attending to the sick

Attending to the sick (about 60,000 identified at today's count) should usually be considered a very high priority in spite of the general rule "an ounce of prevention is worth a pound of cure". Although a complete cure for arsenic lesions does not seem to be possible, the disease in its early stages (dyspigmentation) may be reversible with supply of good water and a good diet. More important, however, is that dyspigmentation and keratoses need not lead to complete disaster. Walking on a bare foot with keratoses leads to other complications like gangrene, and maybe untimely death. Timely treatment, and support for the victim's family, can avoid these dire consequences. It is hard for an overseas group to attend to this treatment and no Bangladesh government agency emphasizes this. It was left to groups such as Dhaka Community Hospital to use their limited resources for the purpose. While an economist might argue that use of funds for attempting to treat the incurable is less effective than other uses, great confidence can be established by any organization that pays attention to the sick.

Getting pure water to the People.

The first issue is clearly to find out who is affected. In this we needed a survey of all wells in the country. A "Rapid Action" survey was begun in 1998 by DCH and others. But a complete survey took a few years. In 2002 measurement problems became evident. Even a comparison of laboratory equipment for measuring arsenic showed appalling reliability. Even one of the best laboratories had measurements way out of line. This had improved by 2004, but the field test equipment, while adequate on average, may still leave a lot to be desired. Most arsenic was being measured with field kits which are unreliable if not carefully used. Perhaps 20% were inadequately measured. Even 20% IS TOO MUCH. It is vital that everyone concerned, villagers, advisors, health authorities, have confidence in the measurements or it will be hard to persuade people to act upon these measurements.

Well switching: the big success

Once the arsenic level in wells have been reliably measured and the wells painted green or red, it is important to encourage switching to use of the safe wells. Some estimates are that only 30% of villagers have switched wells. While this fraction is not high enough, there are still 20 million villagers who now have pure water instead of the impure water they drank before. In the Ariahazar upazilla, Columbia University researchers report the fraction rose to 60%. I attributed this to the intense village-education programme. Therefore the most important remediation effort that could be immediately undertaken is a massive education programme - particularly among the women in the villages. However instead of touting this success, and drawing the obvious conclusion to build upon it, both the Government of Bangladesh and the NGOs have been remarkably quiet.

Deep Tube Wells

In 1998 it was already known that many communities in southern Bangladesh and Dhaka itself obtained their water from deep tube wells which tap an aquifer below a clay layer where the water chemistry was such that the arsenic in the solid phase was not made available in the water. In 1998 overseas experts, which included Allan Smith who is here today, myself and probably Peter Ravenscroft recommended that drilling these deep wells be a national priority. But the Bangladesh government demurred. A report by Islam and Uddin in 2002, which sees to have been the basis for the National Water Policy in 2004 recommended that::

I Arsenic safe aquifers must be protected from future contamination at any cost.

II - Research should be undertaken before any decision is taken to withdraw large amount of water from the presently arsenic safe Late Pleistocene-early Holocene aquifer.
III Till definite data are available about the recharge of these aquifers they should not be allowed for exploitation. In arsenic affected areas, no new tube wells be installed even in the presently arsenic safe aquifer to protect the presently safe water resources.
Tube wells should be considered as the last option. In case no other alternative water supply options .... in very limited areas deep tube wells may be considered.

Even as late as 2004, the Government of Bangladesh adopted a national water policy which inter alia, in their section 5.2.2 proposed to "give preference to surface water over ground water as source for water supply". The negative approach inevitably delayed the widespread installation of deep tube wells even though funding was available. Everyone agrees that there are concerns which must be understood.

Fortunately the Department of Public Health Engineering (DPHE) ignored this policy and installed 80,000 deep tube wells by 2005 providing pure water for 1,500,000 people.

We must all applaud this success

In 2006, DPHE produced an excellent detailed report, chaired by Professor Katim Ahmed, from whom we will hear later today, that goes a long way toward addressing concerns of the waverers and deserves wider circulation than has been achieved, although it can be downloaded from my website (mong others). In particular Table 6.1 of the DPHE report shows that nearly 100% of wells meet the 50 g/m3 standard in some areas. A Japanese group, the Asia Arsenic Network, installed tube wells in the Jessore region of Bangladesh and about half have arsenic above the new WHO standard and about 10% above the old one. This suggested to them, and to other thoughtful critics, that deep tubewells are inappropriate for 25% of the country. Nonetheless most overseas hydrogeologists believe that the deep aquifer will be satisfactory for at least 20 years, (provided that massive use of this aquifer for agriculture is avoided). I note that in response to a question later in the conference, Professor Katim Ahmed stated that the issue is primarily an issue of definition of a deep tube well. The wells dug by Asia Arsenic Network were not deep enough. It is important to advertize this response because critics have raised a pertinent question that must be answered clearly.

