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Membrane filters are key to future of public water supply, scientists say

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As municipalities across the United States reduce their dependence on groundwater sources to mitigate environmental impacts like subsidence and flooding, there is a growing need for better purification processes to keep contaminants found in surface water sources out of the public tap.

Without a drop of hesitation, University of Houston environmental engineer Shankar Chellam says the answer is clear: super-thin membrane filters.

"There's no doubt in my mind that the future of water treatment looks like membranes," says Chellam. "Without that, if you continue to build conventional treatment plants, which we've been doing for 100 years, you will not be able to sufficiently protect against emerging pathogens and chemicals."

The particles in surface water sources come in a variety of sizes, he explains. If they're big enough, they settle to the bottom, and municipal intake systems are designed to collect the cleaner water away from the sediment.

"But these viruses, bacteria, protozoa and other chemical contaminants are either very, very small so that they don't settle readily, or they are dissolved in the water in the first place," Chellam explains. That's when purification becomes necessary.

The most widely used technique today starts with coagulants, which when added to a water supply make tiny particles stick together and then settle. The remaining suspended particles are removed using a filter typically composed of sand grains, but "that's not going to be 100 percent effective," says Chellam, whose research group is studying various types of membranes that might be used to remove even the smallest of contaminants.

While disinfectants, including chlorine, ozone and ultraviolet rays can inactivate microorganisms, Chellam says, membranes made of polymer or ceramics are a better bet for both microbes and chemicals.

Chellam, who studies how contaminants are removed by membrane filters, how they clog filter pores and how the water flow is subsequently affected, is developing pretreatment methods to improve membrane performance.

For Chellam, it's not a matter of whether membrane filtration is the next logical step; it's a matter of when to take that step. Some cities, like Milwaukee, already have.

Sixteen years ago, the protozoan parasite Cryptosporidium parvum escaped Milwaukee's water purification processes, leading to an outbreak of gastrointestinal illness affecting more than 400,000 residents - and motivating Chellam, who was then a doctoral student, to focus on protecting the public water supply.

"The United States had its largest waterborne disease outbreak in recorded history in 1993," Chellam says. "It wasn't in medieval times when we knew nothing."

Cryptosporidium parvum may be tiny, but it can be quite a force to be reckoned with, he says.

"These are very, very hard to kill," he says. "They are quite smart, evolutionarily. What they do is form some kind of cyst around them, and they are able to survive in nature when the conditions are extremely brutal to them."

When Cryptosporidium is incased in its cyst, it's in a vegetative state, Chellam says, just waiting for the right host to come along.

"If you drink them, or if they get into the body of some warm-blooded animal, suddenly they find life. It's a good place to live. It is warm, and food is readily available. They come out of their cyst and proliferate - they reproduce," he says. "Before you know it, you have a really bad stomach ache, diarrhea, and you dehydrate."

In most cases, those with compromised or underdeveloped immune systems are affected disproportionately. In Milwaukee, four people died.

A municipality has to make the difficult but crucial choice between conventional purification methods and more innovative technologies, Chellam says. For Milwaukee, that choice was membranes.

"They wanted to make sure they had the best currently available protection," Chellam says, even if installing large-scale microfilters presents challenges beyond solely costs, such as fouling.

Fouling occurs when particles, organics and bacteria deposit on a membrane filter. Chellam's recent research has focused on fouling caused by bacterial colonization on membranes. The bacteria multiply rapidly — doubling in number roughly every half-hour or so — and encase themselves in extracellular polymeric substances to protect the colony and adhere more strongly to the filter.

Chellam and doctoral student Appala Raju Badireddy are working with collaborators at the Environmental Molecular Sciences Laboratory at the Pacific Northwest National Laboratory to develop a molecular-level understanding of biofouling mechanisms and ultimately to control it.

Last year they reported results from testing the effects of certain bismuth thiols, similar to the primary ingredient in Pepto-Bismol, on bacterial secretion. Using spectroscopy, microscopy and other chemical analyses, they documented a significant reduction in extracellular polymeric substances secretion from certain bacteria, meaning their colonies couldn't bind strongly to the filter.

Today, they are investigating mechanisms by which bismuth thiols reduce secretions from mixed bacterial populations obtained from the city of Houston's wastewater treatment plant.

"The comprehensive characterization of secretions from both pure and mixed microbial cultures to the molecular detail is valuable to understand the mechanisms governing biofouling and bacterial aggregation," Badireddy says. "Our research could potentially lead to the development of antifouling strategies for mitigating biofouling of membranes used for water and even wastewater treatment."

Environmental Protection Agency standards don't require tap water to be microbe-free. It should, however, have 99.99 percent fewer viruses and 99.9 percent fewer Giardia, a close relative of the protozoan Cryptosporidium, than in the surface water source, Chellam says.

"So, if your river has 10,000 viruses per milliliter, your tap water can have one virus per milliliter," he says. "If your river has 1,000 Giardia, your tap water can have one Giardia. And the research has shown that even ingesting one Giardia can make you sick."

Chellam, who doesn't bother to filter his tap water at home, says the bottom line is that people shouldn't expect their tap water to be pure, and they shouldn't let that stop them from drinking it.

"It is not designed to be pure. It's designed to be drinkable," Chellam says. "Reasonably healthy people should not fall sick by drinking tap water."

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