

Arsenic and drinking water

Epidemiology: Because it is odourless and colourless, arsenic used to be the popular choice for homicidal poisonings in England, Wales and France. Once techniques to detect trace amounts became readily available, its use as a poison quickly dropped off. However, its reputation remained thanks to films such as *Arsenic and Old Lace*. Because of this, it is no surprise that the presence of arsenic in drinking water creates ripples of discomfort.

Arsenic has probably always been in drinking water because it is found throughout the earth's crust in a variety of compounds. In many parts of the world, including Taiwan, Argentina and Chile, it is a natural contaminant of ground water; elsewhere, it has leached into drinking water through mining waste. Arsenic is used widely as a timber preservative and herbicide, in glass production and in the electronics industry. It can also be found in relatively high amounts in an organic form in seafoods, but this is easily excreted from the body and is considered nontoxic.¹

Inorganic arsenic is much more toxic than organic arsenic. This is particularly true of the trivalent form because of its increased solubility and affinity for thiol groups in proteins.¹ Inorganic arsenic is rapidly absorbed and distributed throughout the body, competing with phosphorous for active transport into cells. It is metabolized in the liver, methylated to monomethylarsonic or dimethylarsonic acid, and excreted in the urine; this methylation process is incomplete, so about 5%–25% of inorganic arsenic passes through the kidneys into the bladder and is later excreted.²

In 1980 the International Agency for Research in Cancer classified arsenic as an established human carcinogen based on extensive epidemiologic evidence that inhaled arsenic causes lung cancer and ingested arsenic causes skin cancer; genetic studies suggest that arsenic interferes with DNA replication and repair.³ Since 1980, extensive epidemiologic evidence has emerged that links ingested arsenic to bladder cancer. Much of this

evidence is from studies of populations in Taiwan that are exposed to high levels of arsenic in well water. In addition to high rates of Blackfoot disease, a peripheral vascular disease caused by arsenic, arsenicosis (skin manifestations of arsenic poisoning) and skin cancer, males exposed to more than 600 µg/L of arsenic face a risk of bladder cancer that is 28.7 times higher than the risk in the general Taiwanese population.² Studies in Chile, Argentina, England and Japan have shown similar results, resolving any controversy on the association between arsenic exposure and bladder cancer.

What remains controversial, however, is the use of this research in estimating the dose–response relation of arsenic at low doses and the use of these estimates to establish a new standard for drinking water. Some researchers have extrapolated from the Taiwanese data to conclude that the standard for arsenic in drinking water in the United States, currently 50 parts per billion (ppb), requires rapid downward revision.⁴ Others say this extrapolation ignores factors such as the body's ability to detoxify inorganic arsenic at lower levels and protein deficiencies in Taiwan. These deficiencies, which reduce the body's ability to methylate arsenic, are not present in the North America.⁵

Clinical management: Clinical symptoms of acute arsenic toxicity include gastrointestinal irritation leading to dehydration, electrolyte disturbances, renal insufficiency, impairment of the central nervous system and a delayed peripheral neuropathy. Patients experiencing chronic exposure present with nonspecific signs and symptoms such as myalgia, muscle weakness, abdominal pain and excessive sweating.

A urine arsenic test is the best way to determine exposure, and most clinical laboratories can quantify total urinary arsenic excretion; a specific request is needed for an analysis of inorganic arsenic. In the nonacute setting, patients should be told to avoid eating seafood and seaweed for 4 days before the urine

is collected. Chelating agents have a role in the treatment of acute toxicity.¹

Prevention: Several water-treatment methods can remove arsenic safely. As a first step, most systems require arsenic to be oxidized by agents such as oxygen, ozone or potassium permanganate to its pentavalent state. Ferric salts are effective precipitating agents in mildly acidic water, but they produce large amounts of arsenic-rich sludge that need to be removed. Arsenic is effectively absorbed on activated aluminum, and anion exchange resins have shown some success in removing pentavalent arsenic.⁶

Europe and the World Health Organization have recently set 10 ppb as the maximum acceptable level of arsenic in drinking water. The United States has been considering lowering its standard to about 20 ppb. The Canadian standard is currently 25 ppb, a limit that Health Canada admits reflects more the ability of different treatment facilities to reduce arsenic concentrations in drinking water than the actual science of the health effects.⁷

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References

1. Campbell BG. Mercury, cadmium and arsenic: toxicology and laboratory investigation. *Pathology* 1999;31:17–22.
2. Steinmaus C, Moore L, Hoppenhayn-Rich C, Biggs ML, Smith A. Arsenic in drinking water and bladder cancer. *Cancer Invest* 2000;18:174–82.
3. Buchet JP, Lison D. Clues and uncertainties in the risk assessment of arsenic in drinking water. *Food Chem Toxicol* 2000;38:S81–5.
4. Subcommittee to Update the 1999 Arsenic in Drinking Water Report, Committee on Toxicology, National Research Council. *Arsenic in drinking water: update 2001*. Washington: National Academy Press; 2001. Available: www.nap.edu/books/0309076293/html (accessed 2001 Nov 26).
5. Carlson-Lynch H, Beck BD, Boardman PD. Arsenic risk assessment. *Environ Health Perspect* 1994;102:354–6.
6. Peters G, McCurdy R, Hindmarsh JT. Environmental aspects of arsenic toxicity. *Crit Rev Clin Lab Sci* 1996;33:457–93.
7. *Arsenic in drinking water*. Ottawa: Health Canada. Available: www.hc-sc.gc.ca/english/iyh/arsenic.html (updated 2001 Nov 22; accessed 2001 Nov 26).