Arsenic in Drinking Water and Your Patients' Health

This booklet provides information about arsenic in Minnesota groundwater, the health effects and associated concentrations, regulatory levels, and related references.

Arsenic occurs naturally in the environment, including in groundwater. Since groundwater is the primary source of drinking water in Minnesota, many Minnesotans have arsenic in their drinking water. Amounts of arsenic in groundwater are much too small to pose an immediate health threat. However, if consumed over a long period of time, amounts found in groundwater in some areas can cause adverse health effects. Recent research indicates that health may be impacted at lower levels than was previously believed.

What are sources of arsenic in Minnesota's groundwater?

Most arsenic in Minnesota's groundwater is naturally occurring. Rock and soil beneath some parts of Minnesota and the Dakotas contain high levels of arsenic. Most of these deposits are probably from shale that was eroded and redeposited by glaciers many years ago. Water from wells that are in or just below large amounts of shale often has higher levels of arsenic.

Human activities can also contribute to arsenic levels in drinking water. Arsenic is a byproduct of industrial mining processes, such as smelting, and of manufacturing. Inorganic arsenic compounds were once ingredients of household and agricultural pesticides; past use and spills of arsenic containing pesticides have contributed to displaced arsenic. Finally, many outdoor wooden structures, such as decks, playgrounds, landscaping features, and foundations have been treated with a compound called CCA, or chromated copper arsenate arsenic in order to make them resistant to decay. Sometimes treated lumber is recycled as mulch. All these uses can contribute to arsenic in groundwater.

What are arsenic levels in Minnesota's drinking water?

The U.S. Environmental Protection Agency (U.S. EPA) regulates the levels of arsenic and other contaminants allowed in public drinking water. For many years, the standard for arsenic in public drinking water supplies was a maximum contaminant level (MCL) of 50 micrograms per liter (µg/L). In October 2001, in response to research indicating that the existing MCL did not adequately protect the public from health risks associated with long-term exposure to arsenic in drinking water, the U.S. EPA

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reduced the standard from 50 µg/L to 10 µg/L. The MDH has been taking steps to implement the new MCL of 10 µg/L since the early months of 2001; however, public water systems are not *required* to meet the new standard until 2006.

Some groundwater in Minnesota has arsenic as high as 150 µg/L. Investigations of groundwater in Minnesota and other midwestern states suggest that naturally occurring concentrations of arsenic exceeding 10 µg/L are more common than previously recognized. It is estimated that approximately fifteen percent of all wells in Minnesota have arsenic levels of at least 10 µg/L, and about one third of private wells have arsenic over 3 µg/L.

Testing has shown that, in Minnesota, higher arsenic is more likely to occur in an arc stretching from the north-central region of the state, through the western area near the South Dakota border, to south-central Minnesota. However, arsenic levels can vary from one well to the next, even within a small geographic area.

After an initial test at the time a private well is drilled, private drinking water wells are not required to meet federal MCLs or any state standards. Instead, it's up to the well owner to determine whether he or she wants to test the well and to take steps that will reduce chemical concentrations in the water. Therefore, if arsenic is present in the source water, arsenic concentrations in private wells may be higher than the MCL.

Why be concerned about concentrations below the MCL?

MCLs for public drinking water are based not only on considerations of health, but also on whether available technology can achieve a particular standard and what it will cost to comply with that standard. An arsenic standard that would totally preclude any risk of noncancer effects and would reduce any risk of cancer to the same level as standards for other chemicals (in Minnesota, one additional case of cancer in a population 100,000), would be lower than the new MCL of 10 µg/L.

What are the possible health effects of low levels of arsenic?

Health effects of arsenic depend on the form of arsenic, and on the amount of and duration of exposure. A single oral dose of inorganic arsenic of 60,000 µg is fatal for most people. Although this amount, approximately 1/50 the weight of a penny, seems very small, it is extremely high compared to levels naturally present in water and other environmental media.

