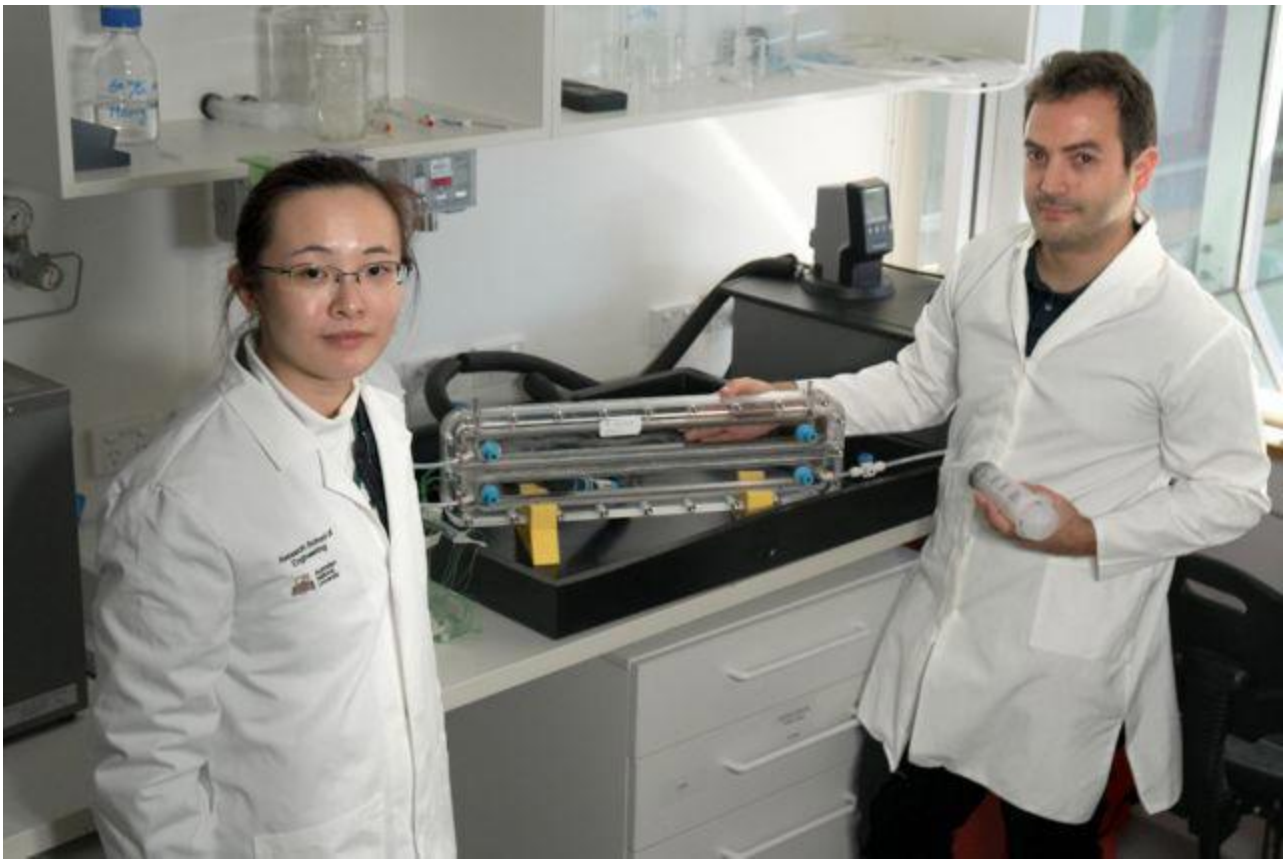
WATER DESALINATION and PURIFICATION



On a large scale, desalination is a promising method to provide abundant fresh water.© Provided by The Cool Down

Australian researchers have announced a breakthrough in desalination science that has the potential to provide millions of people with clean water.

The experts from the Australian National University are perfecting an alternative to creating fresh water from seawater that's more cost-efficient and uses less energy than reverse osmosis and other common methods.

It's a twist on a concept first recorded in science books in the 1850s, according to a university lab report.

"We're going back to the thermal desalination method but applying a principle that has never been used before, where the driving force and energy behind the process is heat," lead chief investigator Dr. Juan Felipe Torres said in the university summary.

It works by using relatively low heat from sunlight or residual warmth created by industrial machines or air conditioners to heat channels, as the university report explained. When salty water is moved through a narrow channel, salt ions collect on the colder side. To maximize the impact, the researchers heated the top side to about 140 degrees Fahrenheit. The lower side was cooler, around 68 degrees.

Holding true to Swiss scientist Charles Soret's findings in the middle of the 19th century, salt moved to the bottom.

Watch now: Uber-wealthy couple makes unprecedented move with $300 million land

"Our mission became to find a way to fast-track the diffusion process," Torres said in the report. "The key was reducing the channel height from 30 centimeters [nearly a foot] to one millimeter [less than 0.04 inches] and adding multiple channels."

As the water passed through the collection of channels, the lower salty water was removed, knocking salinity down about 3% with each pass, according to the summary.

The larger channels required 53 days to reach a "steady state." The new approach cut the diffusion process to minutes.

"Our research shows that after repeated cycles, seawater salinity can be reduced from 30,000 parts per million to less than 500," doctorate student and first author Shuqi Xu said.

Importantly, the water can remain in liquid form, a big advantage over techniques that require vaporization.

The results could be life-saving. Nature reports that worldwide water demand has spiked 600% in the last century. About 300 million people in over 150 countries rely on desalination for clean water, according to information from the World Bank.

However, the supply is lacking despite the tech, as UNICEF stated in a 2023 report that 600 million children around the planet are in need of "safely managed drinking water." Poor sanitation is sullying a lot of water, evidenced by the

400,000 kids under age five who die each year from a dirty supply, per the report.

The good news is that you can take action to save water at home with some simple tricks. A quick adjustment to your toilet tank can save liters of water a day while still working well, as one example. Tightening up your water waste around the house can save thousands of gallons, as well as lower your utility bill.

On a large scale, desalination is a promising method to provide abundant fresh water. The experts in Australia are working to prove their concept with a plant in drought-hit Tonga in the South Pacific, according to Tech Xplore.

They hope to have a commercial unit finalized within eight years.

"A paradigm shift is essential to sustain human life over the next century," Torres said in the lab report.

Seawater desalination advance could benefit billions of people

Credit: Pixabay/CC0 Public Domain

A novel approach to make seawater evaporate faster than freshwater has been hailed as a significant breakthrough in desalination technology that will benefit billions of people worldwide.

Up to 36% of the world's 8 billion people currently suffer from severe freshwater shortages for at least four months of the year, and this could potentially increase to 75% by 2050, threatening the survival of humans.

Seawater desalination is one of the most effective strategies to alleviate the impending scarcity, but existing processes consume massive amounts of energy, leaving a large carbon footprint.

Researchers from the University of South Australia (UniSA) have already demonstrated the potential of interfacial solar-powered evaporation as an energy-efficient, sustainable alternative to current desalination methods, but they are still limited by a lower evaporation rate for seawater compared to pure water due to the negative effect of salt ions on water evaporation.

UniSA materials science researcher Professor Haolan Xu has now collaborated with researchers from China on a project to develop a simple yet effective strategy to reverse this limitation. The findings have been published in the journal *Advanced Materials*.

By introducing inexpensive and common clay minerals into a floating photothermal hydrogel evaporator, the team achieved seawater evaporation rates that were 18.8% higher than pure water. This is a significant breakthrough since previous studies all found seawater evaporation rates were around 8% lower than pure water.

The mineral materials used in the process included halloysite nanotubes, bentonite, zeolite, and montmorillonite in combination with carbon nanotubes and sodium alginate to form a photothermal hydrogel.

"The key to this breakthrough lies in the ion exchange process at the air-water interface," Prof Xu says.

"The minerals selectively enrich magnesium and calcium ions from seawater to the evaporation surfaces, which boosts the evaporation rate of seawater. This ion exchange process occurs spontaneously during solar evaporation, making it highly convenient and cost-effective."

Considering the global desalination market—which numbers about 17,000 operational plants worldwide—even small declines in desalination performance can result in the loss of tens of millions of tons of clean water.

"This new strategy, which could be easily integrated into existing evaporation-based desalination systems, will provide additional access to massive amounts of clean water, benefitting billions of people worldwide," Prof Xu says.

The researchers say the hydrogel evaporator maintained its performance even after months of immersion in seawater.

The next steps will involve exploring more strategies that can make seawater evaporation faster than pure water evaporation and apply them into practical seawater desalination.

More information: Huimin Yu et al, Making Interfacial Solar Evaporation of Seawater Faster than Fresh Water, *Advanced Materials* (2024). DOI: 10.1002/adma.202414045

Provided by University of South Australia

MIT engineers have built a new desalination system that runs with the rhythms of the sun. The researchers report details of the new system in a paper appearing in *Nature Water*.

The solar-powered system removes salt from water at a pace that closely follows changes in solar energy. As sunlight increases through the day, the system ramps up its desalting process and automatically adjusts to any sudden variation in sunlight, for example by dialing down in response to a passing cloud or revving up as the skies clear.

Because the system can quickly react to subtle changes in sunlight, it maximizes the utility of solar energy, producing large quantities of clean water despite variations in sunlight throughout the day. In contrast to other solar-driven desalination designs, the MIT system requires no extra batteries for energy storage, nor a supplemental power supply, such as from the grid.

The engineers tested a community-scale prototype on groundwater wells in New Mexico over six months, working in variable weather conditions and water types. The system harnessed on average over 94% of the electrical energy generated from the system's solar panels to produce up to 5,000 liters of water per day despite large swings in weather and available sunlight.

"Conventional desalination technologies require steady power and need battery storage to smooth out a variable power source like solar. By continually varying power consumption in sync with the sun, our technology directly and efficiently uses solar power to make water," says Amos Winter, the Germeshausen Professor of Mechanical Engineering and director of the K. Lisa Yang Global Engineering and Research (GEAR) Center at MIT.

(Left to right): Jon Bessette, Shane Pratt, and Muriel McWhinnie (UROP) stand in front of the electrodialysis desalination system during an installation in July. Credit: Shane Pratt

"Being able to make drinking water with renewables, without requiring battery storage, is a massive grand challenge. And we've done it."

The system is geared toward desalinating brackish groundwater—a salty source of water that is found in underground reservoirs and is more prevalent than fresh groundwater resources. The researchers see brackish groundwater as a huge untapped source of potential drinking water, particularly as reserves of fresh water are stressed in parts of the world.

They envision that the new renewable, battery-free system could provide much-needed drinking water at low costs, especially for inland communities where access to seawater and grid power are limited.

"The majority of the population actually lives far enough from the coast that seawater desalination could never reach them. They consequently rely heavily on groundwater, especially in remote, low-income regions. And unfortunately, this

groundwater is becoming more and more saline due to climate change," says Jonathan Bessette, MIT Ph.D. student in mechanical engineering.

"This technology could bring sustainable, affordable clean water to underreached places around the world."

Pump and flow

The new system builds on a previous design, which Winter and his colleagues, including former MIT postdoc Wei He, reported earlier this year. That system aimed to desalinate water through "flexible batch electrodialysis."

Electrodialysis and reverse osmosis are two of the main methods used to desalinate brackish groundwater. With reverse osmosis, pressure is used to pump salty water through a membrane and filter out salts. Electrodialysis uses an electric field to draw out salt ions as water is pumped through a stack of ion-exchange membranes.

Scientists have looked to power both methods with renewable sources. But this has been especially challenging for reverse osmosis systems, which traditionally run at a steady power level that's incompatible with naturally variable energy sources such as the sun.

Winter, He, and their colleagues focused on electrodialysis, seeking ways to make a more flexible, "time-variant" system that would be responsive to variations in renewable solar power.

In their previous design, the team built an electrodialysis system consisting of water pumps, an ion-exchange membrane stack, and a solar panel array.

The innovation in this system was a model-based control system that used sensor readings from every part of the system to predict the optimal rate at which to pump water through the stack and the voltage that should be applied to the stack to maximize the amount of salt drawn out of the water.

When the team tested this system in the field, it was able to vary its water production with the sun's natural variations. On average, the system directly used

77% of the available electrical energy produced by the solar panels, which the team estimated was 91% more than traditionally designed solar-powered electrodialysis systems.

Still, the researchers felt they could do better.

"We could only calculate every three minutes, and in that time, a cloud could literally come by and block the sun," Winter says. "The system could be saying, 'I need to run at this high power.' But some of that power has suddenly dropped because there's now less sunlight. So, we had to make up that power with extra batteries."

Solar commands

In their latest work, the researchers looked to eliminate the need for batteries, by shaving the system's response time to a fraction of a second. The new system is able to update its desalination rate, three to five times per second. The faster response time enables the system to adjust to changes in sunlight throughout the day, without having to make up any lag in power with additional power supplies.

The key to the nimbler desalting is a simpler control strategy, devised by Bessette and Pratt. The new strategy is one of "flow-commanded current control," in which the system first senses the amount of solar power that is being produced by the system's solar panels.

If the panels are generating more power than the system is using, the controller automatically "commands" the system to dial up its pumping, pushing more water through the electrodialysis stacks. Simultaneously, the system diverts some of the additional solar power by increasing the electrical current delivered to the stack, to drive more salt out of the faster-flowing water.

"Let's say the sun is rising every few seconds," Winter explains.