Household /Community Arsenic Removal Systems (ARS)

It is obviously possible to remove arsenic from water reliably. There are twin issues:
(a) should arsenic be removed in large central units or in small family size units?
(b) what is the cost and will the equipment be maintained?

It is a reasonable aim for Bangladesh that most water will be eventually supplied centrally or regionally with a pipeline to 80% or more of households. Then skilled engineers can decide on the source of water and method of purification, and guarantee maintenance. But this is some time away, and we will address here more immediate possibilities. A number of groups have addressed simple inexpensive means available to each household. Water is poured into the top container and filters through sand and iron chips to the bottom container where the water is now free of arsenic. It was hoped that these methods would be easily used by villagers, would use local materials, and be affordable. That they would be locally installed was deemed an advantage, because coherent government action, usually perceived to be ineffective in Bangladesh, would be unnecessary It was widely recommended in 1998 as an emergency measure. It was hoped that a million or so such units would be installed pending a longer term solution.

One problem was realized at the outset. The filter material tended to filter the arsenic for a while, and then there would be a "break though" and the filter would not only stop working but give up the arsenic previously removed. The psychological effect of the breakthrough is hard to overstate. It caused distrust. There has been a mixed experience, and certainly not the immediate widespread temporary relief that was the universal hope. Many simple systems were installed. Dipenkar Chakraborti, Meera Smith and John MacArthur all find that systems have stopped working in many places in West Bengal (presumably because of clogging by iron). This is detailed in the 6th report by the Jadavpur University (Kolkata) team[1]. Not only did it seem a waste of resources but it is a tragedy of false hopes. Public confidence was lost. It is difficult to restart such a program. Nonetheless in August 2005, there were 100,000 household arsenic removal units in Bangladesh. Some seem to be successful. What are the components of the success? As we outline the successes below, one thing seems to common to all; there is strong local backup and commitment.

One filter system stands out above all the others. The SONO filter, developed by Abul Hussam of George Mason University in USA and marketed by his brother Abul Munir in Kushtia, and further advertized by his other brother Abul Barkat of the University of Dhaka. So far no one has seen a break through in his system, and in January 2007 Abul Hussam was awarded the Grainger prize, by the US National Academy of Engineering, of $1,000,000 for its development.

It seems clear that the reliability and effectiveness of Arsenic Removal Systems depends upon the water chemistry, and probably on the maintenance. It is also unclear whether laboratory experience is predictive of performance in the field. One feature stands out to the present reviewers: it seems easier to have success when there is a local organization prepared to stand by their equipment, teach people how to use it, and fix matters when they go wrong.

While in 1998 it was thought that the household systems would only be a temporary measure, by 2005 80,000 systems have been installed (mostly with overseas NGO funding) and it is likely that those with a strong local back up team will retain an important niche in the future especially because of the difficulty of getting an agreed strategy for surface waters.

Surface waters

The failure to develop rapidly surface waters in a sanitary manner has been one of the major failures, and for me a personal disappointment, of the arsenic mitigation efforts. It is important to understand why, and to develop a procedure for the future that avoids the past pitfalls. There was a strong emotional push (of which Professor Dipenkar Chakriborti of West Bengal was, as always, the most eloquent), for returning to surface waters. The country is full of water. Why not learn to use it properly? Alas, that proved to be too difficult. Research, and personnel training have so far been inadequate. Instead of an obvious dual (surface and ground waters) approach, there developed an exclusivity that led to intellectual division and delay.

Since the development of the tube well culture was spurred by problems in sanitation of surface waters it was natural to assume that any return to surface water would be accompanied by an emphasis on sanitation. *That did not occur.* The government reports, while giving a preference for surface waters barely discussed sanitation. Worse still, it was reasonable to hope

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[1] Available from SOES, Jadavpur University, Kolkata- 700032, India. Also on the website: www.soesju.org.

that the International Center for Diarhoehal Disease Research (ICDDRÆB), set up in Bangladesh to study the diseases caused by contaminated surface waters, would take a leadership role in ensuring sanitation. *They did not.* Yet there were guidelines by WHO and others based on extensive experience elsewhere such as the Blue Nile project in Africa. Neither the Government of Bangladesh nor the ISSDR'B bothered to emphasize the WHO guidelines.