Over time, daily consumption of relatively lower concentrations of arsenic found in drinking water, combined with arsenic naturally occurring in the diet, can be harmful. Consumption of water containing high concentrations of arsenic -- 100 µg/L, or parts per billion (ppb), and up -- have been associated with many health effects, including cardiovascular and peripheral vascular disease; hypertension; diabetes; gastroenteritis; hematological disorders such as anemia, leukopenia, and eosinophilia; portal fibrosis; neurological and neurobehavioral disorders; hearing loss; renal and respiratory effects; and developmental effects. Skin problems and high blood pressure may occur at even lower levels. Several studies suggest that increased arsenic exposure is associated with decreased intelligence in children.

The time required for a condition to develop is related to the concentration. For example, at higher concentrations, hyperpigmentation of the skin has been reported after just a few months of exposure; at lower concentrations, hyperpigmentation takes years to develop. (For a list of more specific health effects that have been associated with these systems, see the table in Appendix A.)

Long-term consumption of drinking water containing arsenic has been linked to several cancers. The most common types of cancers described in reports include cancer of the skin, bladder, lungs, liver, and prostate. Other cancers that may be associated with arsenic in drinking water include cancers of the kidney, colon, bone, larynx, stomach, lymph nodes, and nasal cavities. Cancers related to arsenic in drinking water typically do not develop for decades. However it is not clear whether an exposure that occurs for only a few years early in life can cause cancer later in life, or whether years of continuous exposure are necessary to cause cancer.

It is difficult to precisely quantify concentrations of arsenic in water that can lead to particular adverse health effects. First, most information about the toxic effects of arsenic comes from human populations that have been exposed, over long periods of time, to naturally occurring arsenic in groundwater that is used as drinking water. People move, their water consumption varies, and concentrations in groundwater vary over time and by location. As a result, it is difficult to quantify exposure, whether of an individual or a population, and different researchers can come up with very different estimates. Second, epidemiological studies of arsenic effects have usually been conducted in areas of the world where natural levels of arsenic in water are very high – for example, several hundred micrograms per liter. Whether results from these studies can be extrapolated to the lower concentrations typically found in water in the United States is not clear. However, a growing body of evidence indicates that consumption of water with lower levels of arsenic may be associated with increased risk of adverse health effects. Third, study design can limit the information that can be derived from a study. Subjects may be grouped into broad exposure ranges, precluding conclusions about a narrower range of concentrations. Different researchers measure exposure differently, complicating comparisons between studies. Finally, genetic differences in how people metabolize arsenic may make some people more susceptible to arsenic toxicity than others.

The following table shows some of the health effects and levels with which researchers have associated arsenic in drinking water. This table focuses on effects found at some of the lower concentrations studied; other health effects may occur at higher concentrations. Because these effects also occur in the general population, the "effect" may actually be increased risk. Results from epidemiological studies are based upon statistical analyses of populations; effects may be seen at lower levels in more sensitive individuals. (Concentrations are derived from the studies themselves, or from California's Public Health Goal for Arsenic in Drinking Water.)

Health Effect	***Concentration in Water***	***Researcher***
IQ deficit	11 µg/L, children; 30 µg/L, adults*	Siripitayakunkit et al., 1999
	10 µg/L, children	Graziano et al., 2004**
Skin keratosis	50 µg/L	Mazumder et al., 1998
Artery, arteriole, and capillary disease	20 - 91.5 µg/L	Engel and Smith, 1994
Cerebral infarct	166 µg/L	Chiou et al., 1997
Cerebrovascular disease	189 µg/L	Chiou et al., 1997
Abnormal electromyograms	60 - 140 µg/L	Hindmarsh et al., 1977
Spontaneous abortion and perinatal death	60 - 270 µg/L	Dési, 1992

*one point IQ loss, as calculated by California's Office of Environmental Health Hazard Assessment in its *draft* Public Health Goal for Arsenic in Drinking Water, using results from Kurttio et al., 1998.

