Repurposed beer yeast encapsulated in hydrogels may offer a cost-effective way to remove lead from water

May 15 2024

Engineered yeast-containing hydrogel capsules could be used to remove lead from contaminated water rapidly and inexpensively. The work, from MIT and Georgia Tech researchers, could be especially useful in low-income areas with high lead contamination. Credit: MIT

Every year, beer breweries generate and discard thousands of tons of surplus yeast. Researchers from MIT and Georgia Tech have now come up with a way to repurpose that yeast to absorb lead from contaminated water.

Through a process called biosorption, yeast can quickly absorb even trace amounts of lead and other heavy metals from water. The researchers showed that they could package the yeast inside hydrogel capsules to create a filter that removes lead from water. Because the yeast cells are encapsulated, they can be easily removed from the water once it's ready to drink.

"We have the hydrogel surrounding the free yeast that exists in the center, and this is porous enough to let water come in, interact with yeast as if they were freely moving in water, and then come out clean," says Patricia Stathatou, a former postdoc at the MIT Center for Bits and Atoms, who is now a research scientist at Georgia Tech and an incoming assistant professor at Georgia Tech's School of Chemical and Biomolecular Engineering.

"The fact that the yeast themselves are bio-based, benign, and biodegradable is a significant advantage over traditional technologies."

The researchers envision that this process could be used to filter drinking water coming out of a faucet in homes, or scaled up to treat large quantities of water at treatment plants.

MIT graduate student Devashish Gokhale and Stathatou are the lead authors of the study, which appears in the journal *RSC Sustainability*. Patrick Doyle, the Robert T. Haslam Professor of Chemical Engineering at MIT, is the senior author of the paper, and Christos Athanasiou, an assistant professor of aerospace engineering at Georgia Tech and a former visiting scholar at MIT, is also an author.

Absorbing lead

The new study builds on work that Stathatou and Athanasiou began in 2021, when Athanasiou was a visiting scholar at MIT's Center for Bits and Atoms. That year, they calculated that waste yeast discarded from a single brewery in Boston would be enough to treat the city's entire water supply.

Through biosorption, a process that is not fully understood, yeast cells can bind to and absorb heavy metal ions, even at challenging initial concentrations below 1 part per million. The MIT team found that this process could effectively decontaminate water with low concentrations of lead. However, one key obstacle remained, which was how to remove yeast from the water after they absorb the lead.

In a serendipitous coincidence, Stathatou and Athanasiou happened to present their research at the AIChE Annual Meeting in Boston in 2021, where Gokhale, a student in Doyle's lab, was presenting his own research on using hydrogels to capture micropollutants in water. The two sets of researchers decided to join forces and explore whether the yeast-based strategy could be easier to scale up if the yeast were encapsulated in hydrogels developed by Gokhale and Doyle.

"What we decided to do was make these hollow capsules—something like a multivitamin pill, but instead of filling them up with vitamins, we fill them up with yeast cells," Gokhale says. "These capsules are porous, so the water can go into the capsules and the yeast are able to bind all of that lead, but the yeast themselves can't escape into the water."

The capsules are made from a polymer called polyethylene glycol (PEG), which is widely used in medical applications. To form the capsules, the researchers suspend freeze-dried yeast in water, then mix them with the polymer subunits. When UV light is shone on the mixture, the polymers link together to form capsules with yeast trapped inside.

Each capsule is about half a millimeter in diameter. Because the hydrogels are very thin and porous, water can easily pass through and encounter the yeast inside, while the yeast remain trapped.

In this study, the researchers showed that the encapsulated yeast could remove trace lead from water just as rapidly as the unencapsulated yeast from Stathatou and Athanasiou's original 2021 study.

Scaling up

Led by Athanasiou, the researchers tested the mechanical stability of the hydrogel capsules and found that the capsules and the yeast inside can withstand forces similar to those generated by water running from a faucet. They also calculated that the yeast-laden capsules should be able to withstand forces generated by flows in water treatment plants serving several hundred residences.

"Lack of mechanical robustness is a common cause of failure of previous attempts to scale-up biosorption using immobilized cells; in our work we wanted to make sure that this aspect is thoroughly addressed from the very beginning to ensure scalability," Athanasiou says.

After assessing the mechanical robustness of the yeast-laden capsules, the researchers constructed a proof-of-concept packed-bed biofilter, capable of treating trace lead-contaminated water and meeting U.S. Environmental Protection Agency drinking water guidelines while operating continuously for 12 days.

This process would likely consume less energy than existing physicochemical processes for removing trace inorganic compounds from water, such as precipitation and membrane filtration, the researchers say.

This approach, rooted in circular economy principles, could minimize waste and environmental impact while also fostering economic opportunities within local communities. Although numerous lead contamination incidents have been reported in various locations in the United States, this approach could have an especially significant impact in low-income areas that have historically faced environmental pollution and limited access to clean water, and may not be able to afford other ways to remediate it, the researchers say.

"We think that there's an interesting environmental justice aspect to this, especially when you start with something as low-cost and sustainable as yeast, which is essentially available anywhere," Gokhale says.

The researchers are now exploring strategies for recycling and replacing the yeast once they're used up, and trying to calculate how often that will need to occur. They also hope to investigate whether they could use feedstocks derived from biomass to make the hydrogels, instead of fossil-fuel-based polymers, and whether the yeast can be used to capture other types of contaminants.

"Moving forward, this is a technology that can be evolved to target other trace contaminants of emerging concern, such as PFAS or even microplastics," Stathatou says. "We really view this as an example with a lot of potential applications in the future."

More information: Devashish Gokhale et al, Yeast-laden hydrogel capsules for scalable trace lead removal from water, *RSC Sustainability* (2024). DOI: 10.1039/D4SU00052H , doi.org/10.1039/D4SU00052H

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