How can we avoid drinking forever chemicals and arsenic?

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Credit: Unsplash/CC0 Public Domain

It is found in polar bears and virgin forests. It is in our shellfish, hot cocoa mixes, and kale.

What is this omnipresent "it"? "It" is per- and polyfluoroalkyl substances, also known as PFAS or forever chemicals, which are used to protect clothing, cookware, cosmetics, and other products from water, grease, or oil. But those chemicals can leach out of those goods to haunt our food, air, plants, and drinking water. So far, scientists have found that PFAS exposure could lead to liver and immune system damage, increased risk of kidney or testicular cancer, birth defects, and other health and environmental problems.

And one of the most common ways to ingest these chemicals is through contaminated water.

"PFAS are typically present at really, really low concentrations," said Kurban Sitterley, a water treatment expert at the National Renewable Energy Laboratory (NREL). "But they can be carcinogenic even at low concentrations."

Luckily, we can extract PFAS and other unwanted contaminants, like arsenic or calcium, from our water using a process called ion exchange. And soon, removing PFAS will not be optional. In June 2023, the Environmental Protection Agency announced its plan to require water utilities to reach near-zero levels of PFAS in drinking water. That means many water treatment facilities will need to upgrade their systems to target this insidious chemical.

"And ion exchange technologies," Sitterley said, "are some of the only selective separation technologies we have that can get these forever chemicals out of water."

Sitterley, who is a member of the National Alliance for Water Innovation (NAWI), recently partnered with Alexander Dudchenko, an associate staff scientist at the Stanford Linear Accelerator Center, to demonstrate a model that could help improve ion exchange systems.

With their new ion exchange model, which the team demonstrated in an NREL report published in September 2023, utilities and researchers can simulate and study different system designs. Utilities can, for example, identify which system might be the most economic option to remove a specific contaminant, like arsenic, calcium, or PFAS. And researchers can tweak the technologies to identify which designs might produce more purified water and less waste, consume less energy, and/or cost less.

"Lots of water treatment facilities are going to have to retrofit their treatment facility to be able to handle PFAS because it's absolutely everywhere," Sitterley said. "That will hopefully be an application for the ion exchange model."

The duo's new model is part of NAWI's free, publicly available Water treatment Technoeconomic Assessment Platform (WaterTAP). With WaterTAP, users can digitally simulate and explore more than 50 different kinds of water treatment technologies.

Say, for example, that Sitterley wants to try out a different resin—the substance in ion exchange systems that sops up contaminants like PFAS. With this model, he could test how various resins affect the system's performance. For example, could the upgrade remove more PFAS? And, if so, would that tweak be worth the cost?

Ion exchange systems use a chemical reaction to replace unwanted ions with harmless ones, like swapping one currency for another. The technology is well studied and versatile, capable of targeting a wide range of contaminants. Today, ion exchange is most often used to soften water—or remove minerals, like calcium or magnesium. Even though so-called hard water is not hazardous (it can even be a valuable source of calcium and magnesium for those who do not get enough from food), calcium and magnesium can gum up pipes and make it harder for soap and detergent to remove grime from clothing and dishes.

After Sitterley and Dudchenko built their model, they also demonstrated how it works—the first of many demos planned to showcase WaterTAP's capabilities. For the ion exchange model demonstration, the team showed how these systems might filter out calcium from drinking water. They also toyed with different system designs to see how changes might impact costs.

"We're trying to see where you can get some kind of economical or performance benefit," Sitterley said.

Sitterley will also continue to refine their model. He is currently working to expand the tool so it can analyze multiple contaminants at a time. Hard water includes far more than just calcium, so if the model can evaluate all the minerals in that mix, it could provide an even more accurate estimate of a system's performance and cost.

And soon, the model could also account for waste disposal costs. If, for example, a water treatment facility uses ion exchange to remove PFAS, what then? Disposing of a potentially harmful chemical is not always cheap. In the future, the model could account for this post-treatment cost (though users can already find this data, if they pair the tool with other WaterTAP models).

"If we can accurately model the waste stream, at least how much is generated and what's in it, I think that would be really valuable," Sitterley said. "A lot of the costs for ion exchange get sucked up in managing the waste stream, whether it's hazardous or not. So, I hope to improve that part of the model soon."

Although WaterTAP is not the only water treatment modeling platform available, it is the only one that is free and available to anyone, anywhere. Sitterley sees his new model, and the rest of the WaterTAP tool, as part of a public service. Water, he said, is not only consumed as drinking water; agriculture, power plants, and industry also consume huge amounts of Earth's dwindling supplies.

"If, ultimately, we get a better understanding of water treatment processes with WaterTAP," Sitterley said. "I think that would be a huge win."

Provided by National Renewable Energy Laboratory

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