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EDITORIAL

Arsenic and Contamination of Drinking-water in Bangladesh: A Public-health Perspective

The article by Mitra and colleagues in this issue of the Journal presents an interesting scenario on arsenic contamination from Bangladesh (1). The paper further confirms the health effects of arsenic and contributes to the literature, especially regarding the inverse relationship between body mass index and the duration of disease. Many tubewells in Bangladesh have been contaminated with arsenic that exceeds both the World Health Organization (WHO) guideline of 10 μg/L and the Bangladesh permissible limit of 50 μg/L. This arsenic calamity of well-water in Bangladesh can be described as the largest known mass poisoning in history, with more than 29 million people exposed through their drinking-water (2-5). Numerous other occurrences of arsenic have been reported worldwide. Some countries, such as Taiwan, Chile, and Argentina, have been recognized for several decades, while others, e.g. Nepal and Vietnam, have been recognized more recently (Table 1).

Bangladesh perspective

In 1983, Krishna Chandra Saha identified the initial cases of arsenic-induced skin lesions at the Department of Dermatology, School of Tropical Medicine in Kolkata, India (6). By 1987, he had already identified several cases who came from neighbouring Bangladesh. In 1993, the Department of Public Health Engineering of Bangladesh confirmed arsenic contamination in Nawabganj district (Barughuria union, Sadar upazila). In 1995, Dipankar Chakraborti, School of Environmental Studies, Jadavpur University, Kolkata, convened an international conference on arsenic and raised the awareness about the arsenic problem of West Bengal and the urgent need for more detailed studies in Bangladesh. Since then, several studies have been conducted on arsenic contamination of drinking-water in Bangladesh. To raise awareness of the seriousness of the arsenic problem in Bangladesh, the Dhaka Community Hospital and the School of Environmental Studies, Jadavpur University, Kolkata, convened another international conference on arsenic encompassing a great number of aspects (7). The evidence about the health problems connected with arsenic exposure that has accumulated since 1993 only confirmed that this is a public-health threat of great magnitude (2-5).

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Geology

The arsenic contamination of groundwater derives from geological strata underlying Bangladesh. Arsenic occurs in two oxidation states in water. In a number of areas worldwide, oxidation and dissolution of arsenian pyrite [$Fe(AsS)_2$] and arsenopyrite [FeAsS] are additional processes that lead to high concentrations of dissolved arsenic (8). The oxidation can be promoted naturally through infiltrating oxygenated groundwaters (9) or through lowering of the groundwater table (by pumping) into stratigraphic zone containing arsenic-rich sulphides (10). Arsenic was naturally transported in the river systems of Bangladesh and adsorbed into fine-grained iron or manganese oxyhydroxides. These were deposited in floodplains and buried in the sedimentary column. Due to the strongly reducing conditions, which developed in the sediments in certain parts of Bangladesh, the arsenic was released into groundwater.

Health effects

The characteristic health effects that result from ingestion of arsenic-contaminated drinking-water are slowly manifested, and the diagnosis is usually straightforward. Skin lesions, i.e. diffuse melanosis followed by spotted melanosis, hyperpigmentation, and keratosis, are common and are the first recognized health effects. The new findings by Mitra and colleagues revealed that 82% of patients had moderate to severe skin lesions, and 72% were young adults (1). Skin alteration is a consistent feature of chronic exposure to arsenic, but there is a considerable variation in clinical presentation. The latency (i.e. the time from first exposure to manifestation of disease) for arsenic-caused skin lesions, particularly keratosis, is typically in the order of 10 years (11). The rapidity of the appearance of skin lesions seems to be dose-dependent (11). Men are described to show more clinical presentation of skin lesions than women under seemingly equal exposure levels, which is also consistent with the findings of the study by Mitra and colleagues (1). The most common signs are hyperpigmentation, especially on the trunk, and keratosis on the palms and soles of the feet. Many other signs and symptoms have also been reported in Bangladesh, i.e. chronic cough, crepitations on the lungs, diabetes mellitus, hypertension, and weakness (12-14), which is also consistent with the findings of the new study (1). It is important to note that affected individuals will not necessarily have all manifestations, and the timing of different symptoms may vary.

