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MOBILE NOTE 1

Arsenic in drinking water

Introduction

Arsenic is a naturally occurring chemical widely distributed throughout the earth's crust with a number of commercial uses, primarily in preservatives and alloying agents. It can be introduced into water through the dissolution of minerals and ores, and from industrial effluents and emissions.

Arsenic can also be consumed by humans via contaminated foodstuffs e.g. due to wide use of arsenic-based pesticides in the past.

However, such arsenic is organic and in that form has extremely low toxicity. Drinking water containing inorganic arsenic therefore represents by far the greatest hazard.

A number of regions in Asia, most notably the Ganges delta in Bangladesh and West Bengal (India), have extremely high concentrations of arsenic in groundwater. Affected aquifers are generally alluvial or deltaic with the arsenic-containing sediments being deposited by major rivers in the region (Red River, Mekong, Ganges, Brahmaputra, Meghna) from Himalayan source rocks (Rosenboom, 2004).

In Bangladesh and West Bengal, most drinking water used to be collected from rivers and ponds which contained little or no arsenic but were contaminated with water-borne diseases such as diarrhoea, dysentery, typhoid, cholera and hepatitis.

Intensive programmes to provide 'safe' drinking water through protected groundwater sources (mainly tubewells) have helped to control these diseases, but in some areas they have had the unexpected side-effect of exposing the population to a new health problem – arsenic.

The World Health Organization (WHO) has also compiled reports of cases of arsenic in drinking water in other countries such as Argentina, Chile, Ghana, Hungary, Mexico, Taiwan, Thailand and the United States of America.

How inorganic arsenic is mobilised (i.e. is released into groundwater in a harmful form the chemical compounds and ores that hold it) is still unclear; a number of chemical pathways have been proposed, and recent studies suggest that certain bacteria may be involved. What recent research has found, however, is that geochemical conditions and processes which give rise to the arsenic problem in the Ganges delta are not anomalies or unusual, and may occur in many geologically recent alluvial deposits such as river deltas.

Health effects of chronic arsenic poisoning

The effects of ingesting arsenic-contaminated drinking water (arsenicosis) may not be apparent for a number of years. The first visible effects involve skin disorders such as hyperpigmentation, depigmentation and keratosis, and peripheral vascular disorders such as Blackfoot Disease, endemic in south-west Taiwan. With time, skin cancer may develop and the risk of other internal cancers (bladder, kidney, liver, and lung) is increased. Cardiovascular and neurological diseases have also been found to be linked to arsenic ingestion.

Although there are indications of a dose-response relationship between levels of arsenic exposure and arsenicosis (e.g. Haque et al, 2003), high concentrations of arsenic in a community's well do not necessarily correlate with high levels of arsenic symptoms, suggesting that other risk factors may also play a role.

For example, studies suggest that malnutrition and hepatitis B will accentuate the effects of arsenic poisoning (Mitra et al, 2004).

Early, milder symptoms (such as hyperpigmentation) can normally be reversed by the patient drinking only arsenic-free water.

However, this does not seem to be effective for later manifestations of arsenicosis. Other potential treatment methods being investigated include zinc and selenium supplements (arsenic agonists), antioxidants with vitamins A, C and E, and chelating agents which bind arsenic in the body so it can be excreted.

WHO Guidelines for Drinking-Water Quality

The WHO Guidelines for Drinking-Water Quality are intended for use as a basis for the development of national standards in the context of local environmental, social, economic, and cultural conditions. The latest edition of the Guideline Recommendations (2004) recognises inorganic arsenic as a documented human carcinogen and provides a provisional guideline value of 0.01mg/L drinking water.

Prior to 1993, the WHO guideline value was 0.05mg/L and this still remains for many countries either as the national standard or as an interim target before tackling populations exposed to lower but still significant concentrations in the 0.01-0.05mg/L range.

The WHO 0.01mg/L value is provisional because of scientific uncertainties surrounding risk assessment of carcinogenicity, the lack of suitable testing methods at low concentrations, and the practical difficulties of removing arsenic from drinking water. It is also for these reasons that many countries (especially in the developing world, but also the USA) have retained the 0.05mg/L value.

Testing for arsenic

Measuring arsenic in drinking water traditionally required laboratory analysis, often using sophisticated and expensive atomic adsorption spectrophotometers (AAS) that demand special facilities and trained staff, prohibitively expensive in developing countries. Even where AAS is available, quality control and external validation remain a problem.

The arsenic levels in each particular well appear to be unrelated to those around it, meaning that no generalisations can be made and every well must be tested individually. In addition, the arsenic levels may change over time and so should ideally be monitored on a regular basis. Laboratories simply do not have the capacity to conduct all of the necessary tests.

To overcome these problems, reliable field test kits are needed. A number of kits are currently available on the market, with reasonable (but by no means ideal) levels of specificity and sensitivity. Doubts concerning the reliability of analytical results can cause confusion and concern, and undermine the efforts of those trying to mitigate the arsenic problem. Alternative and/or improved methods are still urgently needed; it seems that many are under design but have yet to be successfully field tested on a large scale.

Mitigation options

Once affected wells are identified, it is vital to provide safe, arsenic-free drinking water quickly for users.

There are two main options:

1. **Finding an alternative safe source** – deep tubewells (since deeper aquifers seem to have much lower levels of arsenic contamination), renovating or constructing shallow dug wells (however, the evidence of reduced arsenic is mixed and such wells present increased risks of microbial contamination), rainwater harvesting (strong option, although for monsoon season only unless sufficient safe storage is provided), surface water sources (possibly with appropriate household water treatment to reduce the high risks of microbial contamination).