"So, three times a second, we're looking at the solar panels and saying, 'Oh, we have more power—let's bump up our flow rate and current a little bit.' When we look again and see there's still more excess power, we'll up it again. As we do

that, we're able to closely match our consumed power with available solar power really accurately, throughout the day. And the quicker we loop this, the less battery buffering we need."

The engineers incorporated the new control strategy into a fully automated system that they sized to desalinate brackish groundwater at a daily volume that would be enough to supply a small community of about 3,000 people. They operated the system for six months on several wells at the Brackish Groundwater National Research Facility in Alamogordo, New Mexico.

Throughout the trial, the prototype operated under a wide range of solar conditions, harnessing over 94% of the solar panel's electrical energy, on average, to directly power desalination.

"Compared to how you would traditionally design a solar desal system, we cut our required battery capacity by almost 100%," Winter says.

The engineers plan to further test and scale up the system in hopes of supplying larger communities, and even whole municipalities, with low-cost, fully sun-driven drinking water.

"While this is a major step forward, we're still working diligently to continue developing lower cost, more sustainable desalination methods," Bessette says.

"Our focus now is on testing, maximizing reliability, and building out a product line that can provide desalinated water using renewables to multiple markets around the world," Pratt adds.

The team will be launching a company based on their technology in the coming months. The study's co-authors are Bessette, Winter, and staff engineer Shane Pratt.

More information: Direct-drive photovoltaic electrodialysis via flow-commanded current control, *Nature Water* (2024). DOI: 10.1038/s44221-024-00314-6

Aluminum foil that can clean water—researchers develop coating that attracts and traps dangerous microbes

ore than 2 billion people around the world do not have access to safe, uncontaminated drinking water. Around 418 million of them live in African countries.

The problem is most acute in rural communities, where people's primary water sources are rivers, lakes and hand-dug wells, which are often contaminated with harmful pathogens. This contamination is caused by inadequate sanitation facilities, open defecation practices, and agricultural runoff, and it has dire consequences.

Waterborne diseases such as cholera, typhoid and diarrhea claim hundreds of thousands of African lives each year. Children are especially vulnerable to these diseases because of their developing immune systems. And the cycle of waterborne diseases not only affects health: it also perpetuates poverty, as sick children are unable to attend school and adults are unable to work, hindering economic progress.

The existing solutions for water treatment often fall short. Conventional methods, such as boiling or chlorination, can be time-consuming, require fuel or chemicals, and may alter the taste of water, making people less likely to take precautions.

Filtration systems, while proven to be effective, can be expensive and require regular maintenance. This makes them inaccessible to many rural communities.

The need for a simple, affordable and sustainable solution is clear. What if part of that solution is lying in your kitchen drawer right now, in the form of a roll of aluminum foil?

I am an environmental engineer. With my colleagues I have developed a foil coated with a special material called layered double hydroxide (LDH). This material acts like a magnet, attracting and trapping microbes.

In laboratory tests we found the LDH foil remarkably efficient, removing over 99% of E. coli bacteria, a common indicator of water contamination, from water

samples within a few hours. We found that its efficacy also extends beyond E. coli, targeting a wide range of waterborne pathogens, including bacteria, viruses and parasites. This means that the LDH foil offers comprehensive protection against various diseases.

Our invention is not intended to be a standalone solution, and of course further testing will be needed, especially in the field. However, we believe it can become a valuable addition to existing water treatment practices. It can be used along with traditional methods like boiling or filtering, providing an additional layer of protection and ensuring comprehensive water safety.

How it works

This isn't a completely new idea; it was already known that layered double hydroxide could trap contaminants. Our innovation was making it into a simple, easy-to-use foil.

The LDH foil's magic lies in its ability to adsorb or capture harmful pathogens from water. Imagine a sponge soaking up water—that's absorption, where one substance is taken into another. Adsorption, on the other hand, is like sticking magnets to a fridge; substances cling to the surface of another material.

The science behind this process is fascinating. The LDH surface is positively charged, while most microbes have a negative charge on their surface. This creates an electrostatic attraction, drawing the microbes towards the LDH foil like iron filings to a magnet. Other chemical and physical forces contribute to making pathogens bind to the LDH surface, ensuring their effective removal from the water.

We tested the LDH foil in a lab by adding bacteria to clean water and then dipping the foil in to see how many bacteria it could remove. It turns out the foil was really good at its job—it removed more than 99% of the bacteria within 3 to 24 hours, depending on the specific type of LDH foil used, as different formulations exhibited slightly varying adsorption rates.

Advantages tailored for Africa

There are several reasons we believe that LDH foil is ideal for use in African countries.

The first is that it's simple and affordable. The production process is remarkably straightforward and inexpensive. We estimated the cost of producing LDH foil for one year's use is approximately US$6.93 per person. This makes it suitable for local production even in remote areas with limited resources. It not only ensures accessibility but also empowers communities to take ownership of their water safety, fostering self-sufficiency and reducing reliance on external aid.

Secondly, it's easy to use. That's a key advantage in contexts where technical expertise and complex instructions might be barriers to adoption. Its simple design and operation make it accessible to everyone, regardless of their education level or background.

It is also reusable, which is important in resource-constrained environments. After use, the foil can be regenerated multiple times by being re-immersed in simple alkaline solutions like sodium carbonate solution, commonly known as washing soda or soda ash, which is a readily available and inexpensive alkaline salt. This promotes sustainability and reduces the environmental impact associated with disposable water treatment solutions.

We've also taken cultural sensitivity and adaptability into account. The LDH foil's design and implementation can be adapted to fit the cultural context and specific needs of different African communities.

One practical example of this is the use of seawater as the alkaline solution in its production, particularly for coastal communities with easy access to this resource. This is primarily a matter of geography and what resources are available—but it also ties into cultural adaptability. Coastal communities often have a strong connection to the sea and its resources. Similarly, using fertilizers as a magnesium source (magnesium is a key component of the LDH foil's production) will resonate with agricultural communities where these materials are commonplace and familiar.

The road ahead: A collaborative journey

While the LDH foil holds immense promise, its widespread adoption will require a collaborative effort.

Further research and development are needed to optimize its performance, address any potential limitations, and ensure its long-term effectiveness in diverse African environments. We published our study in open access format using a Creative Commons license (CC BY 4.0) to ensure that all our data is publicly available and that others are able to test the LDH foil in specific settings, replicate our findings, and build upon our existing research.

Field trials in various communities will be crucial to gather user feedback, assess its practicality, and identify any cultural or logistical considerations. Moreover, partnerships with local organizations, governments and NGOs will be essential for production, distribution and education on its proper use. The journey towards clean water for all is a shared responsibility. We believe that LDH foil represents a powerful tool in this endeavor.

California Cities Facing Severe Water Cuts in 2025

California is bracing for a dry year as the Department of Water Resources (DWR) announced on Monday an initial State Water Project (SWP) allocation of just 5 percent of requested supplies for 2025.

The SWP, a critical lifeline for the state, supplies water to 29 public agencies serving 27 million state residents. The conservative forecast reflects concerns about California's water outlook amid a warming climate and the possibility of another La Niña year, which is often drier than usual.

This isn't the be-all and end-all, though. The initial allocation for Water Year 2024 was just 10 percent but eventually rose to 40 percent after a wetter than expected season.

The Dos Amigos pumping plant pushes water up hill on the San Luis Canal, part of the California Aqueduct system. Despite some promising rainfall in late November, the initial water allocations for 2025 are just 5 percent of what has been requested. Sundry Photography/Getty© Sundry Photography/Getty

"We need to prepare for any scenario, and this early in the season we need to take a conservative approach to managing our water supply," DWR Director Karla Nemeth said in a statement. "Our wettest months of the season are still to come."

Newsweek contacted the DWR via email for further comment.

The allocation was determined before a series of intense late-November storms brought above-average rainfall to Northern California. Powered by bomb cyclones and atmospheric rivers—long, narrow corridors of water vapor that deliver heavy precipitation—these storms boosted reservoir levels statewide.

Lake Oroville, California's second-largest reservoir, saw water levels surge by more than 18 feet in late November.

"While Water Year 2025 has had a promising start, California needs consistent rain and snow throughout the winter months that will continue to supply reservoirs," Michael Anderson, California's state climatologist, previously told *Newsweek*.

Before the November storms, the state's hydrologic year began on a dry and warm note. This followed record-breaking summer heat and dry conditions in

early October, leaving soils parched and reducing the runoff efficiency of early precipitation.

Soil moisture is crucial to maintaining the water supply in California. If the soil is too dry, snowpack runoff in the spring will be absorbed by the ground instead of heading to the reservoirs.

California's water future hinges on the critical months of December through February, which historically deliver half the state's annual precipitation.

"Should dry conditions return, we may end up with a below-average water year," Anderson said.

The DWR plans to reassess allocations monthly as new data on rainfall, snowpack and runoff becomes available. A final allocation decision is expected by May or June.

Until then, Californians will be urged to prepare for potential water shortages as the state navigates another year of unpredictable extremes.

Teens' $50,000 Invention May Be The Future Of Bottled Water

A 16-year-old Chinese-American student, Brian Ou, has made waves with his invention aimed at tackling one of the world's most pressing environmental challenges: microplastic pollution. Alongside his project partner, Justin Huang, Brian developed a revolutionary device that uses ultrasound technology to filter microplastics from water. Their innovation recently earned them the prestigious $50,000 grand prize [...]

The Growing Threat of Microplastics

Microplastics, tiny plastic fragments less than 5 millimeters in size, pose a severe threat to ecosystems and human health. These particles are often too small to be captured by traditional wastewater treatment facilities, eventually

finding their way into oceans and rivers. Research indicates that microplastics can infiltrate the food chain, potentially causing long-term harm to humans and wildlife alike

How It Works

Brian and Justin's device uses high-frequency ultrasound waves to agitate water, causing microplastic particles to clump together. This process, known as ultrasonic agglomeration, allows the particles to be filtered more effectively than with conventional methods. Unlike chemical or biological treatments, which can be inefficient or harmful to water quality, their device provides a safe and efficient solution

A Eureka Moment

The inspiration for the invention came during a visit to a local water treatment plant. "We were shocked to learn that no efficient methods existed for removing microplastics," Brian said. This realization spurred months of rigorous research and experimentation in their makeshift home lab. Despite limited resources, they developed a functional prototype capable of reducing microplastic content by up to 90% in controlled tests

Real-World Potential

While their device is still in the prototype stage, the potential applications are vast. It could be implemented in industrial wastewater systems, household appliances like washing machines, and even portable water purifiers for rural areas. "If we can scale this up, it could make a real difference," Brian noted

The Path to Recognition

Winning the ISEF prize was a dream come true for the duo. Competing against over 1,800 students from around the globe, Brian and Justin stood out with their innovative approach to a global issue. "We were just thrilled to participate," said Justin. "Winning was beyond our expectations"

Overcoming

Ekkasit Jokthong

The journey was not without its hurdles. Both teenagers balanced schoolwork with intensive project development. Limited funding and access to professional-grade equipment meant they had to rely heavily on creativity and resourcefulness. Yet, their perseverance paid off, attracting the attention of environmental organizations and investors alike

The Next Steps

The $50,000 prize money will be reinvested into further refining their invention. The team plans to collaborate with professional labs to enhance the efficiency and scalability of their device. They aim to make it affordable and accessible to communities worldwide, particularly those most affected by water pollution

A Global Call to Action

Microplastic pollution is a growing concern, with studies showing its presence in everything from drinking water to seafood. Brian and Justin's invention underscores the power of youth-led innovation in addressing complex environmental challenges. "We hope our work inspires others to tackle these issues," said Brian

Broader Implications

Their success also highlights the importance of supporting STEM education and providing young minds with opportunities to innovate. The ISEF competition serves as a platform for students to showcase their ideas and make meaningful contributions to science and technology

Community Support

Brian and Justin credit their achievement to the support of their families, teachers, and local community. “Without their encouragement, this wouldn’t have been possible,” Justin remarked. Their school has since received increased attention, with many students expressing renewed interest in science fairs and environmental projects

Hope for the Future

As microplastic pollution continues to pose a threat to global ecosystems, inventions like Brian and Justin’s offer a glimmer of hope. With continued development and widespread adoption, their device could play a pivotal role in creating a cleaner, healthier world.

Clear Water Ahead

Brian Ou’s journey from a curious teenager to an award-winning inventor demonstrates the power of determination and innovation. His work not only addresses a critical environmental issue but also inspires a new generation of problem solvers to take action.

Scientists develop high-tech sniffing device capable of detecting oil spills — here's why it has potential

Scientists develop high-tech sniffing device capable of detecting oil spills — here's why it has potential

Scientists in Russia unveiled a paperback-sized sniffing device they say can detect oil spills in soil, conduct field studies, and help ensure refineries are in compliance with laws governing their pollution.

Researchers at the Skolkovo Institute of Technology (Skoltech) published the findings of their AI-powered e-nose in the Journal of Hazardous Materials.

The aim of the e-nose is to provide a solution to detect oil that is far cheaper than tandem gas chromatograph-mass spectrometers used in laboratories, and much more practical for field use.

After training the sniffing device with an AI-powered "random forest" model, the Skoltech team said it could detect oil at a cost 20 times lower than the expensive lab devices, per a news release on the study.

Its small size and portability also gave it a series of applications. Lab devices have high accuracy and sensitivity, but take up several square meters of space in contrast.