Table 1. Worldwide occurrences of arsenic contamination in water

Location	Potential exposed population	Concentration (μg/L)	Environmental conditions	Source
Argentina	2,000,000	1-2,900	Natural; volcanic rocks and thermal springs	Groundwater
Bangladesh	>29,000,000	1-4,730	Natural, alluvia	Groundwater
Bolivia	50,000	-	Natural and anthropogenic	Surface water and groundwater
Chile	500,000	100-1,000	Natural and anthropogenic; basin lakes, thermal springs, mining	Surface water
China	>500	40-750	Natural; alluvial sediments	Groundwater
Greece	150,000	-	Natural and anthropogenic; thermal springs and mining	Surface water
Hungary, Rumania	400,000	2-176	Natural; alluvial sediments; organics	Surface water
Inner Mongolia	>400,000	1-2,400	Natural; alluvial and lake sediments; high alkalinity	Groundwater
Mexico	400,000	8-620	Natural and anthropogenic; volcanic sediments, mining	Surface water and groundwater
Nepal	-	-	Natural, alluvia	Groundwater
Spain	>50,000	1-100	Natural; alluvial sediments	Surface water
Taiwan	>100,000	1-1,820	Natural	Groundwater
Thailand	15,000	1-5,000	Anthropogenic, mining	Surface water
Vietnam	>1,000,000	1-3,050	Natural, alluvia	Groundwater
West Bengal, India	>1,000,000	10-3,880	Natural, alluvia	Groundwater

Arsenic as a carcinogen

Mitra and colleagues also identified a case with skin cancer (1). Arsenic was one of the first chemicals recognized as a cause of cancer (15). As early as 1879, the high rates of lung cancer among miners in Saxony were attributed, in part to inhaled arsenic (16), although radon progeny exposure was later pointed out as the main risk factor. A few years later in 1887, Hutchinson first described skin cancer in patients treated with arsenic-containing medication for psoriasis and other skin conditions (17). In the 1930s, evidence suggested arsenic as causing skin cancer (18), and subsequently, data from several countries confirmed this, including studies on a large population in Taiwan (15,19). In the 1960s, evidence emerged in Argentina that arsenic in drinking-water might cause internal cancers, particularly of the lung and urinary tract (20). In 1985, surprising results from Taiwan showed an increased mortality from several cancers (21). Such high rates of cancer were unprecedented for any water contaminant. In 1988, the United States Environmental Protection Agency (USEPA) estimated that the ingestion of 50 μg/L of arsenic results in a skin cancer risk of 1 in 400 (22). By 1992, the risk of internal cancer was estimated to be 1.3 per 100 persons at 50 μg/L (23). The combined evidence from Taiwan and elsewhere was sufficient to conclude that ingested inorganic arsenic was likely to cause several internal cancers (24,25), i.e. the main causes of death due to chronic ingestion of arsenic in drinking-water are internal cancers rather than skin cancer.

Dramatic increases in mortality rates from internal cancers have been reported in Taiwan and Chile

(26-29). Skin cancers are not usually fatal if appropriate treatment is offered. In Taiwan, populations highly exposed to drinking-water containing an average of 800 µg/L of arsenic had relative risks (compared to those who are not exposed) of developing urinary bladder cancer in the order of 30-60 times. In the affected areas of Chile, an estimated 5-10% of all deaths of those aged over 30 years are attributable to arsenic-related internal cancers, particularly bladder and lung cancer (28,29). In Argentina, a mortality study during 1986-1991 in the arsenic-exposed region of Cordoba showed increased risks of bladder and lung cancer among both men and women despite lower exposure levels than in Taiwan or Chile (30,31).

In 1993, the WHO recommended lowering of arsenic in drinking-water to 10 µg/L (32). An assessment of risks estimated that the combined cancer risk and other epidemiological associations found in Taiwan have since been confirmed in Chile (28,29), Argentina (30,31), and Japan (33). Later, two reports of the National Research Council (NRC) affirmed that cancer risks might be in the order of 1 in 100 for 50 µg/L (34,35). This estimated cancer risk is much higher than for any other drinking-water contaminants with a maximum permissible limit (Table 2).

million people in Bangladesh are exposed above the permissible limit–which are conservative estimates–the present generation may suffer from an excess of 200,000-300,000 arsenic-related cancer cases, if they live long enough, and if exposures are not rapidly reduced. This is in addition to non-malignant arsenic-related diseases, and the far more common arsenic-related skin lesions. There is no basis to think that the people of Bangladesh would have any lower risks than populations of other countries, and, in fact, the poorer nutritional status in Bangladesh may indeed increase the risk.

Although there are uncertainties concerning specific estimates of current and future health effects of arsenic exposure, the following may be inferred with regard to Bangladesh. There are large numbers of cases that currently have skin lesions due to ingestion of arsenic, and many more cases will occur if exposure continues. Based upon what is known about the relationship between the ingestion of arsenic and the development of internal cancers, one would expect marked increases in mortality due to internal cancer once the latency periods have been passed. The increase in these cancers will likely be detected only through epidemiological studies, since neither the individual cancer patients nor their physicians will understand that the cancer was arsenic-related.