The WHO guidelines for construction of a dug well are simple, and aim at ensuring that any water be filtered through a lot of soil before entering the well. Yet few NGOs followed these instructions from the start: Dhaka Community Hospital was one who did. Measurement of bacteria levels (with faecal coliform being the main indicator) was realized to be important from the start and in 2001 I bought for DCH equipment from the University of Surrey for the purpose. But we (both DCH and I) failed to establish a proper testing frequency and in summer 2004 (during the monsoon especially) unforeseen increase arose in bacteria levels.

Failure to Chlorinate, followed by success

In spite of the experience of the rest of the world, that chlorination is important in keeping surface waters free from bacteria, it was rarely used in Bangladesh[2]. The WHO guidelines for chlorination were not clear. Although Chakriborti and a few others knew this, their experience was not taken into account early enough. But starting in early 2006, detailed measurements were made by Mostofa and Youssef at DCH (figure 6) . They found, consistently, that chlorination using US EPA recommended amounts, brings the coliform bacteria levels down to reasonable levels, but they rise again rapidly after 20 days. This suggests that the solution for wells in that area and construction is adding chlorine every 2 weeks. Indeed it is easy to drop a few chlorine tablets in the well in the evening and more frequent chlorination should be easy. According to my information, the bacteria levels are kept low even during the present (2007) major flooding episodes. It may be that the problems with other surface water supply systems can be similarly solved

Why the delay?

Now that it is clear deep tube wells can be a solution for much of the country; that household arsenic removal systems can be s a solution if they are as good as those of Abul Hussam; and that surface water systems can be a solution if constructed according to WHO guidelines and chlorinated, what is to stop a rapid acceleration and solution of the problem? Various estimates of the cost of solving the problem have been made. Abul Hussam thinks that he can supply his filter for $30 and this will cost about $3 a person. DCH reckoned that they can supply clean water for $6 a person. Deep Tube wells can be cheaper. But this does not allow for inefficiencies when others take over. Nonetheless it seems that $300,000,000 would go a long way to solve the problem. This sounds like a lot, but only when one thinks of charitable projects. In modern international affairs the unit of currency is clearly the cruise missile. It could be solved for 20 cruise missiles.

Funding of this magnitude is available but only to the government.. The Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) was started in late 1998 and funded by the World Bank to oversee the issues with about $50 million and was planned to run over 4 years. Yet by 2001 BAMWSP had disbursed only US$2 million of the available funds had been disbursed and water-testing and patient identification had been conducted in only 30 out of 463 upazilas. The World Bank had arranged in an unusually short time a loan of about $50 million dollars at low interest rate. World Bank officials (President Jim Wolfensohn) informed me at

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[2] Professor Abul Hussam told me that his father, a medical officer in the Kushtia region, used to give out chlorine tablets to the villagers. This procedure seems to have been forgotten.

the time of their expectation hat this loan would be spent within two years and more would be forthcoming. My discussions in the year 2000 with the Director General of the Kuwait Fund for Economic and Social Development suggested that a similar loan would be available if the Government of Bangladesh applied for it. I personally carried details to Bangladesh for the DCH meeting in 2000. Funds were available to GoB if they had applied for them. The failure of GoB to even ask the Kuwait Fund directly, even after preliminary overtures had been made, emphasizes the basic problem. Organization at all levels seems to be a major bottleneck. This was well described by a perceptive Harvard undergraduate (Pripya Harish Patel, born in West Bengal) in her paper "Crisis of (organizational) Capacity"[3] . Bangladesh has bright people. They have weather that can provide, with irrigation, 4 crops a year. They have natural gas - enough for export. It is the governmental organization that holds them back. That is where they need overseas help. I note that in every one of the three methods, non governmental help has assisted in solving the problems. For deep tube wells, Columbia University and University of Dhaka scientists have been helpful. For household filters the inspiration of Abul Hussam was essential and for surface waters DCH among others have been vital.

The comparatively limited charitable help available has been very important. But the difficulty always is in ensuring that money gets to the place where the work is being done rather than ending up in endless reports, or wastage. I have been fortunate in finding a dedicated group whose money is spent (comparatively) wisely - Dhaka Community Hospital. I have set up the Arsenic Foundation Inc.(http://www.arsenicfoundation.com) to channel funds to them and to similar groups. Gifts are tax exempt in the USA and through the Charitable Aid Foundation tax exempt in UK also. I outline here some functions which seem appropriate government functions.

