The Enemy Below

Resolving arsenic contamination in residential water wells

By Greg Reyneke

We are exposed to arsenic every day through fruit juice, vegetables, rice, grains, dust in the air or even pressure-treated lumber. Currently, the primary recognized cause of unintentional arsenic consumption is drinking groundwater that contains it.

Elevated arsenic levels in the body are believed to interfere with cellular metabolism. Arsenic poisoning produces gastroenteritis, esophageal pain, vomiting and violent diarrhea. Eventually the skin becomes cold and clammy, blood pressure drops, and overall body weakness sets in. Convulsions, followed by death from circulatory failure, may result.

Large doses of arsenic insufficient to kill can cause restlessness, nausea, vomiting, headaches, dizziness, chills, cramps, irritability and variable levels of paralysis and neuropathy that may progress over weeks. Arsenic also is a carcinogen; there is a documented relationship between arsenic in drinking water and the development of bladder, lung, skin, kidney, liver, prostate and nasopharyngeal cancers.

A 2007 study published by the Royal Geographic Society reported that more than 137 million people in more than 70 countries probably already are affected by arsenic poisoning from drinking water. This is not just a problem in developing countries—arsenic toxicity could affect anyone. The U.S. Environmental Protection Agency (EPA) has established a maximum contaminant level of 10 ppb for arsenic in drinking water. This rule is enforced in more than 60,000 community water systems in the U.S., and most counties require adherence to the rule

Figure 1. Arsenic Species Typically Encountered in Water

Name	Common Abbreviation	Chemical Formula	CAS #
Arsenous acid (arsenite)	As^{III}	$As(OH)_3$	13464-58-9
Arsenic acid (arsenate)	As^{V}	$AsO(OH)_3$	7778-39-4
Monomethylarsonic acid	MMA^{V}	$CH_3AsO(OH)_2$	124-58-3
Monomethylarsonous acid	MMA^{III}	$CH_3As(OH)_2$	25400-23-1
Dimethylarsinic acid	DMA^{V}	$(CH_3)_2AsO(OH)$	75-60-5
Dimethylarsinous acid	DMA^{III}	$(CH_3)_2AsOH$	55094-22-9
Trimethylarsine oxide	TMAO	$(CH_3)_3AsO$	4964-14-1

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The arsenic treatment system easily passed county approval, allowing the couple to continue building their first home.

for a home served by a private water source. According to the U.S. Geological Survey, arsenic concentrations exceeding 10 ppb appear to be far more frequently observed in the western U.S. (including Alaska) than in the eastern half.

Arsenic Chemistry

There are seven common arsenic species typically encountered in water (see Table 1). Surface water exposed to air generally contains arsenic in the pentavalent +5 (oxidized) state, whereas hypoxic water (that with low or no dissolved oxygen) contains arsenic in the trivalent +3 (reduced) state. Both types are toxic, but the trivalent form is more easily assimilated by humans, making it more dangerous. Do not be fooled into believing that groundwater only contains pentavalent arsenic though. Some species of bacteria derive energy from oxidizing various materials while reducing arsenates to form arsenites using enzymes known as arsenate reductases. There also are species of photosynthetic bacteria that can oxidize arsenites into arsenates, so remember to speciate whenever practical before attempting a treatment solution.

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A Common Scenario

In this article, I will provide an overview of one dealer's experience addressing arsenic for a homeowner using established technologies that are simple to install and maintain.

A couple was preparing to build their first home. The construction mortgage was approved, plans were drawn up and a new 300-ft-deep well was drilled. The county health department performed a routine water test and the project came to a halt: There was arsenic in the water, which prevented the approval of a construction permit.

The county specified how to address the issue:

- The designer of the treatment solution must provide proof that it is capable of delivering water that meets or exceeds EPA's primary drinking water standards.
- The homeowner must agree to let the county health department test the water after the system is functional and prior to an occupancy permit being issued.
- A maintenance agreement must be established to comply with the manufacturer's recommended maintenance schedule.

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- A record on the chain of title must be signed to show that the drinking water does not meet EPA primary drinking water standards without a functional treatment system.
- The onsite wastewater system must be designed to accommodate the discharge water demands of the treatment solution.

After a local water professional was hired, he immediately tested the water and discovered contaminants at the levels shown in Table 2.

