Arsenic in Drinking Water

Part 2. Human Exposure and Health Effects

John T. O'Connor, EngD, PE, and Thomas L. O'Connor

The discovery of exceptionally high arsenic levels in groundwaters derived from shallow 'tube wells' in Bangladesh and West Bengal, India in 1993 brought worldwide attention to the chronic exposure of as many as 85 million people in what has been called "the largest mass poisoning of a population in history." Publication in 2001 of the results of a survey conducted in 1999 (Environmental Science and Technology 2001, 35, 13) show similarly high concentrations of arsenic in well waters in Vietnam and the water supply for the City of Hanoi. The arsenic concentrations reported in these regions are often an order of magnitude greater than those observed in U.S. ground and surface waters. However, indications are that arsenic may be widespread in shallow well drinking water sources globally.

Taiwanese studies, reported in the American Journal of Epidemiology [153, 411 (2001)], have linked 10 to 50 µg/l arsenic concentrations to urinary tract cancers in Taiwan. Some critics have discounted the significance of these Taiwanese results citing lower arsenic levels and better nutrition in the U.S.

On-going health effects studies and research reports (2001) appear to support the argument for lowering the current USEPA drinking water standard for arsenic. Studies conducted by USEPA, the University of North Carolina, and the University of British Columbia have indicated that methylated metabolites of trivalent arsenic are genotoxic. In other words, they damage DNA in human cells.

Animal studies at the Dartmouth Medical School, reported in Environmental Health Perspectives [109, 245 (2001)], indicate that exposure of rat liver cells to trivalent arsenic concentrations in the range of 5 to 70 µg/l disrupted a hormone receptor. Researchers believe that this may explain why exposure to arsenic in drinking water is associated with Type 2 diabetes and vascular disease. To further explore this possibility, follow-up epidemiology studies are underway on humans exposed to arsenic in drinking water. USEPA administrator Whitman has indicated that this study will be made part of the arsenic review.

Arsenic was previously known to increase the risk of cancer of the lungs, skin, bladder, liver, kidney, prostate and nasal passages. The Public Health Service, Agency for Toxic Substances and Disease Registry (ATSDR), has compiled an comprehensive review of studies related to arsenic and cancer. With respect to exposure through drinking water, the ATSDR Information Center (July, 2001) states that *"An association between environmental exposure to arsenic through drinking-water and skin cancer has been observed and confirmed; two cases of bladder cancer were also described, with latent periods of eight to 20 years. The latent periods for two cases of skin cancer related to arsenic in drinking-water were 20 and 23 years, and the concentrations or uptake of arsenic were reported to be 1.2 and 1 mg per day, respectively, with an estimated total ingested dose of about 8 g in one study. Epidemiological studies in areas with different frequencies of black-foot disease and where drinking-water contained 0.35-1.14 mg/l arsenic revealed elevated risks for cancers of the bladder, kidney, skin, lung, liver and colon in both men and women."*

Although generally at levels exceeding 50 µg/l, arsenic has also been associated with a broad range of non-cancerous health effects. These include cardiovascular, neurological, pulmonary, immunological, endocrine, reproductive and developmental effects.

Based on the health effects evidence, the USEPA has classified arsenic as a human carcinogen and has restricted or canceled many uses of arsenic compounds in pesticides. OSHA has set a standard for arsenic in workplace air. In assessing the health benefits of a lowered standard, USEPA has focussed on bladder and lung cancer and estimated that a 10 µg/l arsenic drinking water MCL would:

- prevent between 19 and 31 cases and 5 to 8 deaths due to bladder cancer annually,
- prevent 19 to 25 cases and 16 to 22 deaths from lung cancer annually,
- reduce the incidence of noncancer health effects from arsenic exposure.

Water Industry and Utility Responses to the Previously Proposed USEPA 5 µg/l Arsenic Standard

In proposing a 5 µg/l arsenic standard, USEPA estimated that implementation of the rule nationally would cost $374 million per year for the next 20 years. USEPA estimated a $28 average annual household cost for arsenic removal for systems serving more than 10,000 people. However, most affected utilities utilize ground water and serve populations less than 10,000. Still, an estimated 75% of these smaller utilities already have treatment facilities.

Agreeing the existing standard should be reduced, but opposing the establishment of a 5 µg/l standard, the American Water Works Association (AWWA), has contended that a standard below 20 µg/l cannot be justified. Moreover, AWWA countered USEPA with cost estimates of $600 million per year to meet a 10 µg/l standard and $1.5 billion per year to meet a 5 µg/l standard. One industry spokesman suggested that some consumers would face bill increases of as much as $1,900 annually.

While conceding the need to reduce arsenic levels, the Association of California Water Agencies challenged the scientific justification and economic feasibility of the previously proposed 5 µg/l standard.

A Western Coalition of (Seven) Arid States (WESTCAS) called for an interim standard of 20 µg/l. Arguing that compliance should be eight years rather than the proposed three, WESTCAS has contended that no available technologies exist for water providers to implement arsenic removal within three years.

At issue is the cost-benefit ratio of increased arsenic removal. It has long been recognized that the establishment of any health-based standard is, in effect, an attempt to place a value on human life or the quality of human life. To quantify (monetize) the benefits of avoiding mortality from bladder and lung cancer, USEPA utilizes a Value of Statistical Life (VSL) estimate. The VSL value used by the Agency as of 1999 is $6.1 million. In addition, USEPA uses a Willingness to Pay (WTP) value to monetize the cancer cases that do not result in a mortality. Since a WTP value for avoiding a non-fatal cancer has not been established, USEPA uses a proxy WTP estimate of $607,000 established for the value of reducing the number of chronic bronchitis cases. Non-cancer health effects are considered essentially non-quantifiable.

Organ System	**Problems** [after Dhaka (Bangladesh) Medical College, 1998]
Skin	Symmetric hyperkeratosis of palms and soles, melanosis or depigmentation, Bowen's disease, basal cell carcinoma and squamous cell carcinoma.
Liver	Enlargement, jaundice, cirrhosis, non-cirrhotic portal hypertension
Nervous System	Peripheral neuropathy, hearing loss
Cardiovascular System	Acrocyanosis and Raynaud's Phenomenon
Hemopoietic System	Megalobastosis
Respiratory System	lung cancer
Endocrine System	Diabetes mellitus and goiter