Measurement

At the December 2008 meeting at DCH there was a major discussion on measurement and it was emphasized that it was crucially important. Countries have for centuries emphasized the importance of Weights and Measures. A simple calculation showed that it would take over 300 years to measure all wells once if the all the existing laboratory equipment in the country were used. The problem was even worse. An inter-laboratory comparison of laboratory measurements arranged by the International Atomic Energy Agency[4] showed that even some of the best institutions were not measuring properly! Accurate measurement of arsenic in drinking-water at levels relevant to health requires laboratory analysis, using sophisticated and expensive techniques and facilities as well as trained staff not easily available or affordable in many parts of the world. The World Health Organization noted as late as 2006:

-Analytical quality control and external validation remain problematic.
-Field test kits can detect high levels of arsenic but are typically unreliable at lower concentrations of concern for human health.

Reliability of field methods is yet to be fully evaluated. The problem may have been personnel training. In recent years both situations are much improved. A more recent (2006) laboratory comparison of laboratory instruments shows much greater reliability, and also absolute accuracy in most cases. (Alas the absolute accuracy of the DCH arsenic measurements was off by 30%. This has been corrected. But the consistency of the DCH resuts was good in 2002 and good now.) The “field kits” used to measure arsenic rapidly in the field depend upon the color changes when arsine gas is produced, and the interpretation of these depends critically upon the training of the user and was much in doubt. A digital device, the Arsenator, was

3 Available on the website http://arsenic.ws
4 Arranged informally by Dr Pier Danesi of IAEA, now retired, as a public service.

developed in Austria which seemed to reduce the subjectivity in observing the color changes, but for reasons unclear to me has not achieved wide acceptance. The field kits were adequate for measurements above 100 ppb but are inaccurate in the region around 30 ppb where they are still needed. Improvements in the field kits, a switch to use of the Hach kit instead of the Merck kit, made by BAMWSP in 2003, and perhaps also a modification in use of the Hach kit suggested by the Columbia University group (allowing 1 hour for the color to develop) has made the problem of less concern, though not completely solved. Outside consultants repeatedly comment on the importance of easily available testing facilities which are known to be reliable . There has been little progress on the recommendations that there be such facilities in every Upazilla. More troublesome, perhaps, in view of the policy emphasis on surface water, is the almost complete failure of information and testing facilities for faecal coliform bacteria. Even in 2006 neither the problem nor the (partial) solution has been widely discussed or taken up by a government department of weights and measures. But any decision analyst will note that many, if not all, decisions are not based on what is best for the country but on what is best for the decision maker personally. This is a problem for neighboring countries also Maybe a large international NGO can take a lead in helping the national governments in this vital task.

Communication

Inadequate communication between the major actors, their consultants and their well-wishers overseas, is a major problem which is easy to remedy in principle but in practice may be intractable. A major step was taken on January 7th 1998 when Sara Bennett set up the website "Arsenic Crisis Information Centre", http://www.bicn.com/acic/, soon followed by an informal discussion group on the web which is still functioning well (arsenic-crisis@yahoogroups.com). However the site itself has not been updated since 2003. Other websites appeared. My own, the arsenic project website, (http://arsenic.ws) appeared in summer 1998, others from SOES webesite www. dcsoesju@org in Kolkata;
Columbia University, http://superfund.ciesin.columbia.edu/home.html;
London, http://www.es.ucl.ac.uk/research/lag/as/index.htm;
Japan http://www.sos-arsenic.net;
and other overseas NGOs. The Bangladeshi websites have been more static. Although some of these sites are continuously maintained from outside Bangladesh, the use of this method of communication has not been much used inside Bangladesh. Not only are Government of Bangladesh reports not easily made available, they are sometimes impossible to acquire from outside the country. Communication does not consist merely in making ideas and data available, in published papers, on the web and in a data repository, someone also has to look at them; to read them; to try to understand them and to act on them. In a major field of science, physics, there exists the Los Alamos Data Archive where papers are submitted before publication for information and open discussion (incidentally making the peer review process simpler). Yet my attempts to get even western authors to allow their papers to be included on a website before they are published (even when I possess a copy) have mostly failed. Few persons in Bangladesh have sent me reports for posting or cross referencing - and then often only after a specific request from me. Mankind often learns more from mistakes than it learns from successes, and although it is hard to admit failures, it is important to do so to help others. This recommendation is probably the least followed. While some western NGOs (particularly Columbia University) have published extensive papers, these are analyses of data and not the data themselves. Analyses inevitably tend to be biased in favor of the authors' preconceptions. If direct data are available the preconceptions can be analyzed.. Moreover, in order to satisfy copyright and other legitimate demands of journal publishers, the papers have an inherent delay and the role or "preprints" used in basic physical sciences has not been common. There was a temporary improvement when the Arsenic Policy Support Group (APSU) started its website http://apsu-bd.org/. Reports were dated. Authors were noted. But this important forward looking project has ended. The APSU website has not been updated even with APSU reports dated before its

