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Arsenic mitigation for safe groundwater

Report by the Secretariat

SITUATION ASSESSMENT

1. The greatest threat to public health from arsenic comes from drinking water, typically through consumption over long periods of water containing low concentrations of inorganic arsenic. Such exposure is associated with several chronic effects, including skin problems such as melansosis, keratosis and cancer, cancers of the bladder, kidney and lung, diseases of the blood vessels of the legs and feet, and possibly also diabetes, high blood pressure, reproductive disorders and impairment of children's intellectual development. Arsenic poisoning (arsenicosis) manifests itself typically over a period of 5 to 20 years. As some affects of arsenic exposure are irreversible, the core public health measure is prevention of human exposure.

2. Arsenic enters aquifers through the dissolution of minerals and ores, resulting in high concentrations in groundwater in some areas. Drinking-water from surface sources does not normally contain high concentrations of arsenic, unless those supplies come from arsenic-contaminated irrigation groundwater. Exposure to inorganic arsenic through the food chain is limited, although absorption by crops irrigated with water highly contaminated with arsenic warrants further research. Absorption of arsenic through the skin is minimal and thus, for example, washing hands or clothes and bathing in water containing arsenic or working in paddy fields with arsenic-contaminated waters do not pose risks to human health. Mitigation strategies should therefore focus primarily on reducing consumption of arsenic-rich drinking-water.

3. Factors that severely limit the ability to determine the extent of the consequences of drinking arsenic-contaminated water include the delayed onset of illness, a lack until recently of common definitions, limited local awareness and poor reporting. In addition, analytical methods to detect concentrations in drinking-water that are significant for health have only recently become readily available in many countries. The unavailability of a test that is simple, applicable in the field and low cost continues to be a significant limit to better understanding of the extent and severity of arsenic contamination of drinking-water and the development of the potential of community-based water-quality testing. WHO's information[1] has led to greater vigilance and acknowledgement of natural arsenic contamination as a cause for concern in diverse countries including Argentina, Bangladesh,

[1] See for example, Gomez-Caminero A. *Arsenic and arsenic compounds.* Environmental Health Criteria 224, second edition. Geneva, World Health Organization, 2001.

Cambodia, Chile, China, Hungary, Mexico, Romania, Thailand, the United States of America, and Viet Nam.

4. About 1 in 100 people who drink water containing more than 0.05 mg/l of arsenic for a long period may eventually die from arsenic-related cancers. This proportion becomes 10% when concentrations exceed 0.5 mg/l.[1] The Taiyuan Declaration on Water Quality and Arsenic (2004) noted in its preamble that 12 countries in Asia were currently affected by arsenic concentrations in groundwater exceeding permissible levels, with at least 50 million people exposed to levels exceeding 50 µg/l. It expressed concern that the combined environmental exposure to date had led to at least 200 000 people developing arsenicosis, a disease for which no cure exists and which results in progressive loss of productivity through disablement and finally death, and furthermore that the exposure of children to arsenic impairs cognitive development and increases the likelihood of adverse health effects later in life.[2] In Latin America it is estimated that at least four million people are exposed to high concentrations of arsenic in drinking-water, primarily rural dwellers consuming water from wells in affected countries, including Argentina, Bolivia, El Salvador, Mexico, Nicaragua and Peru.

5. The mechanism of carcinogenicity and the response to low levels of intake, however, remain uncertain. Significant differences in effects are also reported between countries and regions, for reasons that are not yet adequately understood. Individual susceptibility to arsenic poisoning also differs significantly, depending on age, nutritional status, social conditions and other poorly understood factors. Evidence from Bangladesh, for instance, shows that the impact was marked in poor households, most likely due to nutritional status, greater consumption of water during work, and diet. The chronic progression of arsenicosis may well become a burden to the household and the community's overall financial and time resources. Nevertheless, it is not possible to predict the scale of the health impact.

6. In 1983, the first cases of arsenic-induced skin lesions in India were identified in patients from West Bengal, but by 1987 several cases had been identified in patients from neighbouring Bangladesh. The characteristic skin lesions included changes in pigmentation, mainly on the upper chest, arms and legs, and keratoses of the palms of the hands and soles of the feet. Eventually, with WHO support, water sources used by the patients were analysed, and the finding of high concentrations of arsenic in drinking-water confirmed the diagnosis of arsenic-caused disease.