"Our approach can be used to monitor reservoir productivity in oil fields," said Skoltech researcher Valery Zaitsev. "The e-nose will determine the chemical properties of volatile oil compounds in the air based on their smell."

The trained e-nose was capable of detecting oil in soil as much as 12 hours after contamination and after some evaporation had occurred. It also successfully determined the origin of nine different types of oil featuring lighter and heavier oil with varying volatile compounds.

Lighter oil evaporates quicker, which makes it difficult to detect after some time. Heavier oil, meanwhile, escapes in small amounts, which complicates identifying the source. The team's sniffing device used an algorithm to meet those challenges.

If companies harness the e-nose correctly, the devices could help detect oil spills and soil contamination quicker. It can also allow them to monitor conditions to avoid running afoul of pollution restrictions and triggering major fines.

That will ideally mean avoiding endangering neighboring communities that pay a heavy cost for their excess pollution. Dangerous pollutants like benzene can heighten threats for residents to contract leukemia and respiratory illnesses, while methane can warm the planet to dangerous levels.

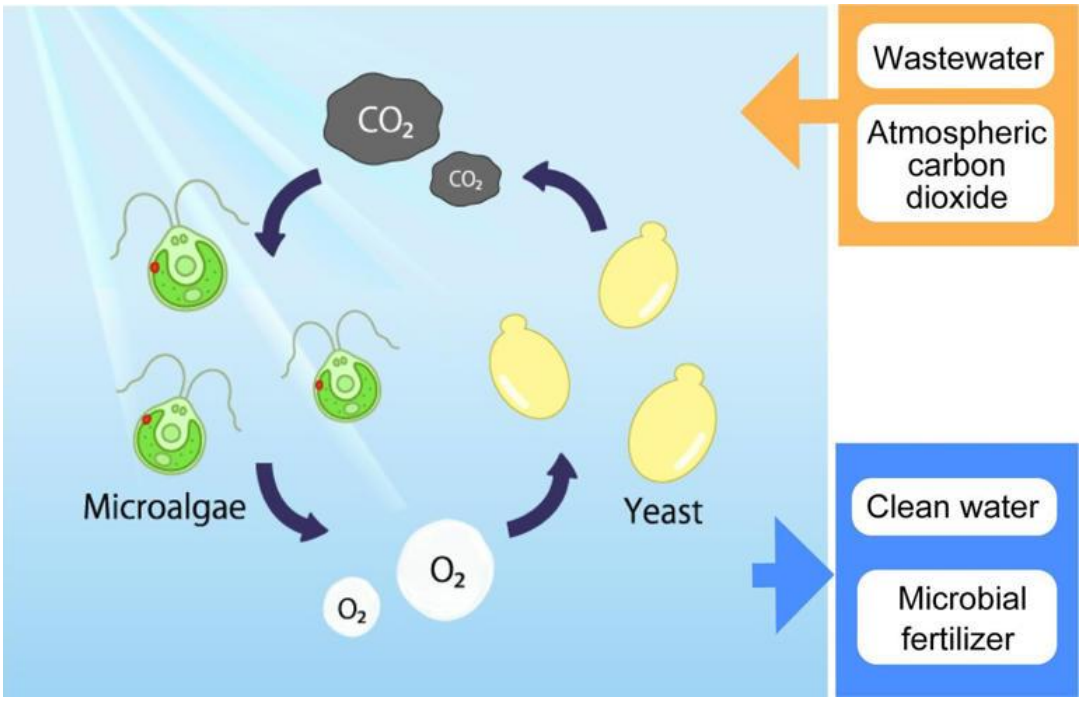
Zaitsev suggested that "the e-nose can also help to identify the exact locations of new oil fields," which would aid companies in maximizing new drilling opportunities.

Head of the project Fedor Fedorov pointed to its uses by oil companies as "a device and an algorithm for monitoring emissions and training the e-nose for specific tasks."

"Since our device is expected to be used by industrial companies, our immediate goal is to implement it as a commercial product," Fedorov disclosed. Until then, the team at Skoltech will keep refining the sniffing device to replicate a human nose.

"In the meantime, we will try to teach the e-nose to perceive odors like humans do, for example, to determine whether an odor is pleasant or unpleasant and to what extent," he concluded.

Scientists discover yeast-green algae mix improves water treatment



Green algae and yeast enhance each other's growth potential, thereby increasing the efficiency of wastewater treatment. Credit: Osaka Metropolitan University

Bakeries and wineries can't do without yeast, but they have no need for green algae. Wastewater treatment facilities, however, might just want to have these microorganisms team up. Osaka Metropolitan University researchers have

discovered that these simple organisms form the best combination in terms of boosting wastewater treatment efficiency.

The active sludge method of wastewater treatment requires electricity to ensure the flow of oxygen that feeds bacteria and other organisms that process the water. Adding microalgae to conduct photosynthesis, which produces oxygen, improves energy-efficiency, but low carbon dioxide levels hinder their growth. Enter the yeast Saccharomyces cerevisiae, which produces carbon dioxide.

Associate Professor Ryosuke Yamada of the Graduate School of Engineering led the group in investigating which combination of these types of microorganisms would provide the highest efficiency in wastewater treatment.

The findings were published in *Applied Microbiology and Biotechnology*.

Reported for the first time to the researchers' knowledge, the group found that the combination of the green algae Chlamydomonas reinhardtii and yeast had the best efficiency. Notably, the combination enhanced the green algae's ability to absorb ammonium and phosphate ions.

"The green algae and yeast are highly safe for humans, especially considering that treated wastewater is discharged into the environment," Professor Yamada explained.

"These microorganisms can also accumulate useful compounds such as polysaccharides, fats, and oils in their cells, and be used as microbial fertilizers, so it is possible to expect useful compounds to be produced at the same time as the wastewater is being treated."

More information: Miiku Takahashi et al, Co-utilization of microalgae and heterotrophic microorganisms improves wastewater treatment efficiency, *Applied Microbiology and Biotechnology* (2024). DOI: 10.1007/s00253-024-13309-w

Provided by Osaka Metropolitan University

Solving the global water crisis: Hydropanel produces 10 liters of safe drinking water every day

Water is a fundamental human need, but access to safe, clean drinking water is far from universal. Even in industrialized nations, the water supply faces challenges from contamination, aging infrastructure, and climate-induced scarcity.

Innovative technologies like atmospheric water generators (AWGs) and hydropanels are providing new pathways to clean water for households and communities worldwide.

The State of Water Insecurity

In the United States, the water infrastructure is under strain. Forty percent of America's 50,000 community water systems have reported quality violations, according to the EPA. Nearly 15% of Americans rely on wells, and half of these private sources fail to meet basic quality standards.

https://youtu.be/w_LP3UQDLrc

California exemplifies the severity of this issue, with 450,000 residents served by systems that do not comply with the Safe Drinking Water Act.

The most common contaminants in failing water systems include heavy metals like lead, copper, arsenic, and uranium, along with bacteria such as E. coli. Many of these pollutants stem from industrial, agricultural, or mining activities, while aging infrastructure exacerbates the problem.

Heavy metals pose a particularly insidious threat. Their accumulation in the body over time can lead to severe health issues, including cancers, neurological disorders, and developmental delays in children. Lead exposure, for instance, impairs brain development and immune function, while arsenic is a known carcinogen even at low levels.

Enter Atmospheric Water Generators

AWGs offer a compelling solution by capturing water vapor from the air and condensing it into liquid form. These devices can function in diverse climates, providing clean water in regions with poor-quality or unreliable supplies.

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For example, the SOURCE hydropanel from Zero Mass Water uses solar power to extract moisture from the air, converting it into potable water enriched with calcium and magnesium for improved taste and health benefits.

A standard SOURCE array consists of two panels and can produce between 4 to 10 liters of water daily. The system includes a 30-liter reservoir for storage, with a direct connection to a home's tap or refrigerator.

Maintenance is minimal, requiring only annual filter changes and a mineral cartridge replacement every five years. Over its lifetime, a single unit can generate the equivalent of 43,800 bottles of water, eliminating the associated plastic waste.

The initial cost of a SOURCE system is approximately $4,000 for the base array plus $500 for installation—the long-term benefits are substantial. Over its 10-year lifespan, the daily cost of operation averages $1.23, or $0.12 to $0.30 per liter.

https://youtu.be/S2Cq_TpNXoQ

Critically, these devices offer a lifeline for remote or underserved communities. They are entirely independent of external water supplies or electrical grids, making them ideal for off-grid homes, emergency preparedness, and drought-prone regions.

According to Zero Mass Water, the technology performs reliably even in arid climates, such as Scottsdale, Arizona, where humidity levels drop below 5% during summer.

Tackling Hidden Contaminants

Many small or rural communities face unique challenges in maintaining water quality. Federal regulations often fall short in these areas due to a lack of testing, underfunded infrastructure, or decentralized systems like private wells. Heavy metals such as copper, lead, and arsenic frequently contaminate water supplies in these regions, posing severe health risks.

Solar-powered water extractor on a school campus. (CREDIT: Source)© The Brighter Side of News

Lead and copper, commonly found in aging plumbing, leach into water through corroding pipes. Arsenic, a naturally occurring but highly toxic element, enters drinking water through industrial runoff or agricultural practices. Mercury, another dangerous contaminant, often originates from mining activities or improper waste disposal.

The long-term health effects of these toxins are profound. Chronic exposure can damage organs, impair cognitive development, and lead to fatal diseases. Pregnant women and children are particularly vulnerable, highlighting the urgency of addressing water quality issues comprehensively.

Hydropanels like SOURCE present a sustainable alternative. Unlike rainwater harvesting, these devices capture pure water vapor from the atmosphere. The water is mineralized for optimal taste and health before being stored for consumption.

Installation is straightforward, with panels mounted on rooftops or properties to optimize solar exposure. Once operational, the system functions independently, providing clean drinking water while reducing reliance on bottled water or trucked-in supplies.

SOURCE® drinking water systems change the state of community drinking water from insecurity to abundance.
(CREDIT: Source)© The Brighter Side of News

Bridging the Gap Between Technology and Accessibility

Despite the promise of AWGs and hydropanels, their adoption is limited by cost. A broader rollout of these systems would require public and private investment to reduce prices and increase accessibility. Nevertheless, the environmental and health benefits make these devices a worthwhile investment for those who can afford them.

As climate change intensifies water scarcity and contamination risks, innovative solutions like hydropanels offer a glimpse into a more sustainable future. They

empower households to take control of their water supply, ensuring access to clean, safe drinking water regardless of geography or infrastructure limitations.

Water security is not just a local issue but a global one. Technologies like atmospheric water generators and hydropanels provide scalable, sustainable solutions to an age-old problem.

By investing in these innovations, communities can protect their most vital resource while promoting health, sustainability, and resilience.

Biodegradable sponge could remove 99.9% of microplastics from water

US engineers turn salty seawater into drinking water with new cheap method

Researchers have developed carbon cloth electrodes that efficiently remove boron from seawater, potentially replacing costly chemicals in desalination.

The electrodes remove boron from desalinated water by splitting molecules into ions. Hydroxide ions bind to boron, which adheres to positive electrodes, ensuring safer drinking water production.

The breakthrough, developed by a team of engineers at the University of Michigan (UM) and Rice University, marks a crucial advancement in making seawater safe for drinking.

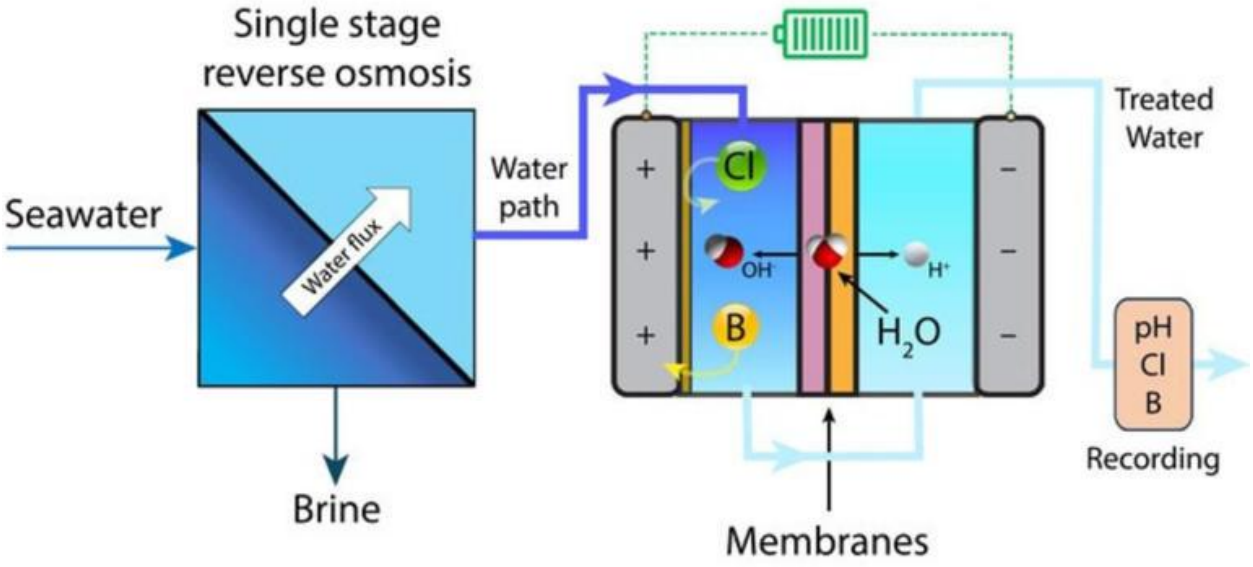
“Our device reduces the chemical and energy demands of seawater desalination, significantly enhancing environmental sustainability and cutting costs by up to 15 percent, or around 20 cents per cubic meter of treated water,” said Weiyi Pan, a postdoctoral researcher at Rice University and a study co-first author, in a statement.