demise. It vanished in mid December 2006. It seems not yet to have been taken over by another GoB organization. I intend, myself, to maintain the arsenic website: http://arsenic.ws as a part of my Harvard University website. I encourage any and all of you to look at it and submit data and articles to be put thereon.

Piped water and the long term

Some aspects of a long term future seem clear. The population is dense even in the countryside so that a regional central water supply, centrally purified as appropriate and with simple piping to each village, is likely to be usual in 50 years time. In most of the world surface waters are used for these centrally purified supplies, and it is possible that this will be the case in Bangladesh However, many experts believe that the central supply will come from deep tube wells in most of the country, following the Dhaka pattern, but clearly there will be regional differences. However even those most optimistic about the ability of a deep aquifer to supply drinking water to all the people argue that the use of the deep aquifer for agriculture, for which less bacteriologically pure surface waters may suffice and uses more than 100 times as much as drinking water, should be discouraged and probably forbidden. A central village well (in most cases a deep tube well) might supply the whole village in situations where most or all tube wells are polluted by arsenic. These wells could be in a school. But the fact that most of Bangladesh has electricity leads to another suggestion. The water can be pumped into an overhead tank whence it can be led to water taps throughout the village by simple PVC piping. This has been implemented by Dhaka Community Hospital, using improved dug ells as the source of water, and has proved very successful. In a separate report, (another) Ahmed has shown that villagers are prepared to pay more for running water than they are for arsenic free water and popularity of this system among the villagers, is evident. The Bangladesh Water Supply Program Project is organizing and arranging funding for 300 villages over a period of five years. It seems probable that most of these will use deep tube wells as the water source. I note that once clean deep tube well water is pumped to an overhead tank, or carried some distance, bacteria are bound to arise and chlorination must be considered. The overhead tank makes this relatively easy.

Agriculture

In the long term we must be concerned about irrigation water for agriculture. Arsenic pulled out of the ground will be taken up by rice and other foodstuffs. Already there are indications that the uptake by people is equivalent to about 3 micrograms per litre in the water. Continued use can only make it worse as arsenic builds up on the surface. In 1998 Alan Smith proposed a simple experiment. Measure urine samples in a polluted village. Replace water for drinking and cooking with bottled arsenic free water for a week and measure again. The final measure will be due to the food, and the difference due to the water. However this simple direct test has not yet been done. In the meeting one participant mentioned that the rice used in the villages has much more arsenic than the rice used for export. It is important to advertize this fact, because it appears that the Government of Bangladesh has been reluctant to mention arsenic in rice for fear of upsetting the export market. As we consider the arsenic in the surface soil as a result of pulling arsenic out of the ground, we should also remember that arenic is still being fed as a growth enhancer to chickens, and the arsenic will inevitably appear in the farm waste.

Future carastrophes

The Nobel Laureate Niels Bohr commneted that it is hard to make predictions, especially for the future. Another scientitist wisely comented: “all models are wrong; some models are useful”. Sir Austen Bradford Hill, in a Presidential address to the Royan Statistical Society in 1965 discussed the attributes of an association between two variables that might lead one to assign causality. Clealry the relationship between carcinogenic potency in rats and mice and in in people, about which I wrote in 1979, is not causal. It can only be used as a useful guide. But exceptions must be noted and fully explored. That I and others failed to do. We must be more alert in the future.

Conclusion

Although we must all be disappointed that 2/3 of the villagers who drank arsenic laden water still do so after 9 years, it is possible to see changes. Although a new National Water Policy has not formally recognized it, deep tube wells are accepted in Bangladesh and are being installed. After some delay chlorination has now been shown to be effective so that surface waters may be really viable. Household arsenic removal units can work. I look forward to a complete resolution of the problem in another 9 years on my 90th birthday.

In concluding I wish to thank Keith Richards, Hugh Bremmer, Peter Ravenscroft and the Royal Geographical Society for inviting me, and I thank also the multitude of scientists, too numerous to name, who have discussed arsenic with me and influenced my thinking since 1978.