7. Until the 1970s most drinking-water in rural Bangladesh was collected from surface sources subject to faecal contamination, resulting in diseases such as diarrhoea, dysentery, typhoid, cholera and hepatitis. Groundwater is generally relatively free from pathogenic microorganisms and is readily available in shallow aquifers in the Bengal basin. Consequently, during the 1970s UNICEF worked with the Bangladeshi Government to install tube-wells to improve access to drinking-water for the population, and during the 1980s the local private sector progressively took over from UNICEF; today there are about 8.6 million tube-wells in the country. The tube-well initiative is said to have contributed significantly to the halving of infant and under-five mortality rates in Bangladesh between 1960 and 1996.

[1] Smith AH, Lingas EO, Rahman M. Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. *Bulletin of the World Health Organization*, 2000; *78*(9):1093-1103.

[2] Adopted at the Inter-Regional Conference on Water Quality and Arsenic and Mitigation. (Taiyuan, China, 23-26 November 2004).

8. In centralized water supplies, such as water piped to urban areas, identification of low-arsenic sources and removal of arsenic from water are relatively straightforward. The problem of arsenic contamination is therefore especially pertinent in rural areas with many small groundwater sources. The most common arsenic-mitigation strategies in such areas include use of uncontaminated or less-contaminated wells, replacement of arsenic-contaminated sources by less-contaminated ones, and removal of arsenic from contaminated water before consumption.

9. Wells close to one another may contain water with very different concentrations of arsenic because they tap into aquifers at different depths with different degrees of contamination. Some success has been achieved through colour coding wells to distinguish those suitable for collection of drinking-water from others that may be suitable only for other purposes. In Bangladesh, deeper wells, sometimes 200 metres or more deep, are less likely to be contaminated with arsenic, but they have to be installed carefully to prevent seepage of water from superficial sources, and their long-term sustainability may be questionable.

10. Substitution of water from other less-contaminated sources such as surface waters and rainwater is an alternative mitigation strategy. In such cases, however, “risk substitution” is a concern – for example, replacing the risk from arsenic in drinking-water by the risk of infectious waterborne disease or of mosquitos breeding in water-storage vessels. Rainwater harvesting, particularly suitable in areas with high rainfall such as Bangladesh, has proven effective in some circumstances.

11. Several options exist for removing arsenic from drinking-water. The approaches to effective community-level arsenic-removal systems include:

- ion exchange, using commercially produced synthetic resins that can remove some compounds from water; these resins remove arsenates but not arsenites

- filtration with activated-alumina (commercially available in coarse grains); activated alumina beds usually have much longer run times than ion-exchange resins – typically, several tens of thousands of beds can be treated before the alumina needs to be regenerated or replaced. Activated alumina works best in slightly acidic waters (pH 5.5 to 6.0)

- sand filtration. When arsenic-rich water also contains high concentrations of dissolved iron, removal of the iron by filtration will also remove much of the arsenic. Thus, the three-pitcher water-filtration system (in Bangladesh) and “bio-sand” filters (in Cambodia and Nepal) have been found to operate effectively at household levels and at relatively low cost.

12. To be successful, efforts to modify behaviour in favour of use of alternative sources or household treatment of water must be supported by communication. Long-term solutions should therefore include wide-scale education and training about the harmful effects of arsenic and how to avoid them.

13. In some cases, no single technology alone can provide communities with a sustainable, continuous and affordable supply of safe water. If a water source that is safe year-round is not available, it may be necessary as a short-term solution to use one source (for instance groundwater or rainwater) during wet seasons and another during dry seasons (for example, contaminated water after removal of arsenic or pond water treated with household disinfectant).

14. In all cases, technologies should meet several basic technical criteria: the water supplied must be chemically and microbiologically safe; systems should be able to supply water in adequate

quantity, throughout different seasons; the technologies should be robust and the wastes produced should not have an undue adverse effect on the environment; and operational safety should be ensured.