Table 2. Presence of carcinogenic agents in drinking-water with maximum permissible limit and calculating excess cancer risk according to WHO (32) and USEPA (36,37)

Chemical	µg/L	Excess cancer risk (per10-5)	Reference no.	µg/L	Excess cancer risk (per10-5)	Reference no.
Arsenic	10	60	32	50	1000	36,37
Benzene	10	1	32	5	0.2-0.8	36,37
Benz[a]pyrine (PAHs)	0.7	1	32	0.2	4.2	36,37
1,2 Dichloroethane	30	1	32	5	1.3	36,37
Hexachlorobenze	1	1	32	1	4.6	36,37
Vinyl chloride	5	1	32	2	8.4	36,37

The ecological studies of arsenic-exposed populations in Taiwan, Chile, and Argentina have been the primary source of information implicating aetiology of arsenic in cancers of skin, lung, bladder, and possibly other organs. The health effects of arsenic exposure through drinking-water have been studied for a longer period in these other countries than in Bangladesh. Based on these earlier studies, scientists have modelled cancer risks, and these models suggest that the cancer risk (for all cancers combined) is on the order of 1 in 100 for arsenic exposure levels around 50 µg/L of water. Using the same method, the estimate of risk for 500 µg/L of arsenic in drinking-water would be 1 per 10 persons. Assuming that 29

An overall strategy is required to supply and monitor safe arsenic-free drinking-water for the currently-exposed population. Short-term responses include (i) identification of a nearby tubewell with water of low arsenic content, (ii) treating surface and groundwater, (iii) harvesting rainwater, and (iv) using water of deep aquifers. Community mobilization and motivation will be essential for a sustainable solution to the problem. After implementation of a safe-water method, continuous monitoring of its operation and maintenance is necessary over the course of several months, as people may find the alternative options more complicated and may return to using tubewell water. Twenty-five percent of patients were still drinking arsenic-contaminated water in Mitra's study, suggesting the need for enhancing public awareness (1). Therefore, public education needs to be well-designed and carried out in an appropriate manner regarding risk-reduction options.

In conclusion, the arsenic contamination problem must be addressed in an integrated and comprehensive approach to minimize the risk to the affected population. Prudent public-health decisions should not wait. The rapidity of the response is crucial. The longer the exposure continues, the greater the likelihood of more cases of arsenic-related diseases.

REFERENCES

1. Mitra AK, Bose BK, Kabir H, Das BK, Hossain M. Arsenic-related health problems among hospital patients in southern Bangladesh. *J Health Popul Nutr* 2002;20:198-204.
2. Smith AH, Lingas EO, Rahman M. Contamination of drinking-water by arsenic in Bangladesh: a public health emergency. *Bull World Health Organ* 2000;78:1093-103.
3. McLellan F. Arsenic contamination affects millions in Bangladesh. *Lancet* 2002;359:1127.
4. British Geological Survey. Arsenic contamination of ground water in Bangladesh, 2001. (http://www.bgs.ac.uk/arsenic/bangladesh.html).
5. Ahmed MF. An assessment of arsenic problems in Bangladesh. *In*: Proceedings of the International Workshop on Arsenic Mitigation, Dhaka, Bangladesh, 14-16 January 2002. Dhaka: Local Government Division, Ministry of Local Government, Rural Development and Co-operatives, Government of Bangladesh, 2002: 15-20.
6. Saha KC. Chronic arsenical dermatoses from tubewell water in West Bengal during 1983-87. *Indian J Dermatol* 1995,40:1-12.
7. Dhaka Community Hospital. International Conference on Arsenic Pollution of Ground Water in Bangladesh: Causes, Effects and Remedies. Dhaka: Dhaka Community Hospital, 1998. (http://www.dchtrust.org).
8. Welch AH, Westjohn DB, Helsel DR, Wanty RB. Arsenic in ground water of the United States: occurrence and geochemistry. *Ground Water* 2000;38:589-604.
9. Nickson R, McArthur J, Burgess W, Ahmed KM, Ravenscroft P, Rahman M. Arsenic poisoning of Bangladesh groundwater. *Nature* 1998;395:338.
10. Mandal BK, Chowdhury TR, Samanta G, Basu GK, Chowdhury PP, Chanda CR *et al*. Arsenic in groundwater in seven districts of West Bengal, India–the biggest arsenic calamity in the world. *Curr Sci* 1996;70:976-87.
11. Guha Mazumder DN, Haque R, Ghosh N, De BK, Santra A, Chakraborty D *et al*. Arsenic levels in drinking water and the prevalence of skin lesions in West Bengal, India. *Int J Epidemiol* 1998;27: 871-7.
12. Rahman M, Tondel M, Ahmad SA, Axelson O. Diabetes mellitus associated with arsenic exposure in Bangladesh. *Am J Epidemiol* 1998; 148:198-203.
13. Rahman M, Tondel M, Ahmad SA, Chwodhury IA, Faruquee MH, Axelson O. Hypertension and arsenic exposure in Bangladesh. *Hypertension* 1999;33: 74-8.
14. Milton AH, Hasan Z, Rahman A, Rahman M. Chronic arsenic poisoning and respiratory effects in Bangladesh. *J Occup Health* 2001;43:136-40.
15. International Agency for Research on Cancer. IARC monographs on the evaluation of the carcinogenic risk of chemicals to humans: some metals and metallic compounds, v. 23. Lyon: International Agency for Research on Cancer 1980: 39-141.
16. Neubauer O. Arsenical cancer: a review. *Br J Cancer* 1947;1:192-251.
17. Hutchinson J. Arsenic cancer. *Br Med J* 1887;2: 1280-1.
18. Arguello RA, Conget DD, Tello EE. Cancer and endemic arsenism in the Cordoba Region. *Rev Argent Dermatol* 1939;22:461-87.
19. Tseng WP, Chu HM, How SW, Fong JM, Ln CS, Yeh S. Prevalence of skin cancer in an endemic area of chronic arsenicism in Taiwan. *J Natl Cancer Inst* 1968;40:453-63.
20. Bergoglio RM. Mortality from cancer in regions of arsenical waters of the province of Corboda, Argentina. *Presa Med Arg* 1964;51:994-1008.
21. Chen CJ, Chuang YC, Lin TM, Wu HY. Malignant neoplasm among residents of a blackfoot disease-endemic area in Taiwan: high-arsenic artesian well water and cancers. *Cancer Res* 1985;45:5895-9.
22. U.S. Environmental Protection Agency. Special report on ingested inorganic arsenic, skin cancer; nutritional susceptibility. Washington, DC: Risk Assessment Forum, Environmental Protection Agency, 1988. 136 p. (EPA-625/3-87/013).
23. Smith AH, Hopenhayn-Rich C, Bates MN, Goeden HM, Picciotto IH, Duggan HM *et al*. Cancer risks from arsenic in drinking water. *Environ Health Perspect* 1992;97:259-7.