The key to effective system design is to employ a layered approach to ensure best performance with minimum maintenance. The following sequence of treatment was chosen:

Table 2. Well Water Testing Results

Contaminant	Concentration
Iron	0.221 mg/L
Manganese	0.07 mg/L
Silica	21.2 mg/L
pH	7.3
Phosphate	None Detected
Turbidity	0.2 ntu
Arsenic (unspeciated)	0.023 mg/L

- A 100-µ filter protects downstream components. The filter is changed annually or as pressure drop necessitates it.
- A greensand-plus filter addresses iron and manganese in the water while also oxidizing arsenite into arsenate. This metered on-demand system cleans using potassium permanganate as a regenerant (approximately 4 oz per cleaning). The system cleans itself after approximately 2,500 gal of domestic usage and discharges approximately 80 gal to the onsite wastewater system when it cleans.
- A 10-µ filter clarifies the water and protects the downstream arsenic sorbent train from sediment loading. The filter is changed annually or as pressure drop necessitates it.
- The arsenic treatment train utilizes a hydrous metal sorbent. A dual-pass design ensures redundant performance. The recommended service interval is based on projected exhaustion of the lead tank only. The lag tank serves as a secondary safety polish. During service, the lead tank is replaced and returned to the factory for recycling. Media exhaustion calculations indicate the lead tank will need replacement after six years, based on an average 300-gal-per-day water usage in the home.

This system was simple for the dealer to install and easily earned county approval. You, too, can help your customers with contaminants like arsenic, but remember that health and lives are at stake. If you are facing an arsenic treatment project, do not just rely on articles like this—consult with a Master Water Specialist or consulting engineer to ensure you do not miss anything. WQP

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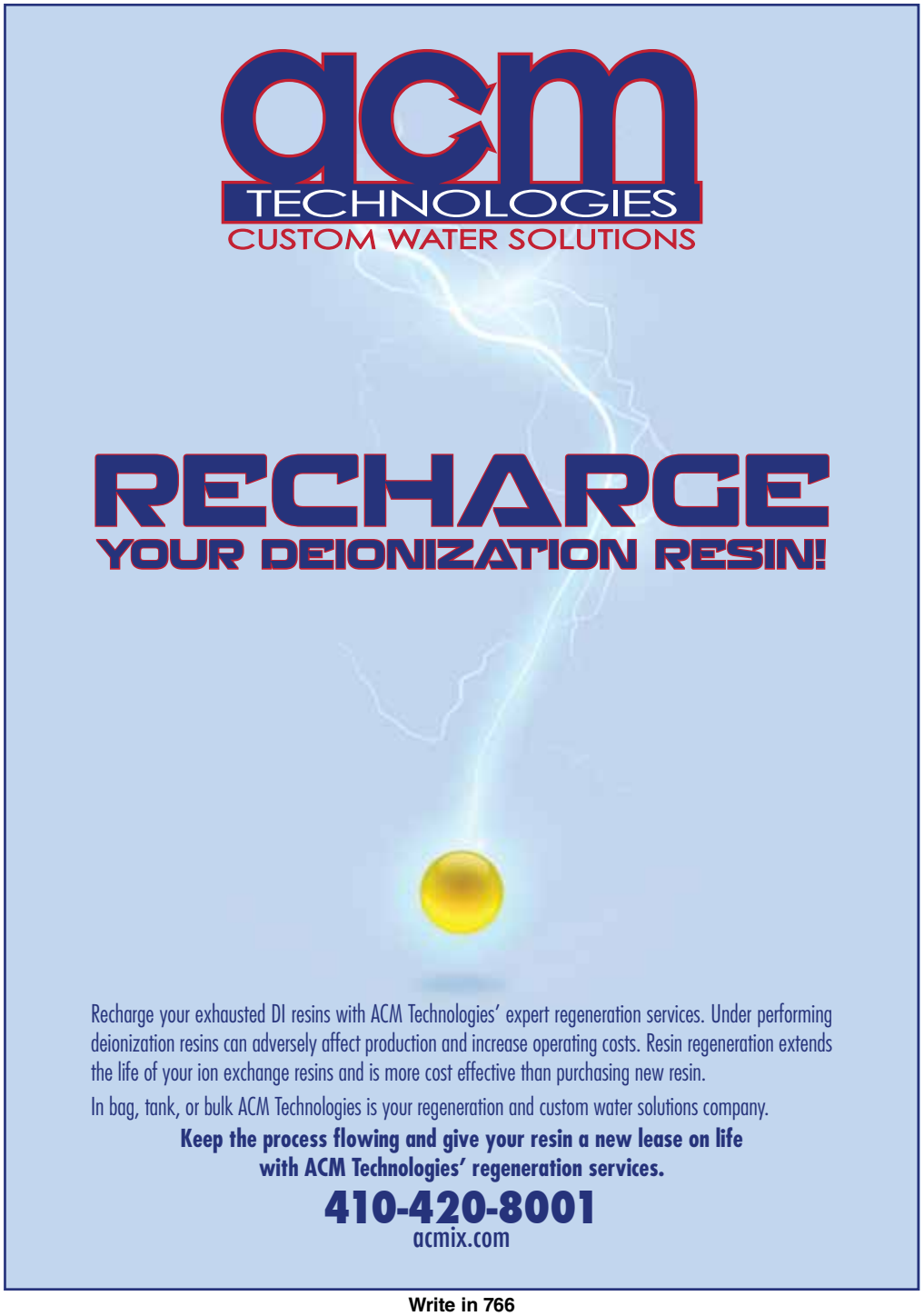

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