15. If a satisfactory water source free from unsafe concentrations of arsenic cannot be established and while a long-term plan is being elaborated, the short-term goal should be to reduce arsenic concentrations in drinking-water, even if regulatory standards cannot be met immediately, because the toxic effects of arsenic are dose-dependent.

ACTION BY WHO

16. WHO has had a stated position on the health risks of arsenic in drinking-water since 1958. Successive editions of *International standards for drinking-water* (1958, 1963, and 1971) and *Guidelines for drinking-water quality* (1984, 1993 and 2004) have published reviews of the data which have led to a progressive lowering of the standard or guideline value in response to emerging evidence of significant health concerns. The current WHO guideline value for arsenic in drinking-water (0.01 mg/l) is provisional in view of scientific uncertainties (see paragraph 5 above). Further information from rigorous epidemiological studies especially on health effects in children and observed in different conditions would assist further development of the *Guidelines*. WHO has also provided updated health-impact information in its Environmental Health Criteria document (see paragraph 3 above).

17. When the arsenic crisis in Bangladesh started, WHO played a major role in identifying the problem and immediately alerted the Government of Bangladesh to the associated health risks, commissioning water-quality testing in the Chapai Nawabganj area in 1993, and organizing a regional consultation (New Delhi, 29 April – 1 May 1997) on policy and mitigation measures. Since 1998 the Government of Bangladesh, supported by WHO and other development partners, has been active in addressing the associated water quality and health issues. WHO staff also cooperated with the Government's technical and advisory committees (including the Arsenic Coordinating Committee) and the coordinating mechanism for external support agencies.

18. In Bangladesh, WHO launched an expanded programme of activities in 1998 in the context of interagency concern, with partners including FAO, UNESCO, the World Bank, IAEA, UNICEF and UNIDO. Joint studies with local institutes tested household arsenic-removal techniques and the quality of alternative drinking-water sources. Studies on the extent of arsenic contamination indicated that between 28 and 35 million people in Bangladesh were at risk of drinking contaminated water; more recent estimates suggest that about 20 million people are at risk of arsenic exposure (i.e. they have ready access to water containing more than 50 ppb arsenic.

19. A United Nations Foundation grant of US$ 2.5 million, approved in July 2000, enabled WHO and UNICEF to support a project to provide alternative supplies of clean drinking-water to 1.1 million people in three of the worst-affected subdistricts in Bangladesh. The project used an integrated approach involving communication, skills building for all stakeholders at subdistrict level and below, tube-well testing, management of patients and provision of alternative water supply options. A concern has been that promotion of awareness and involvement of public health staff has to continue.

20. The WHO/PAHO Pan-American Center for Sanitary Engineering and Environmental Sciences has developed simple field kits for the screening of arsenic content of drinking-water, as well as the technology and a product for household-level removal of arsenic from drinking-water, which have been applied in Argentina, Mexico and Peru. WHO's response in the Region of the Americas has also

included providing guidance to countries on risk assessment and risk management in rural communities in Argentina, Mexico, Nicaragua and Peru.

21. International recognition of arsenicosis in Bangladesh and West Bengal, India, since the early 1990s has led to intensified efforts worldwide to assess the gravity of the presence of arsenic in drinking-water. WHO's contribution has included cooperating with countries to assess the potential risk to their populations and with other organizations of the United Nations system to produce a state-of-the-art review, which will be published in 2006. It also includes development and testing of arsenic remediation technologies.

22. Recognizing the need for internationally-recognized case definitions for arsenicosis, WHO developed a field guide to detection, management and surveillance of arsenicosis.[1]

23. The consequences of drinking water containing arsenic exemplify emerging concerns relating to drinking-water and health. In addition to arsenic mitigation activities and cooperation with Member States actually or potentially affected by arsenic-contaminated drinking-water. The Secretariat has been working to increase preparedness for other emerging issues, for instance through developing a simple tool for rapid assessment and screening to determine what chemicals in drinking-water were likely to pose a danger to health.

ACTION BY THE EXECUTIVE BOARD

24. The Board is invited to note this report.

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[1] WHO. *A field guide for detection, surveillance and management of arsenicosis*. New Delhi, WHO Regional Office for South-East Asia, 2004.