Efficient boron removal from seawater

Boron, a natural seawater component, becomes a toxic contaminant in drinking water when it bypasses conventional salt-removing filters. Seawater's boron levels often exceed the World Health Organization's limits for safe drinking water and surpass the tolerance of many agricultural plants.

Conventional reverse osmosis membranes struggle to remove boron, as it exists in seawater as electrically neutral boric acid, which passes through filters designed to repel charged particles.

"We developed a new technology that's fairly scalable and can remove boron in an energy-efficient way compared to some of the conventional technologies," said Jovan Kamcev, assistant professor of chemical engineering and macromolecular science and engineering at UM and a co-corresponding author of the study, in a statement.



The diagram illustrates how the researchers' electrodes remove boron. Initially, most salt ions are removed through reverse osmosis.

In order to solve this problem, desalination plants usually add a base to change boric acid into a negatively charged form. After removing this charged boron in a second step of reverse osmosis, the base is neutralized using acid. But the expense of these other procedures goes up a lot.

The new device simplifies the process, reducing the need for extra chemicals and energy. This innovation enhances environmental sustainability and lowers costs by up to 15 percent, saving approximately 20 cents per cubic meter of treated water.

Sustainable water solutions

Global desalination capacity reached 95 million cubic meters per day in 2019, and new membranes designed for boron removal could save approximately $6.9 billion annually.

The team highlights that large-scale facilities, such as San Diego's Claude "Bud" Lewis Carlsbad Desalination Plant, stand to save millions of dollars per year.

These cost reductions could make seawater a more viable source of drinking water, addressing the escalating global water crisis. Freshwater supplies are projected to meet just 40 percent of demand by 2030, according to a 2023 report by the Global Commission on the Economics of Water.

The advanced electrodes efficiently remove boron by trapping it within pores lined with oxygen-containing structures that specifically bind to boron while allowing other ions to pass through. However, boron must carry a negative charge to adhere to the capture sites.

The electrodes create positive hydrogen ions and negative hydroxide ions by splitting water between two layers rather than by introducing a chemical base to induce this charge. By binding with boron, the hydroxide provides the charge required for it to adhere to the positive electrode. By doing away with the requirement for a second reverse osmosis step, this method lowers expenses and energy consumption.

After the boron is eliminated, hydrogen and hydroxide ions recombine to create neutral, boron-free water, offering a sustainable and effective method of desalinating saltwater.

"Our study presents a versatile platform that leverages pH changes that could transform other contaminants, such as arsenic, into easily removable forms," said Menachem Elimelech, a professor of Civil and Environmental Engineering

and Chemical and Biomolecular Engineering at Rice University, and a co-corresponding author of the study, in a statement.

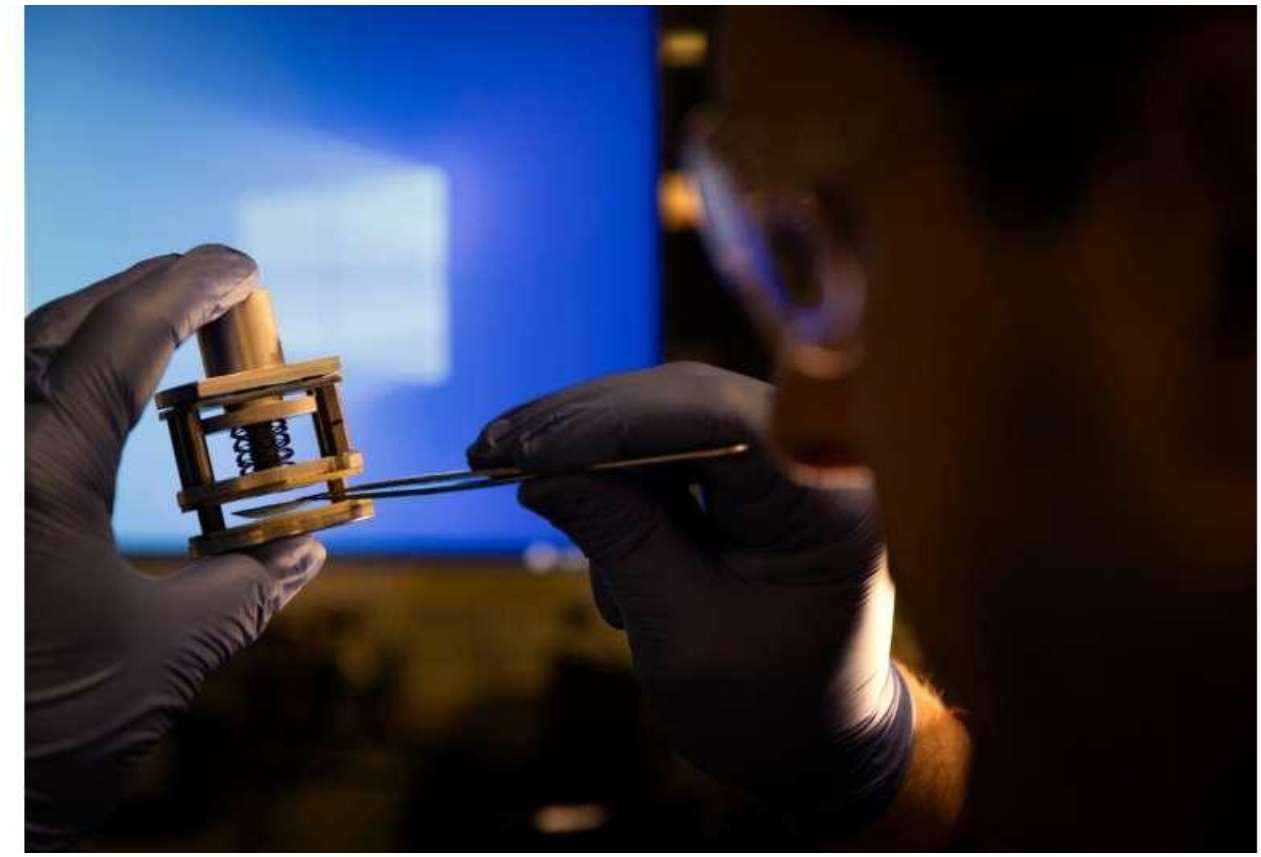
Additionally, the functional groups on the electrode can also be modified to specifically bind with various contaminants, enabling more energy-efficient water treatment.

The details regarding the team's research were published in the journal *Nature Water*.

JANUARY 20, 2025

New water purification technology helps turn seawater into drinking water without tons of chemicals

by University of Michigan



Jovan Kamcev, an assistant professor of chemical engineering and macromolecular science and engineering at U-M, places a filter membrane between two electrodes, which measure how well the membrane conducts electricity. This helps his team predict how well it can purify water. Credit: Marcin Szczepanski, Michigan Engineering.

Water desalination plants could replace expensive chemicals with new carbon cloth electrodes that remove boron from seawater, an important step of turning seawater into safe drinking water.

A study describing the new technology has been published in *Nature Water* by engineers at the University of Michigan and Rice University.

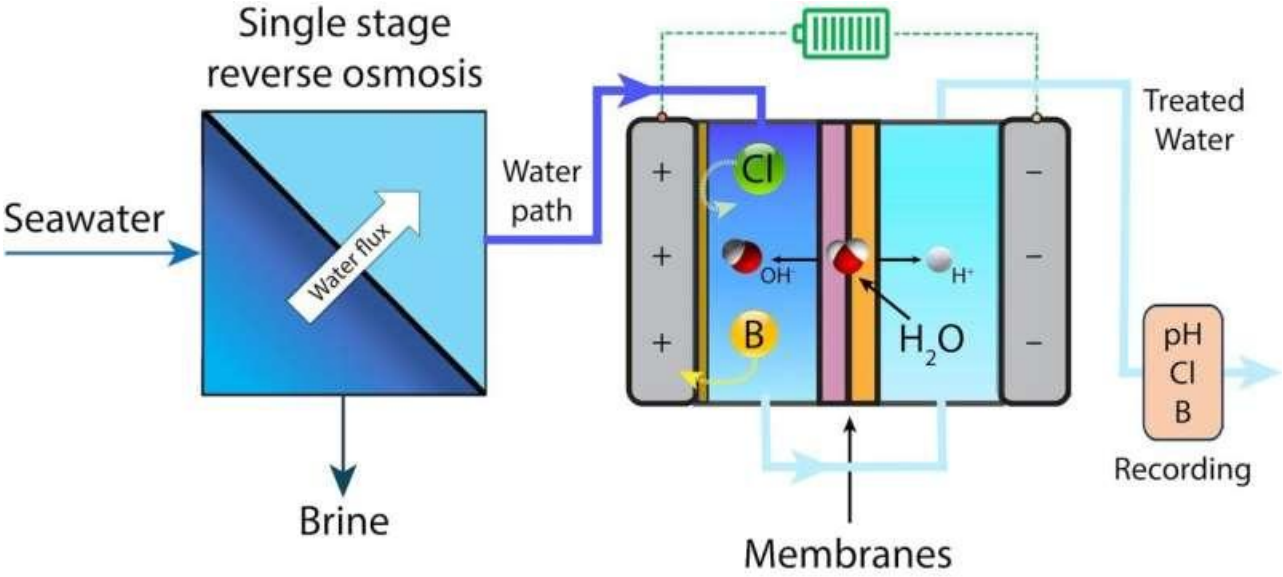
Boron is a natural component of seawater that becomes a toxic contaminant in drinking water when it sneaks through conventional filters for removing salts.

Seawater's boron levels are around twice as high as the World Health Organization's most

lenient limits for safe drinking water, and five to 12 times higher than the tolerance of many agricultural plants.

"Most reverse osmosis membranes don't remove very much boron, so desalination plants typically have to do some post treatment to get rid of the boron, which can be expensive," said Jovan Kamcev, U-M assistant professor of chemical engineering and macromolecular science and engineering and a co-corresponding author of the study. "We developed a new technology that's fairly scalable and can remove boron in an energy-efficient way compared to some of the conventional technologies."

In seawater, boron exists as electrically neutral boric acid, so it passes through reverse osmosis membranes that typically remove salt by repelling electrically charged atoms and molecules called ions. To get around this problem, desalination plants normally add a base to their treated water, which causes boric acid to become negatively charged. Another stage of reverse osmosis removes the newly charged boron, and the base is neutralized afterward by adding acid. Those extra treatment steps can be costly.



This diagram shows how boron is removed by the researchers' electrodes. First a majority of the salt ions are removed with reverse osmosis. Then the water flows into a cell containing a membrane with positive (pink) and negative (orange) layers. Similarly charged electrodes face the membrane layers, and when a current is applied, water molecules at the interface of the membranes split into hydrogen and hydroxide ions. The hydroxide ions stick to boron, causing it to stick to the positive electrode. Credit: Jovan Kamcev, Kamcev Research Lab, University of Michigan, and Weiyi Pan, Elimelech Research Lab, Rice University.

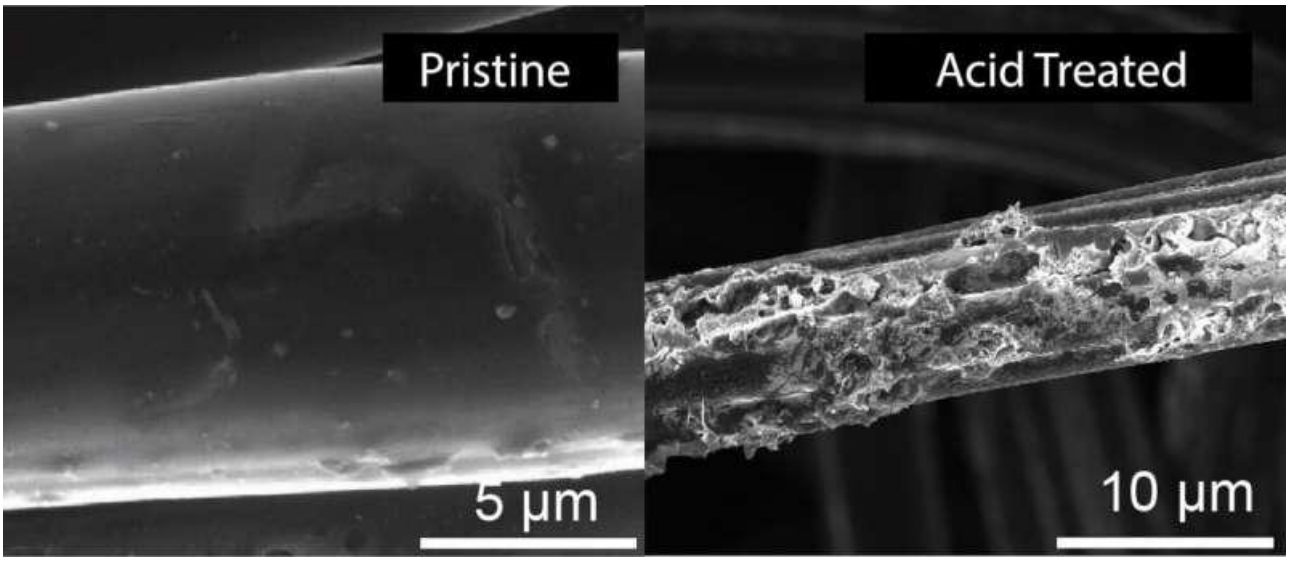
"Our device reduces the chemical and energy demands of seawater desalination, significantly enhancing environmental sustainability and cutting costs by up to 15 percent, or around 20 cents per cubic meter of treated water," said Weiyi Pan, a postdoctoral researcher at Rice University and a study co-first author.