Figures

Figure 1 Typical dyspigmentation of the hand

Figure 2 Keratosis of two feet

Figure 3: A keratosis can turn to gangrene

Figure 4; This case of Bowen's Disease (skin cancer) occurred near Huhhot, Inner Mongolia

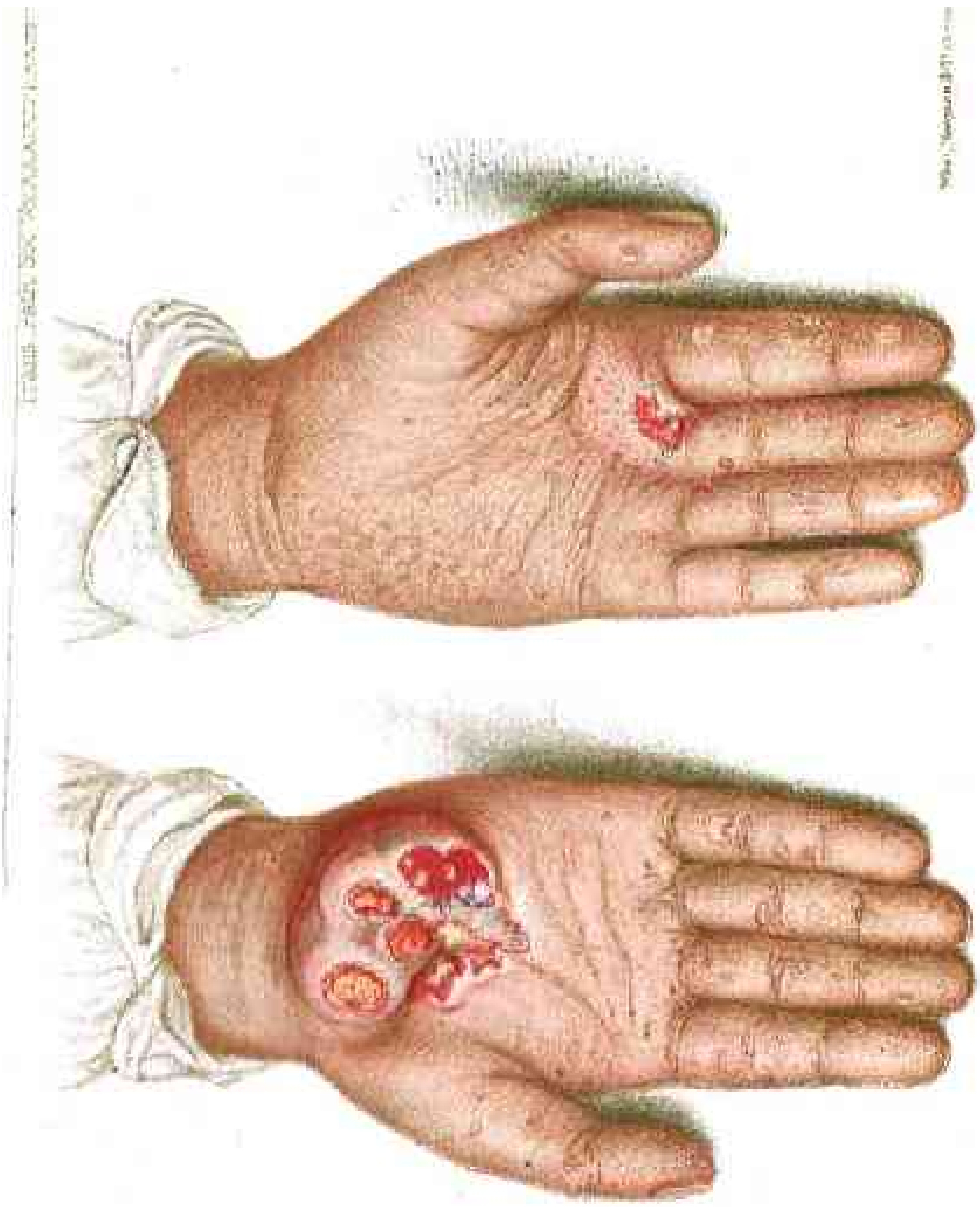


Figure 5. Skin Cancer observed in 1887 from use of Fowler's Solution

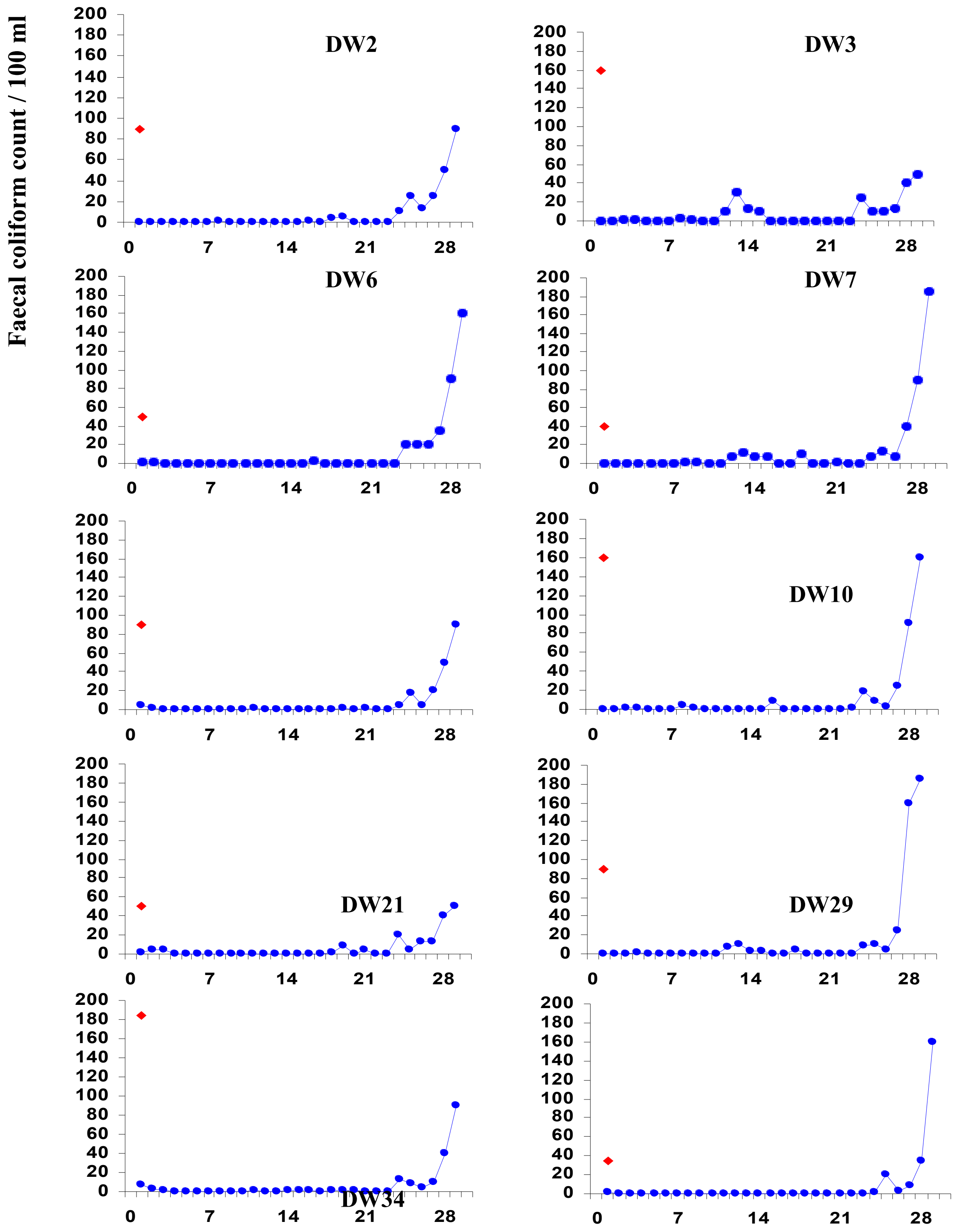
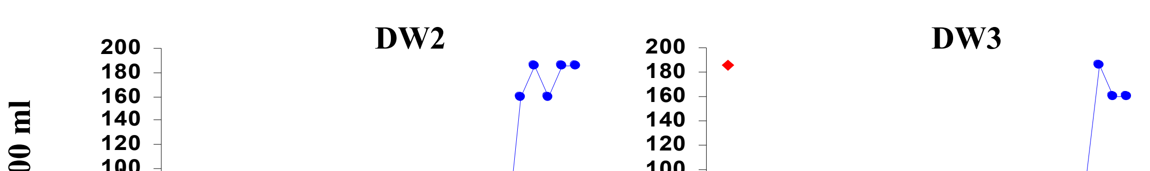