**unpublished as of December 2004.

Cutaneous and cardiovascular effects follow a temporal progression. Cutaneous effects are first manifested as hyperpigmentation: typically, a finely freckled pattern on the trunk and extremities. Hyperpigmentation progresses to palmar-plantar hyperkeratoses on the palms and soles of the feet. Areas of hyperkeratoses may subsequently develop nonmelanoma skin cancers. In extreme cases, peripheral vascular disease may result in gangrene of the extremities, particularly the feet. Initial symptoms of numbness or coldness of the extremities progress to ulceration, gangrene, and spontaneous amputation.

Exposures to arsenic and other carcinogens are usually evaluated in terms of increased risk of cancer within a population. High background cancer rates can make it difficult to detect an increase due to exposure to a particular substance. In order to allow detection of an increase in risk over background risk, cancer studies tend to be conducted using populations that have experienced very high exposures. Risk associated with lower exposures is then extrapolated from risk found at higher exposures.

Estimates of cancer risk associated with arsenic in water have increased as a result of recent studies and reevaluations of existing studies. An earlier estimate from the U.S. EPA suggested that, for every two micrograms of arsenic in one liter of drinking water (2 µg/L), one additional person in a population of 10,000 that consumes that water for a lifetime might get cancer. A more recent reevaluation by the National Research Council (conducted at the request of the U.S. EPA) suggests that, for lung and bladder cancer alone, the increased risk at three micrograms per liter (3 µg/L) may be between 4 and 10 additional cases in a population of 10,000. Thus the risk estimate has increased between three to seven fold. While estimates of cancer risk associated with arsenic in water still vary widely, nearly all parties agree that risk is higher than was previously believed.

Some research indicates that cigarette smoking and exposure to ultraviolet light may exacerbate the effects of arsenic exposure. Refraining from smoking and avoiding excessive direct exposure to sunlight could reduce arsenic-associated risk. Because of other risks associated with these activities, the Minnesota Department of Health (MDH) recommends avoiding smoking and excessive exposure to sunlight.

Is there arsenic in food?

Food is the primary source of arsenic exposure for most people. However, the form of arsenic most commonly found in food, organic arsenic, has little or no toxicity. In the environment, arsenic is usually combined with other elements. Arsenic combined with carbon and hydrogen is referred to as "organic arsenic;" arsenic combined with other elements, such as oxygen, chlorine, or sulfur, is referred to as "inorganic arsenic." Arsenic from plants and animals is usually organic, while arsenic in soil, rock, and water is usually inorganic. Generally, organic forms of arsenic are less harmful than inorganic forms.

The U.S. Agency for Toxic Substances and Disease Registry estimates that we consume about 50 µg/L of arsenic in our daily diet. Estimates of how much of this is inorganic range from less than ten percent up to twenty percent (i.e., from less than five up to ten µg/day). U.S. EPA experts on arsenic suggest that average exposure to arsenic in drinking water is less than four µg/day. However, concentrations of arsenic in groundwater can range widely -- from very low to over 1000 µg/L. Therefore, adverse effects from consumption of arsenic are usually attributed to exposures through drinking water.

What are the options for reducing arsenic in drinking water?

There are several options for reducing arsenic in drinking water. However, the success of any of these options in achieving a reduction is closely tied to existing levels of arsenic, geological characteristics, and, in the case of installation of a treatment unit, to proper maintenance.

- **Install a water treatment system:** Characteristics of Minnesota's groundwater, including high iron content, make removal of arsenic to low levels more difficult to achieve than in many other areas. An individual considering installation of a treatment system will want to know how much arsenic the system is likely to remove and what installation and maintenance costs will be. A dealer familiar with the characteristics of groundwater in the area should be able to provide this information.

- **Construct a new well:** Drilling a new well can sometimes reduce arsenic levels. However, a new well may still contain arsenic - even if the well was properly constructed, and in an appropriate location. For more information about new well construction, contact your nearest MDH district office, and ask to speak with a well specialist.