Given that global desalination capacity totaled 95 million cubic meters per day in 2019, the new membranes could save around $6.9 billion annually. Large desalination plants—such

as San Diego's Claude "Bud" Lewis Carlsbad Desalination Plant—could save millions of dollars in a year.

Those kinds of savings could help make seawater a more accessible source of drinking water and alleviate the growing water crisis. Freshwater supplies are expected to meet 40% of demand by 2030, according to a 2023 report from the Global Commission on the Economics of Water.

The new electrodes remove boron by trapping it inside pores studded with oxygen-containing structures. These structures specifically bind with boron while letting other ions in seawater pass through, maximizing the amount of boron they can capture.



When treated with acid, the carbon cloth fibers in the researchers' electrodes gain oxygen-containing features that can trap boron. Credit: Jovan Kamcev, Kamcev Research Lab, University of Michigan.

But the boron-catching structures still need the boron to have a negative charge. Instead of adding a base, the charge is created by splitting water between two electrodes, creating positive hydrogen ions and negative hydroxide ions. The hydroxide attaches to boron, giving it a negative charge that makes it stick to the capture sites inside the pores in the positive electrode.

Capturing boron with the electrodes also enables treatment plants to avoid spending more energy on another stage of reverse osmosis. Afterward, the hydrogen and hydroxide ions recombine to yield neutral, boron-free water.

"Our study presents a versatile platform that leverages pH changes that could transform other contaminants, such as arsenic, into easily removable forms," said Menachem Elimelech, the Nancy and Clint Carlson Professor of Civil and Environmental Engineering and Chemical and Biomolecular Engineering at Rice University, and a co-corresponding author of the study.

"Additionally, the functional groups on the electrode can be adjusted to specifically bind with different contaminants, facilitating energy-efficient water treatment," Elimelech said.

More information: Weiyi Pan et al, A highly selective and energy efficient approach to boron removal overcomes the Achilles heel of seawater desalination, *Nature Water* (2025). DOI: 10.1038/s44221-024-00362-y
Journal information: Nature Water
Provided by University of Michigan

JANUARY 15, 2025

Over 97 million US residents exposed to unregulated contaminants in their drinking water, analysis reveals

by Silent Spring Institute

Credit: Unsplash/CC0 Public Domain

Nearly a third of people in the U.S. have been exposed to unregulated contaminants in their drinking water that could impact their health, according to a new analysis by scientists at Silent Spring Institute. What's more, Hispanic and Black residents are more likely than other groups to have unsafe levels of contaminants in their drinking water and are more likely to live near pollution sources.

The findings, published in the journal *Environmental Health Perspectives,* add to growing concern about the quality of drinking water in the United States and the disproportionate impact of contamination on communities of color.

Close to 100 contaminants are currently regulated under the U.S. Safe Drinking Water Act. This means public water utilities must test for these contaminants and take steps to ensure levels don't exceed certain limits by installing new treatment systems and taking other measures.

"Yet, we know there are thousands of other harmful chemicals that are not regulated that make their way into groundwater and surface waters, and some of these chemicals can ultimately end up in drinking water supplies," says co-author Laurel Schaider, a senior scientist at Silent Spring Institute.

Schaider and her team looked at data from the U.S. Environmental Protection Agency (EPA) collected between 2013 and 2015 under its Unregulated Contaminant Monitoring Rule program. The team analyzed data from 4,815 public water systems and found 27%—

serving 97 million residents—had detectable levels of at least one of the following chemicals:

- 1,4-dioxane, a solvent classified by EPA as a probable human carcinogen, also found in consumer products
- PFAS (per- and polyfluoroalkyl substances), non-stick chemicals widely used in consumer products, associated with cancer, thyroid disease, high cholesterol and other health problems
- chlorodifluoromethane (Freon 22), an ozone-depleting gas previously used as a refrigerant and used in the production of fluoropolymers (e.g. Teflon)
- 1,1-dichloroethane, a solvent used in paints, plastics, and pesticides associated with cancer.

Communities with a higher proportion of Hispanic and Black residents generally were more likely to be exposed to these unregulated contaminants in their drinking water and were more likely to be situated close to pollution discharge sites including wastewater treatment plants, airports and military training areas, and industrial sites.

"Our findings show that the percentage of Hispanic and Black residents in a community is a consistent predictor of poorer water quality," says lead author Aaron Maruzzo, a scientist at Silent Spring Institute.

These racial disparities could not be explained by income or other measures of socioeconomic status, he says, suggesting that factors such as racism and the historical practice of redlining that led to the disproportionate siting of industrial facilities in communities of color could be playing a role.

The study builds on previous research by Silent Spring, which found Hispanic residents are more likely to be exposed to higher levels of nitrate in their drinking water.

EPA set a legal limit on nitrate decades ago to protect infants from a fatal condition known as "blue baby syndrome.". Newer evidence suggests exposure to nitrate at levels below the federal standard can also increase the risk of colorectal and bladder cancer.

A 2023 study, co-authored by Schaider, looked at community water systems in 18 states and found those with a higher proportion of Hispanic and Black residents had higher levels of PFAS in their drinking water.

The new Silent Spring analysis is the first to look at disparities in exposure to PFAS and other unregulated contaminants in all U.S. states, as well as Tribal lands and U.S. territories.

In addition, recent testing shows PFAS are significantly more widespread in drinking water than previously thought, so the number of residents impacted by contaminants at the time the data were collected is an underestimate, says Schaider.

In April 2024, EPA announced drinking water standards for six PFAS chemicals. The study's findings underscore the need for federal action to regulate more contaminants and provide communities of color with more resources to address the impacts of pollution.

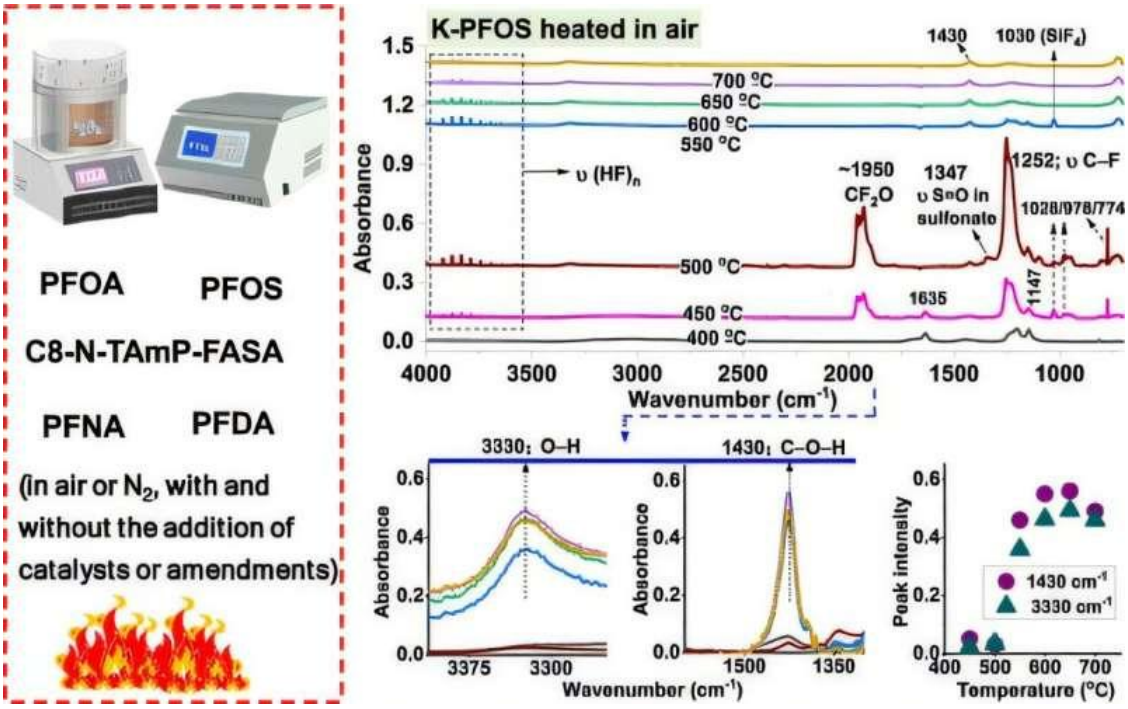
"Ultimately, we need to do a better job at protecting source waters and reducing discharges of pollutants into water bodies that feed into our drinking water supplies," says Schaider.

More information: Socioeconomic disparities in exposures to PFAS and other unregulated industrial drinking water contaminants in U.S. public water systems, *Environmental Health Perspectives* (2025). DOI: 10.1289/EHP14721
Journal information: Environmental Health Perspectives
Provided by Silent Spring Institute

FEBRUARY 5, 2025

A material used to clean household aquariums offers a simple solution to break down forever chemicals

by Theo Schwinke, University of Missouri



Credit: *Environmental Science & Technology* (2024). DOI: 10.1021/acs.est.4c05782

A University of Missouri researcher has discovered a new method to remove so-called "forever chemicals" from our drinking water.

Per- and polyfluoroalkyls (PFAS) are industrial chemicals used to manufacture thousands of products, including cosmetics, carpeting, non-stick cookware, stain-resistant fabrics, firefighting foams, food packaging and waterproof clothing.

They're everywhere—the environment, our food and even in our bodies. Peer-reviewed studies have shown that exposure to PFAS may lead to decreased fertility, developmental delays in children and increased risk of some cancers. And they take hundreds or even thousands of years to break down.

For roughly the past 10 years, researchers have been looking for ways to remove PFAS from the environment or at least degrade them into harmless, inorganic compounds.

Now, Feng "Frank" Xiao, an associate professor in Mizzou's College of Engineering, and team have found a simple solution using common tools and materials.

"You don't need organic solvent or really high temperatures," Xiao, an expert in degrading PFAS, said. "Just heat the PFAS with granular activated carbon, or GAC."

GAC is composed of granules of coal, wood or other carbon-rich materials that have been heated. It is already commonly used to filter a wide range of harmful chemicals from contaminated water or air. Consumers use it to clean household aquariums or filter drinking water, and it can be purchased online for just a few dollars per pound.

In a paper recently published in the journal *Environmental Science and Technology*, Xiao and his team describe how they heated PFAS with common GAC at 572 degrees Fahrenheit (300 degrees Celsius). As a result, the researchers achieved 90% mineralization of the PFAS, breaking the forever chemicals down into harmless, inorganic fluorine.

Before now, reaching this level of mineralization required temperatures in excess of 1,292 degrees Fahrenheit (700 degrees Celsius), high pressure or solvents. Xiao's method is much more cost effective and sustainable, as GAC is inexpensive and can be reheated again and again.

Potential applications

The key to Xiao's innovation is the combination of GAC and heat.

"Once GAC is involved, the thermal degradation of PFAS occurs much faster, and the mineralization is more intense," Xiao said. "It's not an expensive process, compared to reverse osmosis, and it can be done at local scale with a regular furnace."

The discovery represents a significant breakthrough in managing PFAS-containing solid wastes, biosolids and spent adsorbent media that are major concerns to farmers and communities.

"In the Midwest, we use a lot of herbicides and give animals a lot of pharmaceuticals," Xiao said. "These substances can contain high amounts of PFAS. Through this new removal method, we can drastically reduce the compounds' presence in our lives."

Xiao chose Mizzou for the opportunities he has to collaborate with other leading researchers and for the quality of the scholarship of undergraduate and graduate students.

"I teach environmental courses, and the students really care about the environment. They care about the water quality, and they care about our ecosystem," Xiao said.

Xiao communicates to those students his passion for practical research and the opportunities they have to create a better world through engineering.

"The real-world application of this discovery is that we can effectively and efficiently remove forever chemicals and other contaminants from our water," he said. "This is the technology we need."

More information: Runze Sun et al, New Insights into Thermal Degradation Products of Long-Chain Per- and Polyfluoroalkyl Substances (PFAS) and Their Mineralization Enhancement Using Additives, *Environmental Science & Technology* (2024). DOI: 10.1021/acs.est.4c05782
Journal information: Environmental Science and Technology , Environmental Science & Technology
Provided by University of Missouri

FEBRUARY 20, 2025'

'Fog harvesting' could yield water for drinking and agriculture in the world's driest regions

by Frontiers

Panoramic view of Alto Hospicio, located in Chile's Atacama desert, one of the driest places in the world. Credit: Dr. Virginia Carter Gamberini.

With less annual rainfall than 1 mm per year, Chile's Atacama Desert is one of the driest places in the world. The main water source of cities in the region are underground rock layers that contain water-filled pore spaces which last recharged between 17,000 and 10,000 years ago.

Now, local researchers have assessed if "fog harvesting," a method where fog water is collected and saved, is a feasible way to provide the residents of informal settlements with much needed water.

"This research represents a notable shift in the perception of fog water use—from a rural, rather small-scale solution to a practical water resource for cities," said Dr. Virginia Carter Gamberini, an assistant professor at Universidad Mayor and first co-author of the *Frontiers in Environmental Science* study.