2. **Removing arsenic from the water** – new types of treatment technologies are being tested e.g. co-precipitation, ion exchange, activated alumina filtration, slow-sand filtration. These may be developed for either community or household

level arsenic removal. However, a problem with all of these is that the arsenic removed is left in a more concentrated (and so more toxic) form which must be disposed of.

For all of the possible mitigation technologies, it is important to consider potential risk substitution i.e. replacing one public health risk (arsenic) with another (e.g. diarrhoeal disease, vector-borne disease).

There is still a serious need for the development of new technologies that effectively combat the arsenic problem whilst limiting opportunities for pathogen contamination. It is also essential to remember that acceptability and affordability by the potentially affected population are as important for sustainability as technical and economical aspects of interventions and require evaluation. Ongoing support through surveillance of arsenic and microbiological contamination and hygiene promotion will be essential to ensure long-term risk management and allow mitigation strategies to be modified and evolved as necessary (Howard, 2003).

Situation in Bangladesh

The threat to public health presented by arsenic contamination of drinking water has attracted much attention since the 1990s, largely due to the scale of the problem in Bangladesh, described as "the largest poisoning of a population in history" (Smith et al, 2000).

Important reasons for this include the number of people who may be exposed and fear of dramatic future health effects as a result of water already consumed.

The current problem of arsenic in drinking water actually arose from one of the most effective public health measures in Bangladesh over recent years – an extensive tubewell programme which, together with other water, sanitation and hygiene measures, has resulted in a significant decrease in the mortality due to diarrhoeal diseases (Hoque et al, 1996). Approximately 80% of the 130 million population of Bangladesh is currently served by microbiological-ly-safe shallow tubewells. However, in 1993 elevated levels of arsenic were discovered in groundwater and further testing has revealed the massive extent of this new public health threat.

A systematic groundwater survey led by the British Geological Survey examined 3534 water samples from 61 districts (of the total 64).

Although the sample size is small considering the variation of arsenic content within short distances, the study still provides a reasonable indication of arsenic distribution:

- 42% of all tubewell samples

exceeded the WHO guideline value of 0.01mg/L, 25% exceeded the national standard of 0.05mg/L

- Tubewells >150m deep generally show much lower arsenic levels
- An estimated 29 million people are exposed to arsenic levels above 0.05mg/L, around 22% of the total population of Bangladesh

Part of the problem is that most of the tubewells are privately owned, and there is no easy way for the user to know if a given tubewell has a dangerous level of arsenic.

With substantial assistance from the World Bank and Swiss Development Cooperation (a credit of US$32.4 million), the Government has initiated a national program to address the arsenic problem, the Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP). So far, the main activities have focused on water quality testing and control, community screening for arsenicosis and development of suitable mitigation measures:

- The major stakeholders involved in BAMWSP have tested around 4.9 million tubewells, of which 29% (1.4 million) were contaminated with arsenic >0.05mg/L.
- Over 38,000 patients suffering from arsenicosis have been identified through community screening by NGOs and trained health workers.
- Because of the long latency period between exposure and arsenicosis, accurate calculations of the expected burden of disease cannot be made.
- However, even conservative estimates predict at least 200,000 future cases of cancer can be expected based on current exposure.
- From current knowledge, only a few reliable options are available

to provide safe drinking water in Bangladesh, including: shallow hand pumps for zones where arsenic is undetected; arsenic-free water from deeper aquifers (>100 or 200 m); rain water harvesting; pond-sand-filtration; bucket-type household treatment; and piped water supply from safe or treated sources. These are gradually being implemented to varying degrees

- Four new arsenic removal technologies have recently been certified by the Bangladesh Council of Scientific & Industrial Research (BCSIR), meaning that they can now be marketed in the country and made available to affected communities.
- The poor availability of reliable information hinders action at all levels. For this reason, a National Arsenic Mitigation Information Centre (NAMIC) has been established within BAMWSP to provide technical

and operational support to facilitate decision-making.

- Many other sources of information regarding arsenic in drinking water are now also widely available, some of which are given at the end of this document.

Outstanding questions and key issues

Delayed effects from arsenic poisoning, lack of common definitions, and poor reporting and local awareness in affected areas are major problems in determining the extent of the arsenic-in-drinking-water problem and developing adequate solutions.

In addition, knowledge of the health effects of arsenic is incomplete e.g. the dose-response relationship, how factors such as hepatitis B, nutritional status and the actual form of arsenic may affect the health outcome. One major difficulty is determining an accurate level of actual arsenic intake, both due to problems with recall and current methods available for measuring arsenic in water at concentrations important for human health.

The technology for arsenic removal from piped supply is moderately costly and requires technical expertise.

It is inapplicable in most rural areas and some urban areas of developing countries.

The majority of other available mitigation measures each have potential disadvantages and may present alternative health risks which must be considered.

Despite considerable advances in the recognition and mitigation of the effects of arsenic in drinking water, a number of urgent requirements still remain:

- Simple, reliable, low-cost field testing equipment
- Robust technologies for arsenic removal at wells and in households, adaptable to ensure sustainability in different settings
- Increased availability and dissemination of all information

It is also important to remember that whilst arsenic poisoning in Bangladesh and West Bengal certainly presents a massive public health problem, in most developing countries water-related diseases actually represent a much greater overall threat to health than chemical hazards.

In assessing drinking water quality, both microbiological and chemical testing should be carried out and balanced public health decisions made.

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WHO press releases, fact sheets and features, as well as other information on this subject, can be obtained from the WHO internet home page: http://www.who.int/

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