Evolving Risk Assessment of Arsenic Contamination in Groundwater

By Kelly A. Reynolds, MSPH, Ph.D.

Once thought to be a pristine water supply requiring little to no treatment prior to consumption, groundwater is now a frequent target of public health concern. Enforcement of the groundwater disinfection rule (promulgated in November 2006)[1] is expected to dramatically reduce human exposures to microbial contaminants; however, other 'silent pollutants', such as inorganic arsenic, present additional concerns. Acceptable levels of arsenic in drinking water supplies, and how related risk estimates were derived, remain a controversial issue.

Drinking water risks

Sources of arsenic in the environment are highly varied and include natural mineral deposits and industry applications (wood preservatives, pesticides, glass manufacturing and others). Significant levels of arsenic can leach into the water supply from weathering rocks and eroding geological materials. This leaching may be amplified during mining operations where soil and subsurface materials are further disturbed and manipulated. Extremely small doses (i.e., 0.5 parts per billion) of arsenic in drinking water are estimated to cause one cancer case per 10,000 persons, when consumed over a lifetime. This level of risk is considered acceptable for non-fatal health outcomes but exceeds typical acceptable cancer risks.

The majority of source drinking waters in the US contain less than 10 parts per billion (ppb) of arsenic (the current MCL); however, 12 percent of water supplies exceed 20 ppb and, in high risk areas, concentrations of 1,000 to 3,400 ppb have been reported.[2] Overall, approximately 25 million residents and hundreds of millions of people worldwide are being chronically exposed to arsenic levels above federal limits in their water sources, which are also criticized for not being adequately protective. Regions in the West and parts of the Midwest and New England have a high percentage of utilities reporting positive arsenic results, many above the MCL.

Groundwater supplies are particularly vulnerable to arsenic contamination. Levels vary widely by state and specific well locations. Therefore, analysis of individual wells is required in order to estimate exposures related to specific drinking water sources. Numerous studies have been published from both public and private groundwater sources across the US where arsenic contamination is several orders of magnitude greater than the federally mandated maximum contaminant level (MCL).

Acute symptoms of arsenic exposure are rare; however, low-level chronic exposures are thought to occur in approximately five percent of community water systems in the US and an unknown number of private wells. Depending on concentration and exposure duration, symptoms may range from altered immune function to nausea and diarrhea to diabetes and cancer.

Arsenic exposures may be a key contributor to the manifestation of chronic diabetes. Persons with type 2 diabetes have consistently higher levels of arsenic in their urine (the main route of arsenic excretion), suggesting an association between low-level, chronic exposure and excretion (see On Tap, October, 2008). Arsenic has also been shown to interfere with hormonal processes, including estrogen, testosterone and progesterone biochemical pathways and the immune response.[3] Studies in laboratory mice have shown higher rates of respiratory infections, such as from the influenza A virus, when exposed to environmentally-relevant levels (100 ppb) of arsenic in their drinking water.[4]

Changing standards

The difficulty in regulating arsenic exposures stems from the fact that any level of the pollutant in the water supply appears to be harmful to humans. Therefore, the maximum contaminant level goal is zero ppb (or no detectable arsenic). Beginning in 1942, US EPA set an MCL for arsenic at 50 ppb in drinking water. From 1999 to 2001, the National Academy of Sciences (NAS) published a series of reports critical of the standard and requested a review of the risk data. The 50-ppb standard was estimated to produce a lifetime cancer risk of one in 100, well above acceptable risk limits. In 2001, the arsenic MCL was lowered to 10 ppb with a required public-utility compliance date of January 2006. Values as low as three ppb were deemed technologically feasible, but a vigorous debate on the cost and benefits ensued.

Using previous methods of risk assessment, the new 10-ppb standard was estimated to reduce lifetime cancer risk to one in 500, based on a consumption rate of two liters per day per person. While this risk level was still unacceptable by US standards, small water companies were already facing impractical cost increases and limitations of technologies only capable of removing 95 percent of the arsenic in drinking water. To add to the confusion, many experts maintained that previous risk estimates were overestimated, and that the lifetime cancer risk from the 50 ppb standard was closer to one in 1,000, a 10-fold improvement.[5]

Improved risk assessment

Since the 2001 NAS reports, new information has been discovered related to the effects of ingested arsenic in the body. This science (known as pharmacokinetics) aids in the evaluation of what level of ingested arsenic is actually absorbed into the body to elicit a health effect. Accurate information related to human tolerance to arsenic is important for the estimation of adverse outcomes. Using real human data (i.e., epidemiological studies) is preferred since animal data often does not reflect the human condition. Many of the risk estimates on low-dose exposures to arsenic, however, are extrapolated from animal data. After arsenic is absorbed in the system, many complex reactions occur in humans that occur differently in other animal species. In the environment and throughout biological metabolism, arsenic changes form—a condition that can alter its toxicity and availability in the body.

Advances in the development of genomic technologies are helping researchers to better characterize how humans metabolize arsenic, and to identify populations that may be more sensitive to arsenic exposures. Gender, age, genetics and behavioral factors are considered important risk determinants for arsenic exposure endpoints. In 2003, US EPA began to reassess the cancer risks related to inorganic arsenic, using broader and more recent scientific studies.

By 2005, the updated assessment was submitted for review to the agency's Scientific Advisory Board (SAB), which eventually led to a new draft *Toxicological Review for Inorganic Arsenic (Cancer),* made available for public comment in early 2010 and again in November.[6] The new report includes an extensive review of human population studies and incorporates an evaluation of how arsenic interacts adversely inside the human body. The document provides an extensive review of the scientific literature on arsenic conducted around the globe.

The overall conclusions from the literature are that:

- arsenic can cause a variety of cancers (skin, bladder, kidney, lung, liver, prostate);
- humans are generally more susceptible to arsenic-induced carcinogenesis than the commonly used mouse model;
- the exact mode of action of arsenic-induced cancer is unknown, requiring the continued assumption of carcinogenicity at any detectable level;
- a variety of behavioral and metabolic differences in children are thought to put them at higher risk of environmental arsenic exposures;
- genetic factors are suspected to play a role across gender and cultural differences in arsenic effects, and
- nutritional and smoking status also have an effect of increased arsenic-related health risks.

The goal of continued analysis of arsenic exposures is to decrease the uncertainty in the risk assessment and provide a more accurate evaluation of the true health impact of arsenic in the drinking water supply. Once released, the final draft of US EPA's *Toxicological Review of Inorganic Arsenic* is expected to provide resources for a more accurate risk assessment given the best available data.

Risk management

Understanding health outcomes related to arsenic exposures is addressing only part of the uncertainty. How many people are being exposed is largely unknown. More than 15 percent of Americans are drinking water from private wells. These water supplies are not regulated by US EPA and are not routinely monitored. Arsenic contamination in private wells must be managed by the individual homeowner, requiring periodic testing and possibly, POU water treatment.

The good news is that arsenic testing is relatively inexpensive, costing around $30 per sample. In addition, readily available POU water treatment options, such as activated alumina, RO or steam distillation, are effective for arsenic removal, depending on the species of arsenic in the water.[7] Given the prohibitive cost of centralized system upgrades, many small public water systems have opted to supply customers with POU devices. Despite the uncertainties in arsenic risk assessment, POU technologies can reduce the risk of cancer, and are especially recommended for private well owners who are not under the regulatory umbrella requiring routine monitoring and controls.

References

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