"Our findings demonstrate that fog can serve as a complementary urban water supply in drylands where climate change exacerbates water shortages."

Catching moisture

Fog collectors typically consist of a mesh suspended between two posts. The mesh serves as an interception surface to catch moisture. Droplets collate on the mesh and fall into a gutter leading to water storage tanks. It's a passive system that requires no external energy.

The researchers conducted a year-long field study in Alto Hospicio, a fast-growing municipality located in the hyper-arid Atacama Desert. Because of the city's rapid growth, approximately 10,000 people live in informal settlements. Only 1.6% of these settlements are connected to water distribution networks and most inhabitants receive water via trucks.

"The collection and use of water, especially from non-conventional sources such as fog water, represents a key opportunity to improve the quality of life of inhabitants," Carter said.

Graffiti in Alto Hospicio that shows how the city is currently supplied with water. Credit: Dr. Virginia Carter Gamberini.

The researchers found that in a 100 square kilometer area surrounding Alto Hospicio, between 0.2 and 5 liters of fog water could be harvested per square meter each day. This potential, however, is confined to the higher lying altitudes outside of the city's limits.

During the study's peak season, in August and September of 2024, collection potential reached up to 10 liters per square meter and day.

"By showcasing its potential in Alto Hospicio, one of Chile's most stigmatized yet rapidly urbanizing cities, this study lays the groundwork for broader adoption in other water-scarce urban areas," said Nathalie Verbrugghe, a researcher at Université libre de Bruxelles and first co-author of the article.

Fog harvesting, however, should not be seen as the sole solution to water scarcity but as part of a broader urban water management strategy, the researchers said.

- Panoramic view of Alto Hospicio, a fast-growing municipality located in the hyper-arid Atacama Desert. Credit: Dr. Virginia Carter Gamberini.

- 
Alto Hospicio receives less annual rainfall than 1 mm per year. Credit: Dr. Virginia Carter Gamberini.

Easing water shortages in urban areas

The collected water could be used for drinking, irrigation of green spaces, and local food production. However, large storage systems, piping infrastructure, and ways of distribution would be necessary, the researchers said.

Based on an annual average water collection rate of 2.5 liters per square meter per day, the researchers said that 17,000 square meters of mesh could produce enough water to meet the weekly water demand (300,000 liters) for urban slums, and 110 square meters could meet the annual demand for the irrigation of the city's green spaces (100,000 liters). Similarly, fog water could be used for soil-free agriculture, with yields of 15 to 20kg of leafy green vegetables in a month.

For the same to work in other places, the geographic and atmospheric conditions need to be just right.

"Key prerequisites include fog density, suitable wind patterns, and well-oriented elevated landforms. Additionally, since fog is seasonal in many regions, this variability should be considered," said Verbrugghe.

Future research will also need to evaluate the feasibility of fog harvesting in larger settlements.

"We hope to encourage policymakers to integrate this renewable source into national water strategies," concluded Carter. "This could enhance urban resilience to climate change and rapid urbanization while improving access to clean water."

More information: Unlocking the fog: Assessing fog collection potential and need as a complementary water resource in arid urban lands -The Alto Hospicio, Chile Case, *Frontiers in Environmental Science* (2025). DOI: 10.3389/fenvs.2025.1537058
Provided by Frontiers

Revolutionary solar panels sucks 10 liters of clean drinking water out of the air per day

By harvesting water vapor from the air and condensing it into liquid, atmospheric water generators can essentially pull water from the air

Share this story

[Sept. 13, 2023: Derek Markham]

Solar-powered water extractor. (CREDIT: SOURCE.CO)

By harvesting water vapor from the air and condensing it into liquid, atmospheric water generators can essentially pull water from the air, and these devices hold a lot of promise for providing an independent source of drinking water.

And although drought-stricken regions and locations without safe or stable water sources are prime candidates for water production and purification devices such as those, residences and commercial buildings in the developed world could also benefit from their use, and they make a great fit for off-grid homes and emergency preparedness kits.

The statistics speak for themselves:

- 40 percent of America's 50,000 community water systems have had water quality violations, according to the EPA.
- 15 percent of Americans still rely on wells as their main source of water. A full 50 percent of that water wouldn't pass a quality test.
- Over 450,000 California residents who are served by a Community Water System are subjected to water that is failing to meet the Safe Drinking Water Act.
- Evidence shows that American households facing water insecurity and poor water quality are likely to have lower incomes and live in areas where infrastructure has been systemically underfunded.
- 100 percent of California's failing systems serve less than 100,000 people; 96.4 percent serve less than 10,000 people. Tulare County, where Allensworth is located, has largest number of systems without safe water. (Community Water Center's Drinking Water Tool identifies exactly where communities have the environmental burden of no clean water and are also disadvantaged.)
- The most common contaminants found in these water systems are arsenic, nitrate, lead, copper, Uranium, and E.Coli.

Some water generators, such as the WaterSeer, get a lot of hype (and a lot of skepticism) but haven't been able to deliver. Others, like the Ecoloblue devices, are a bit more costly and complex, but they actually exist and can be bought and put to work.

Zero Mass Water's SOURCE device, is a rooftop solar device that produces water instead of just electricity. The company's SOURCE hydropanel arrays are now available in the US, where "It works in almost every climate, and almost every day of the year."

A standard SOURCE array is made up of two hydropanels, with additional panels added as needed for the water production or the local climate, and this self-contained unit is designed to be mounted onto the roof of a building, where it can then produce an average of 4-10 liters per day.

An onboard 30-liter reservoir holds the collected water and mineralizes it with calcium and magnesium, and the outflow of the device can be plumbed right to a tap (or refrigerator or dispenser) inside the building for ease of use.

No maintenance is said to be necessary other than annual filter changes and swapping out the mineral cartridge every five years, which a subscription program delivers when it's time.

The system will produce the equivalent of 43,800 bottles of water over its lifetime, with no plastic waste.

A Practical Solution

According to Zero Mass Water, even those in low-humidity and arid regions can put SOURCE units to work to generate water, which is a question that many skeptics of the system bring up.

Solar-powered water extractor on a school campus. (CREDIT: SOURCE.CO)

"Our array on the Zero Mass Water headquarters in Scottsdale, Arizona makes water year-long despite low relative humidity. The Phoenix-Metro area can get below 5% relative humidity in the summer, and SOURCE still produces water in these incredibly dry conditions."

SOURCE water generators are costly, at least in terms of the initial investment. A standard array with two panels runs about $4000, plus another $500 for installation, and is said to be engineered to last at least 10 years. That brings the cost to about $1.23 per day, or between $0.12 and $0.30 per liter, when averaged out over the life of the unit.

Solar-powered desalination device will provide clean water to 400,000 Kenyans

Converting seawater into safe drinking water takes an enormous amount of energy, which makes it a costly and polluting process.

Converting seawater into safe drinking water at a large scale takes an enormous amount of energy, which makes it a costly and polluting process.

Now, a Dutch-based blended finance manager Climate Fund Managers (CFM), and Solar Water Solutions are working together to develop the installation of up to 200 desalination units in Kitui County, Kenya. The project eventually aims to provide clean water made of brackish groundwater for 400,000 Kenyans.

The new solar-powered desalination system works without connecting to a grid, without any batteries or chemicals, ever. This means the system will need zero battery investments, zero running costs, have zero emissions and zero carbon footprint.

The team working on the project claims that their containerized SolarRO reverse osmosis system is the world's first desalination system powered by 100% solar energy. This fully automatic standalone system is installed in a 20ft container. The system will convert from 3500 L/h up to 7000 L/h from seawater, with total dissolved solids (TDS) 36,000 ppm. The production capacity is up to 10,000 liters per hour from brackish water, powered entirely by solar panels.

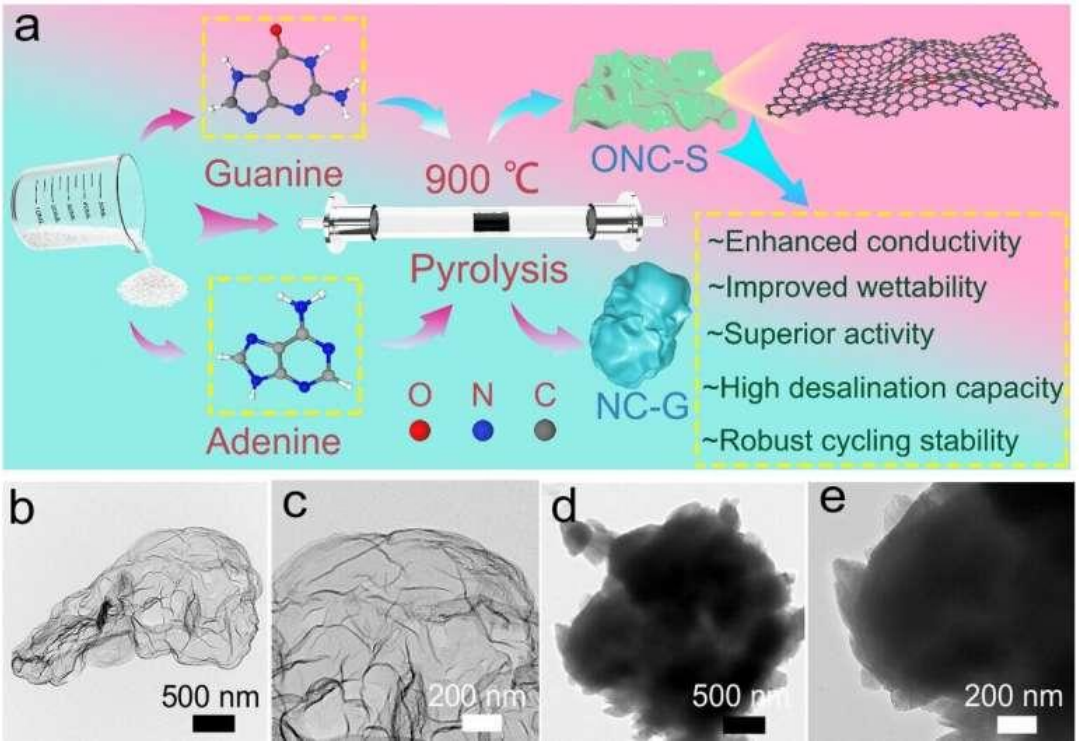
"Through this partnership with CFM and locally with Kitui County and Epicenter Africa, we can together revolutionize access to safe, affordable water in rural Kenya," said Antti Pohjola, CEO of Solar Water Solutions. "This project marks a breakthrough in solar-powered water infrastructure. It wouldn't have happened without the four key elements: A sustainable technology that brings down the cost of clean water, access to finance with a leading institutional investor, local partners, and a market-based business model."

The stations themselves may not be visually impressive, but they are an ideal solution for water production in remote islands and rural areas.

FEBRUARY 27, 2025

Seawater purification technique outperforms commonly used materials, even activated carbon

by Nagoya University



Synthesis and characterizations for ONC-S and NC-G. Credit: *Nature Communications* (2025). DOI: 10.1038/s41467-025-56694-0

Researchers have discovered a new technique for improving the electrodes that convert seawater into potable water using oxygen. The findings were reported in *Nature Communications*. The research was led by Yusuke Yamauchi at Nagoya University, Japan in collaboration with Xingtao Xu at Zhejiang Ocean University,

"As the world's population has been increasing, water scarcity will likely become a critical issue," Yamauchi said, explaining the motivation behind the study. "We were excited to develop a material that outperformed all existing materials, even activated carbon."

The technique works by removing ions from seawater using electrodes, leaving deionized, drinkable water. In the process, ions from seawater are attracted to the electrode surface and charged ions are stored in an electric double layer formed there. In addition to purifying

water, the ions can be extracted from the electrodes following separation, allowing useful ions, such as sodium, to be repurposed for industrial processes.

The most commonly used electrodes are porous carbonaceous electrodes, which use a carbon and nitrogen base with pores to create a high surface area for extracting ions from liquids. The researchers theorized that 'heteroatom doping,' which introduces atoms to alter a material's structure and improve performance, could improve electrode conductivity and stability.

"We used oxygen for doping, as oxygen creates synergistic effects with nitrogen that increase the adsorption of ions. We found that in the presence of oxygen, the affinity of nitrogen for ions was increased," Asakura said. "We were excited to discover that oxygen affects capacitive deionization. Our team was the first to demonstrate this role of it."

An unexpected benefit emerged when the researchers discovered that oxygen-doped electrodes had even greater surface area, likely because the doping process changed the carbonization activity. This increased surface area enhances the purification efficiency.

Yamauchi believes their findings are an important reminder for researchers not to neglect certain techniques. "Other groups overlooked the potential use of oxygen in this process," he said. "That's why we included 'unveiling the neglected role of oxygen doping' in the paper's title."

Although carbon-based materials are already relatively inexpensive, the researchers believe that their findings will further reduce the cost of purifying water, making the technology more accessible to underserved coastal communities facing freshwater shortages. Beyond water purification, this innovation has promising applications in the automotive industry, where similar electrodes are vital components in fuel cells, particularly those used in hydrogen-powered vehicles.