24. Bates MN, Smith AH, Cantor KP. Case-control study of bladder cancer and arsenic in drinking water. *Am J Epidemiol* 1995;141:523-30.
25. Bates MN, Smith AH, Hopenhayn-Rich C. Arsenic ingestion and internal cancers: a review. *Am J Epidemiol* 1992;135:462-76.
26. Chen C-J, ChenKuo T-L, Wu M-M. Arsenic and cancers (letter). *Lancet* 1988;1:414-5.
27. Chen C-J, Chen CW, Wu M-M, Kuo TL. Cancer potential in liver, lung, bladder and kidney due to ingested inorganic arsenic in drinking water. *Br J Cancer* 1992; 66:888-92.
28. Ferrecio C, Gonzalez, Milosavjlevic V, Marshall G, Sancha AM, Smith AH. Lung cancer and arsenic concentrations in drinking water in Chile. *Epidemiology* 2000;11:673-9.
29. Smith AH, Goycolea M, Haque R, Biggs ML. Marked increase in bladder and lung cancer mortality in a region of northern Chile due to arsenic in drinking water. *Am J Epidemiol* 1998;147: 660-9.
30. Hopenhayn-Rich C, Biggs ML, Fuchs A, Bergoglio R, Tello EE, Nicolli H *et al*. Bladder cancer mortality associated with arsenic in drinking water in Argentina. *Epidemiology* 1996;7:117-24.
31. Hopenhayn-Rich C, Biggs ML, Smith AH. Lung and kidney cancer mortality associated with arsenic in drinking water in Corboda, Argentina. *Int J Epidemiol* 1998;27:561-9.
32. World Health Organization. Guidelines for drinking water quality. V. 1. Recommendations. Geneva: World Health Organization, 1993:41-2.
33. Tsuda T, Babazono A, Yamamoto E, Kurumatani N, Mino Y, Ogawa T *et al*. Ingested arsenic and internal cancer: a historical cohort study followed for 33 years. *Am J Epidemiol* 1995;141:198-209.
34. U.S. National Research Council. Subcommittee on Arsenic in Drinking Water. Arsenic in drinking water. Washington, DC: National Academy Press, 2001. 225 p.
35. U.S. National Research Council. Subcommittee on Arsenic in Drinking Water. Arsenic in drinking water. Washington, DC: National Academy Press, 1999. 310 p.
36. Ground water and drinking water. Washington, DC: U.S. Environmental Protection Agency, 2002. (www.epa.gov/safewater/mcl.html).
37. Integrated risk information system. Washington, DC: U.S. Environmental Protection Agency, 2002. (www.epa.gov/iriswebp/iris/index.html).

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