- **Connect to a public water system:** Beginning in 2006, owners of wells with arsenic levels over 10 µg/L, will be able to reduce arsenic in their drinking water by hooking up to a public water supply system.

- **Buy bottled water:** Use of bottled water may help reduce arsenic exposure. However, bottled water is not subject to U.S. EPA standards for public drinking water and not all bottled water is the same. Bottlers who belong to the International Bottled Water Association are required to ensure that arsenic concentrations are 10 µg/L or under.

Are there other ways to reduce my exposure to arsenic?

Water is not the only source of exposure to arsenic. However, because most people are served by public water systems, reduction of arsenic concentrations in water is a relatively easy way to reduce a population's exposure.

While meat, including poultry, and fish and grains may contribute approximately half the arsenic in the diet, and dairy products approximately one-third, most of this is the less toxic organic form of arsenic rather than the inorganic form. The U.S. EPA estimates that dietary intake of inorganic arsenic is approximately 14 µg/day, above and beyond the amount consumed in water. A varied and well-balanced diet will prevent excessive exposure from any given source.

People ingest a small amount of soil each day. Children, especially, are prone to higher rates of soil consumption because of hand-to-mouth activity. Proper washing of hands and produce will reduce this route of exposure.

Cigarettes contain arsenic, as well as other toxic substances. Avoiding smoking is an effective way to limit arsenic exposure.

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For information via the internet:

Chromated copper arsenate treated wood,
http://www.health.state.mn.us/divs/eh/hazardous/topics/CCA_fact.pdf
Community water supplies,
http://www.health.state.mn.us/divs/eh/water/com/fs/arsenic.html
Options for reducing arsenic in drinking water,
http://www.health.state.mn.us/divs/eh/wells/arsenic.html
Results of testing wells in western Minnesota [Minnesota Arsenic Study (MARS)],
http://www.health.state.mn.us/divs/eh/hazardous/arsenicstudy.pdf
Testing private wells for arsenic,
http://www.health.state.mn.us/divs/eh/wells/arsenic.html

For more information about arsenic, contact:
Minnesota Department of Health, Health Risk Assessment Unit at
(651) 201-4899; or 1-800-657-3908; or TDD (651) 201-5797

If you require this document in another format, such as large print, Braille, or cassette tape, call (651) 201-4899.
www.health.state.mn.us/divs/eh/

Appendix A: Health Effects Associated with Arsenic

Associations between systems and health effects in the following table are based on information printed in the National Research Council's 1999 and 2001 publications: Arsenic in Drinking Water, and in California's draft Public Health Goal for Arsenic in Drinking Water.

System	Health Effects	
--	Death	
--	Body weight decreases	
Cardiovascular	Raynaud's disease Gangrene of extemities Blackfoot disease Ischemic heart disease Cerebrovascular disease Cerebral infarction	Cyanosis of extemities Palpitations/chest discomfort Peripheral vascular disease Thrombosis Arterial thickening
Dermal	Skin cancer Melanosis Keratosis Hyperkeratosis	Depigmentation Leukoderma Melanoderma
Endocrine	Diabetes mellitus	
Gastrointestinal	Hematemesis Hemoperitoneum Melena Gastrointestinal hemorrhage	Nausea Cramps Diarrhea
Hematological	Anemia	
Hepatic	Liver cancer Cirrhosis Ascites Hepatomegaly Increased serum alkaline phophatase and albumin	Vascular and central fibrosis Portal hypertension Abdominal pain Fatty liver Enlargement and proliferation of bile ducts
Nervous	Functional denervation Fatigue Headache Dizziness	Paraesthesia Numbness Decreased IQ in children
Ocular	Chronic conjunctivitis Conjunctival injection	Periocular edema
Renal	Urinary tract cancer Bladder cancer	Cysts
Respiratory	Lung cancer Cough Bronchitis	Bronchiectasis Bronchophneumonia Inflammation of bronchi and larnyx