More information: Jiabao Li et al, Unveiling the neglected role of oxygen doping in nitrogen-doped carbon for enhanced capacitive deionization performance, *Nature Communications* (2025). DOI: 10.1038/s41467-025-56694-0
Journal information: Nature Communications
Provided by Nagoya University

FEBRUARY 24, 2025

Brewing tea reduces toxic heavy metals in drinking water, study finds

by Northwestern University

New study finds that brewing tea naturally removes lead and other toxic heavy metals from water. Credit: Vinayak P. David Group/Northwestern University

Good news for tea lovers: That daily brew might be purifying the water, too.

In a new study, Northwestern University researchers demonstrated that brewing tea naturally adsorbs heavy metals like lead and cadmium, effectively filtering dangerous contaminants out of drinks. Heavy metal ions stick to, or adsorb to, the surface of the tea leaves, where they stay trapped until the used tea bag is disposed of.

The study was published in the journal *ACS Food Science & Technology.*

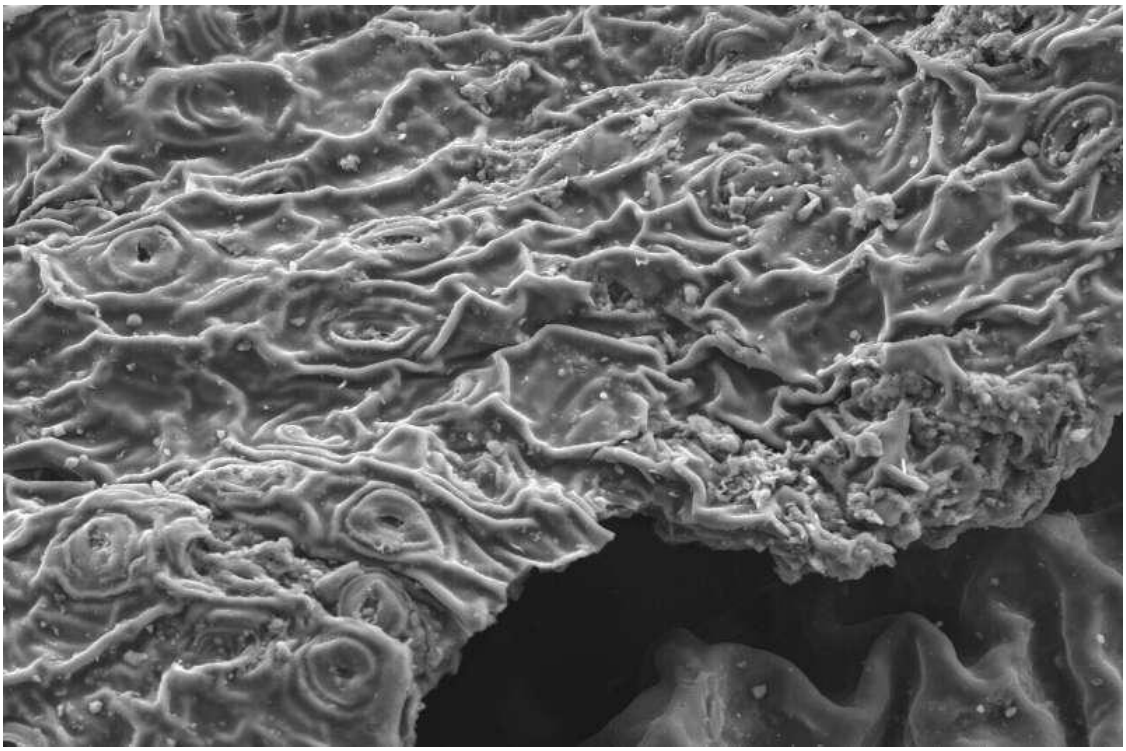
"We're not suggesting that everyone starts using tea leaves as a water filter," said Northwestern's Vinayak Dravid, the study's senior author.

"For this study, our goal was to measure tea's ability to adsorb heavy metals. By quantifying this effect, our work highlights the unrecognized potential for tea consumption to passively contribute to reduced heavy metal exposure in populations worldwide."

"I'm not sure that there's anything uniquely remarkable about tea leaves as a material," said Benjamin Shindel, the study's first author.

"They have a high active surface area, which is a useful property for an adsorbent material and what makes tea leaves good at releasing flavor chemicals rapidly into your water. But what is special is that tea happens to be the most consumed beverage in the world.

"You could crush up all kinds of materials to get a similar metal-remediating effect, but that wouldn't necessarily be practical. With tea, people don't need to do anything extra. Just put the leaves in your water and steep them, and they naturally remove metals."



Scanning electron microscope image of black tea leaves, magnified by 300 times. Black tea, which is wilted and fully oxidized, exhibits a wrinkled and surface, potentially increasing the available surface area for adsorption. Credit: Vinayak P. David Group/Northwestern University

An expert on sorbent materials and sponge entrepreneur, Dravid is Abraham Harris Professor of Materials Science and Engineering at Northwestern's McCormick School of Engineering. At the time of the research, Shindel was a Ph.D. student in Dravid's laboratory; now he works with the U.S. Department of Energy's National Energy Technology Laboratory.

Exploring different variables

To conduct the study, the Northwestern team explored how different types of tea, tea bags and brewing methods affect heavy metal adsorption. The various varieties tested included "true" teas such as black, green, oolong and white, as well as chamomile and rooibos teas. They also examined the differences between loose-leaf and commercially bagged tea.

The researchers created water solutions with known amounts of lead and other metals (chromium, copper, zinc and cadmium), and then heated the solutions to just below boiling temperature. Next, they added the tea leaves, which steeped for various time intervals—from mere seconds to 24 hours.

After steeping, the team measured how much of the metal content remained in the water. By comparing metal levels before and after adding the tea leaves, they were able to calculate how much was effectively removed.

Cellulose bags work best—and don't release microplastics

After multiple experiments, Dravid, Shindel and their team identified several trends. Perhaps somewhat unsurprising: The bag matters. After testing different types of bags without tea inside, the researchers found cotton and nylon bags only adsorbed trivial amounts of the contaminants. The cellulose bags, however, worked incredibly well.

In the study, researchers tested various varieties of teas, including "true" teas such as black, green, oolong and white, as well as chamomile and rooibos teas. They also examined the differences between loose-leaf and commercially bagged tea. Credit: Vinayak P. David Group/Northwestern University

The key to a successful sorbent material is high surface area. Similar to how a magnet attaches to a refrigerator door, metal ions cling to the surface of a material. So, the more area for the particles to stick to, the better. Shindel posits that cellulose, which is a biodegradable natural material made from wood pulp, has higher surface area—and therefore more binding sites—than sleeker synthetic materials.

"The cotton and nylon bags remove practically no heavy metals from water," Shindel said.

"Nylon tea bags are already problematic because they release microplastics, but the majority of tea bags used today are made from natural materials, such as cellulose. These may release micro-particles of cellulose, but that's just fiber which our body can handle."

Longer steeping time, fewer metals

When comparing different varieties of tea, the researchers discovered tea type and grind played minor roles in adsorbing contaminants. Finely ground tea leaves, particularly black tea leaves, adsorbed slightly more metal ions than whole leaves. Again, the researchers attributed this to surface area.

"When tea leaves are processed into black tea, they wrinkle and their pores open," Shindel explained. "Those wrinkles and pores add more surface area. Grinding up the leaves also increases surface area, providing even more capacity for binding."

Out of all the experiments, one factor stood out most. Steeping time played the most significant role in tea leaves' ability to adsorb metal ions. The longer the steeping time, the more contaminants were adsorbed.

"Any tea that steeps for longer or has higher surface area will effectively remediate more heavy metals," Shindel said. "Some people brew their tea for a matter of seconds, and they are not going to get a lot of remediation. But brewing tea for longer periods or even overnight—like iced tea—will recover most of the metal or maybe even close to all of the metal in the water."

In the study, researchers examined the differences in loose-leaf and bagged teas. They found cotton and nylon bags only adsorbed trivial amounts of the contaminants. The cellulose (or paper) bags, however, worked incredibly well. Credit: Vinayak P. David Group/Northwestern University

Future opportunities

Although results depend on several factors—steeping time and water-to-tea ratio, for example—tea preparation removes an amount of lead from water that should be significant from a public health perspective.

From their experiments, the researchers estimate that tea preparation can remediate about 15% of lead from drinking water, even up to lead concentrations as high as 10 parts per million. That estimate applies only to a "typical" cup of tea, which includes one mug of water and one bag of tea, brewed for three to five minutes.

Changing the parameters remediates different levels of lead. Steeping for longer than five minutes, for example, adsorbs more lead compared to the average steeping time.

"Ten parts lead per million is obviously incredibly toxic," Shindel said. "But with lower concentrations of lead, tea leaves should remove a similar fraction of the metal content in the water. The primary limiting factor is how long you brew your tea for."

In high-resource areas of the world, it's unlikely that concentrations will reach such high levels. And if there is a water crisis, brewing tea will not solve the problem. But Shindel said the study's results provide useful new information that could be applied to public health research.

"Across a population, if people drink an extra cup of tea per day, maybe over time we'd see declines in illnesses that are closely correlated with exposure to heavy metals," he said.

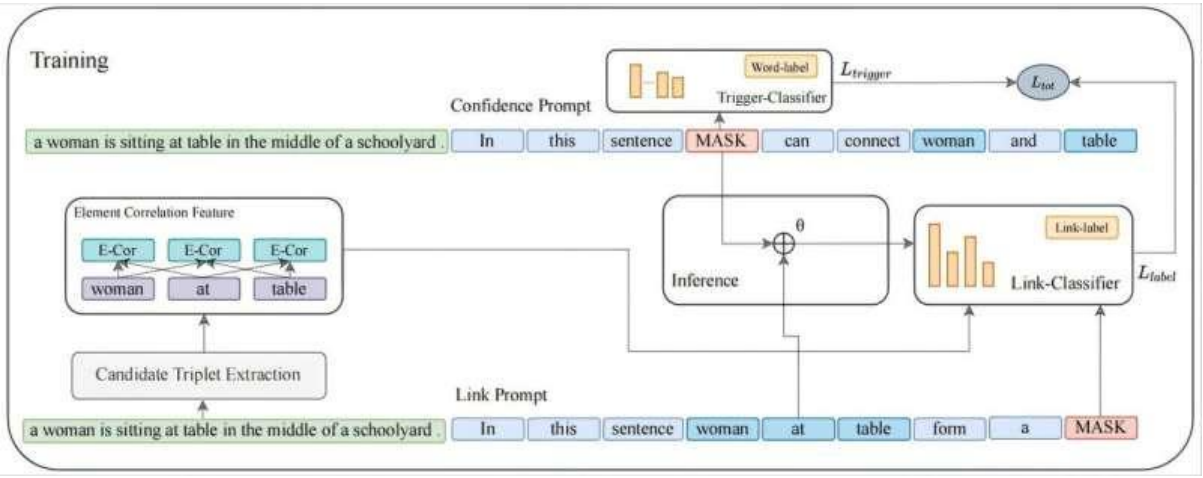
"Or it could help explain why populations that drink more tea may have lower incidence rates of heart disease and stroke than populations that have lower tea consumption."

More information: Brewing clean water: The metal-remediating benefits of tea preparation, *ACS Food Science & Technology* (2025). dx.doi.org/10.1021/acsfoodscitech.4c01030
Provided by Northwestern University

MARCH 5, 2025

Cracking the code on gypsum and silica scaling in water desalination

by Higher Education Press



Credit: Tiezheng Tong , Shinyun Park , Yiqun Yao

Mineral scaling, a significant issue in membrane desalination, reduces water recovery rates and diminishes system performance. Gypsum and silica are two prevalent types of scaling, each form through different processes—crystallization for gypsum and polymerization for silica.

These formation mechanisms lead to contrasting behaviors: gypsum scaling, marked by rapid kinetics and intrusive crystal growth, causes pore wetting, while silica scaling forms highly adhesive, irreversible layers. The impact of these scales on desalination efficiency underscores the need for a deeper understanding of their formation and mitigation.

On October 20, 2024, researchers from Arizona State University and Colorado State University published a review in *Frontiers of Environmental Science & Engineering*. The

study meticulously examines the contrasting behaviors and mitigation strategies of gypsum and silica scaling in membrane desalination processes.

The research provides an in-depth analysis of gypsum and silica scaling, offering insights into their distinct behaviors. Gypsum scaling occurs through the crystallization of calcium sulfate, resulting in rapid kinetics and directional crystal growth.

These large, high-aspect ratio crystals can intrusively penetrate membrane pores, leading to issues like pore wetting in membrane distillation. The presence of organic foulants complicates gypsum scaling, as some substances can inhibit crystal growth through adsorption.

In contrast, silica scaling arises from the polymerization of silicic acid, producing amorphous, adhesive scales that form a gel-like layer on membranes, causing nearly irreversible flux decline. Silica scaling is less responsive to membrane surface properties, making it more challenging to mitigate.

The study also outlines various strategies for addressing each scaling type. For gypsum scaling, hydrophilic polymer brushes and zwitterionic coatings show promise, while silica scaling may benefit from modified membrane surface charges to promote electrostatic repulsion. Additionally, the use of antiscalants and pretreatment methods like electrocoagulation are explored.

Dr. Tiezheng Tong, first author of the study, emphasized, "Our comprehensive analysis of gypsum and silica scaling provides a foundation for developing more targeted and efficient strategies to combat mineral scaling in desalination. This research is crucial for improving the sustainability and efficiency of water treatment processes."

The findings have significant implications for the desalination industry, offering strategies that can help prevent or mitigate scaling. By tailoring membrane surface properties, selecting appropriate antiscalants, and employing pretreatment methods, researchers and engineers can improve desalination efficiency and extend system longevity.