Fig 6A **Col**liform count in water samples of 10 dugwells (DW2, DW3, DW6, DW7, DW8, DW10, DW21, DW29, DW34, and DW66) of Pabna district in the month of July. Faecal coliform was measured before and after adding chlotech. Faecal coliform (chlotech -), ● Faecal coliform (chlotech +)



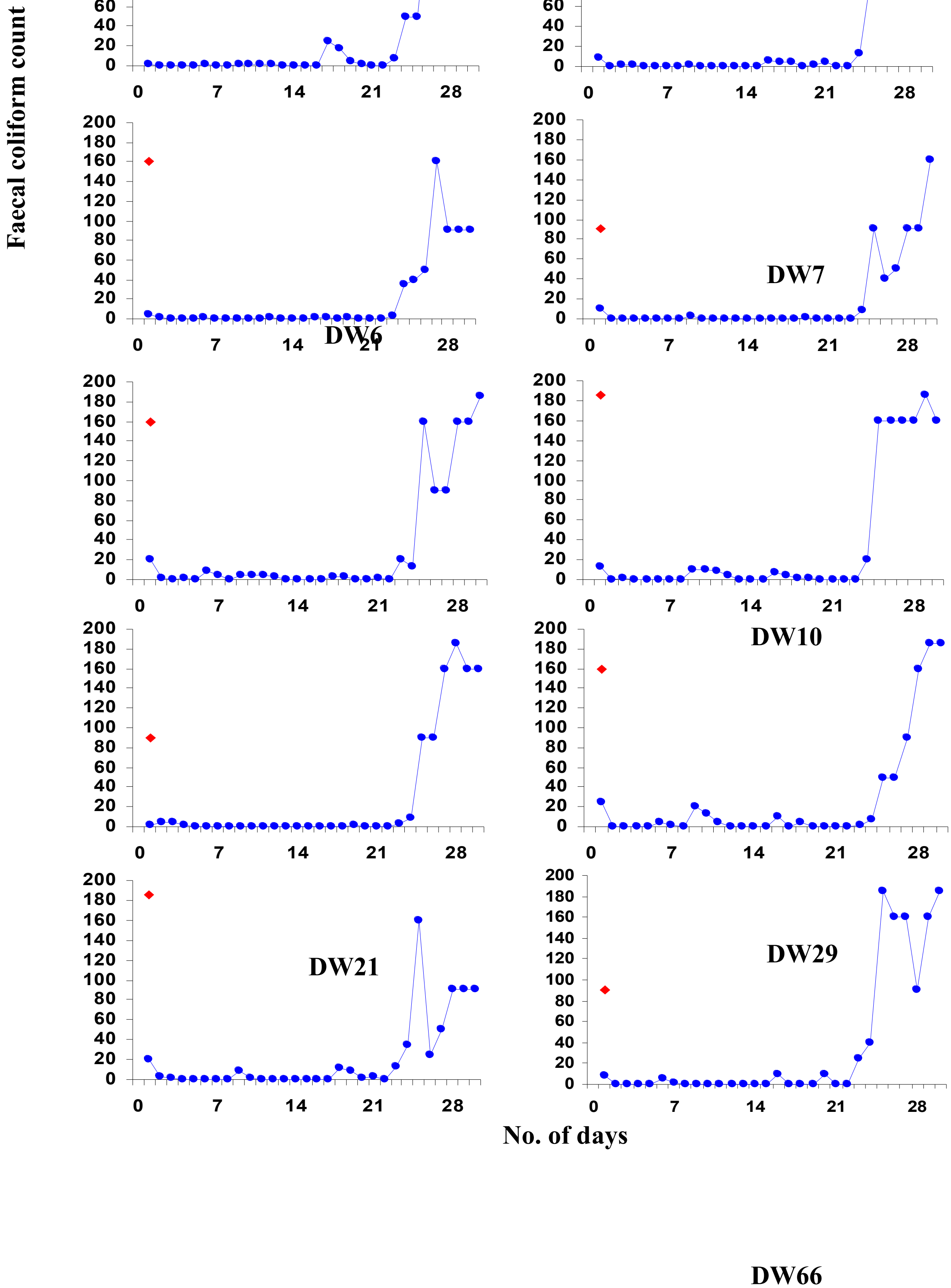


Fig 6B: Faecal coliforms count in water samples of 10 dugwells (DW2, DW3, DW6, DW7, DW8, DW10, DW21, DW29, DW34, and DW66) of Pabna district in the month of August. Faecal coliform was measured before and after adding chlotech.

♦ Faecal coliform (chlotech -), ● Faecal coliform (chlotech +).