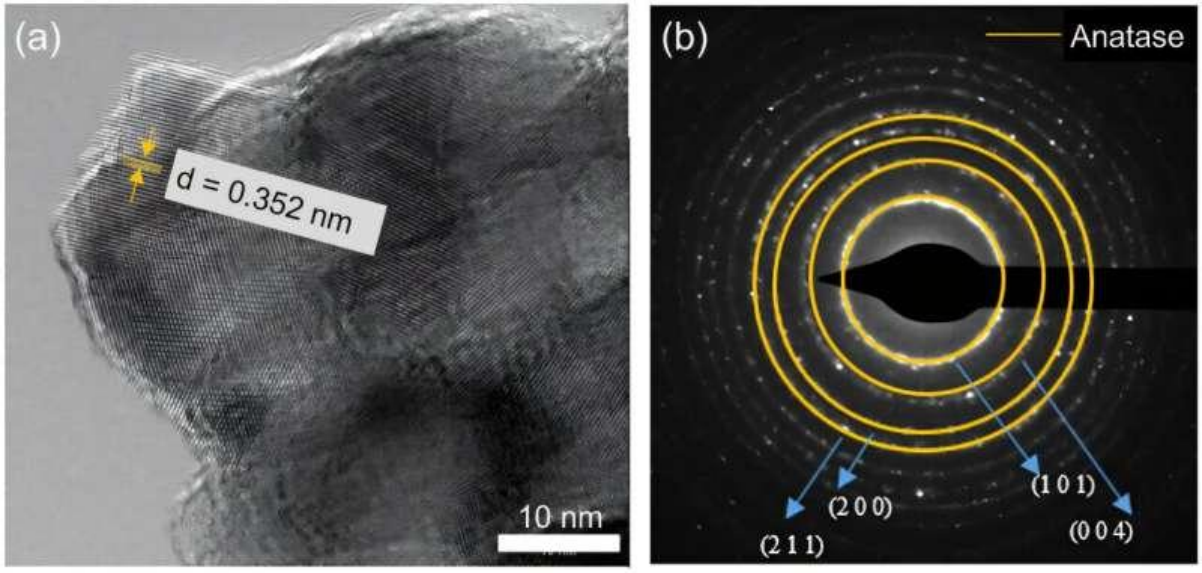
These advancements not only enhance water recovery rates but also contribute to the broader goal of sustainable water management, particularly in areas facing water scarcity, by ensuring more efficient and reliable desalination processes.

More information: Tiezheng Tong et al, A tale of two minerals: contrasting behaviors and mitigation strategies of gypsum scaling and silica scaling in membrane desalination, *Frontiers of Environmental Science & Engineering* (2024). DOI: 10.1007/s11783-025-1923-9
Provided by Higher Education Press

MARCH 24, 2025

3D nanotech blankets offer new path to clean drinking water

by Tatyana Woodall, The Ohio State University



(a) High-resolution TEM Image showing (101) plane of anatase phase of pure TiO_2 nanofibers; b) the SAED pattern of the nanofibers. Credit: *Advanced Science* (2025). DOI:10.1002/advs.202502981

Researchers have developed a new material that, by harnessing the power of sunlight, can clear water of dangerous pollutants. Created through a combination of soft chemistry gels and electrospinning—a technique where electrical force is applied to liquid to craft small fibers—the team constructed thin fiber-like strips of titanium dioxide (TiO_2), a compound often utilized in solar cells, gas sensors and various self-cleaning technologies.

Despite being a great alternative energy source, solar fuel systems that utilize TiO_2 nanoparticles are often power-limited because they can only undergo photocatalysis, or create chemical reactions, by absorbing non-visible UV light. This can cause significant challenges to implementation, including low efficiency and the need for complex filtration systems.

Yet when researchers added copper to the material to improve this process, their new structures, called nanomats, were able to absorb enough light energy to break down harmful pollutants in air and water, said Pelagia-Iren Gouma, lead author of the study and a professor of materials science and engineering at The Ohio State University.

"There hasn't been an easy way to create something like a blanket that you can lay on water and start creating energy," she said. "But we are the only ones who have made these structures and the only ones to demonstrate that they actually work."

The study was recently published in the journal *Advanced Science*.

When titanium dioxide absorbs light, electrons are formed that oxidize water and attack pollutants, slowly destroying them until they become benign. When copper is added, that process is supercharged, making it even more effective.

To determine this, researchers worked to characterize the nanomat's updated properties to understand how it behaved and what made it different from other self-cleaning nanoparticles, said Gouma. Surprisingly, researchers found that compared to traditional solar cells, these nanomats can be more successful at power generation when placed under natural sunlight, she said.

"These nanomats can be used as a power generator, or as water remediation tools," she said. "In both ways, you have a catalyst with the highest efficiency reported to date."

These lightweight, easy-to-remove fiber mats can float and operate atop any body of water and are even reusable through multiple cleaning cycles. Because nanomats are so effective, researchers envision that they could be used to rid water of industrial pollutants in developing countries, turning otherwise contaminated rivers and lakes into sources of clean drinking water.

Additionally, because this technology doesn't generate any toxic byproducts like some solar cell systems, nanomats are extremely environmentally friendly. "It's a safe material, it won't hurt anything, and it's as clean as it can be," said Gouma.

Still, although this team's technology is incredibly efficient, how long it will take to scale up commercially depends on how quickly industries take notice of the product. "We have the tools to make them in large quantities and translate them to various industries," said Gouma. "The only limitation is that it needs someone to take advantage of these abundant resources."

Overall, the study's findings suggest that nanomats could be a promising tool in many future photocatalytic applications, including long-term sustainability efforts like environmental remediation as well as solar-driven hydrogen production.

In the meantime, the team plans to examine ways to optimize the material further.

"This material is completely novel in terms of a new form of nanotechnology," said Gouma. "It's really impressive and something that we are very excited about."

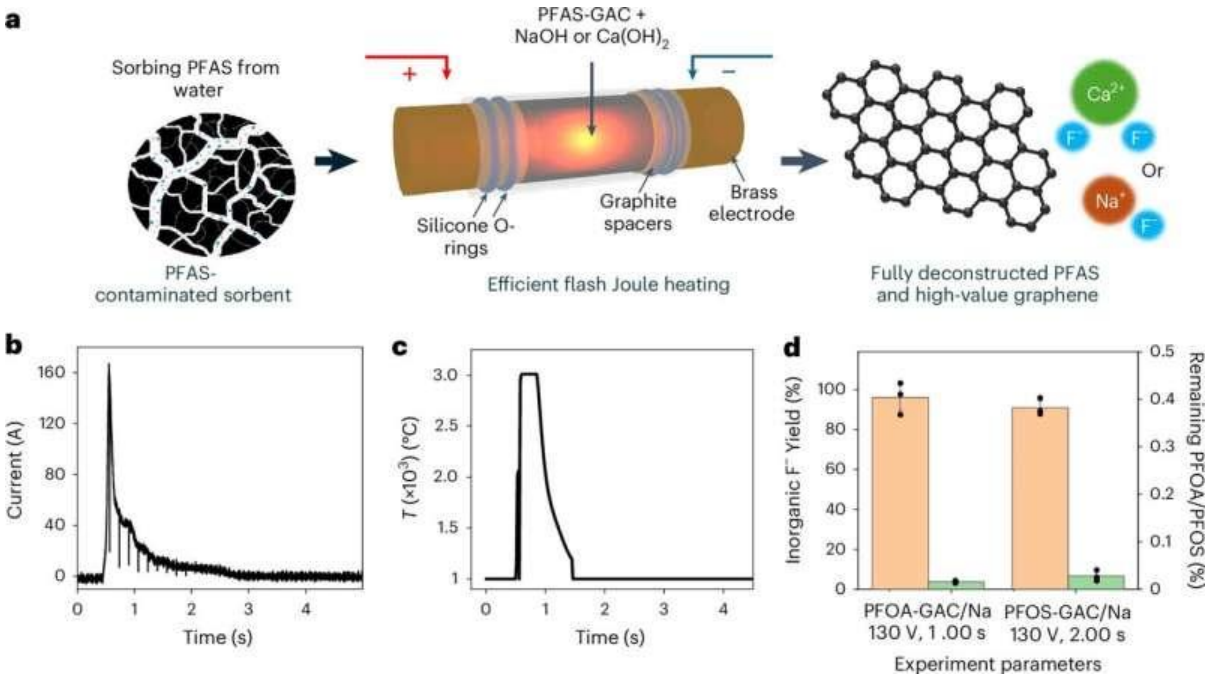
More information: Fateh Mikaeili et al, 3D Self-Supported Visible Light Photochemical Nanocatalysts, *Advanced Science* (2025). DOI: 10.1002/advs.202502981. advanced.onlinelibrary.wiley.c … .1002/advs.202502981
Journal information: Advanced Science

Provided by The Ohio State University

MARCH 31, 2025

Purification method removes PFAS from water while transforming waste into high-value graphene

by Rice University



Scheme, current and temperature of the FJH study. Credit: *Nature Water* (2025). DOI: 10.1038/s44221-025-00404-z

Rice University researchers have developed an innovative solution to a pressing environmental challenge: removing and destroying per- and polyfluoroalkyl substances (PFAS), commonly called "forever chemicals."

A study led by James Tour, the T.T. and W.F. Chao Professor of Chemistry and professor of materials science and nanoengineering, and graduate student Phelecia Scotland unveils a method that not only eliminates PFAS from water systems but also transforms waste into high-value graphene, offering a cost-effective and sustainable approach to environmental remediation. This research was published March 31 in *Nature Water*.

PFAS are synthetic compounds in various consumer products, valued for their heat, water and oil resistance. However, their chemical stability has made them persistent in the environment, contaminating water supplies and posing significant health risks, including

cancer and immune system disruptions. Traditional methods of PFAS disposal are costly, energy-intensive and often generate secondary pollutants, prompting the need for innovative solutions that are more efficient and environmentally friendly.

"Our method doesn't just destroy these hazardous chemicals; it turns waste into something of value," Tour said. "By upcycling the spent carbon into graphene, we've created a process that's not only environmentally beneficial but also economically viable, helping to offset the costs of remediation."

The research team's process employs flash joule heating (FJH) to tackle these challenges. By combining granular activated carbon (GAC) saturated with PFAS and mineralizing agents like sodium or calcium salts, the researchers applied a high voltage to generate temperatures exceeding 3,000 degrees Celsius in under one second.

The intense heat breaks down the strong carbon-fluorine bonds in PFAS, converting them into inert, nontoxic fluoride salts. Simultaneously, the GAC is upcycled into graphene, a valuable material used in industries ranging from electronics to construction.

The research results yielded more than 96% defluorination efficiency and 99.98% removal of perfluorooctanoic acid (PFOA), one of the most common PFAS pollutants. Analytical tests confirmed that the reaction produced undetectable amounts of harmful volatile organic fluorides, a common byproduct of other PFAS treatments. The method also eliminates the secondary waste associated with traditional disposal methods such as incineration or adding spent carbon to landfills.

"This dual-purpose approach is a game changer," Scotland said. "It transforms waste into a resource while providing a scalable, cost-effective solution to an urgent environmental issue."

The implications of this research extend beyond PFOA and perfluorooctane sulfonic acid, the two most studied PFAS; it even works on the most recalcitrant PFAS type, Teflon R. The high temperatures achieved during FJH suggest that this method could degrade a wide range of PFAS compounds, paving the way for broader water treatment and waste management applications. The FJH process can also be tailored to produce other valuable carbon-based materials, including carbon nanotubes and nanodiamonds, further enhancing its versatility and economic appeal.

"With its promise of zero net cost, scalability and environmental benefits, our method represents a step forward in the fight against forever chemicals," Scotland said. "As concerns over PFAS contamination continue to grow, this breakthrough offers hope for safeguarding water quality and protecting public health worldwide."

More information: Phelecia Scotland et al, Mineralization of captured perfluorooctanoic acid and perfluorooctane sulfonic acid at zero net cost using flash Joule heating, *Nature Water* (2025). DOI: 10.1038/s44221-025-00404-z
Journal information: Nature Water

Scientists Discover Bizarre New Lifeforms in Earth's Mysterious Critical Zone

BY MICHIGAN STATE UNIVERSITYAPRIL 9, 2025

Earth's Critical Zone extends from the tops of trees down through the soil to depths up to 700 feet and depicts the microbes which live throughout this zone. This zone supports most life on the planet as it regulates essential processes like soil formation, water cycling, and nutrient cycling, which are vital for food production, water quality, and ecosystem health.

Deep soils vital for life host an active new microbial phylum, CSP1-3. These microbes may be key to innovative water purification and environmental solutions.

Scientists have discovered a new phylum of microbes in the Earth's Critical Zone, deep soil layers that help purify groundwater. As water filters through this zone, these microbes break down leftover pollutants, improving water quality. The Critical Zone also plays a vital role in soil formation, nutrient cycling, and water regulation, key processes for food production and ecosystem health. Since microbes are essential to life on Earth, understanding this newly found group could boost conservation efforts and help address climate change.

Leonardo da Vinci once said, "We know more about the movement of celestial bodies than about the soil underfoot."

James Tiedje, a world-renowned expert in microbiology at Michigan State University, agrees with da Vinci. But he aims to change this through his work on the Critical Zone, part of the dynamic "living skin" of the Earth.

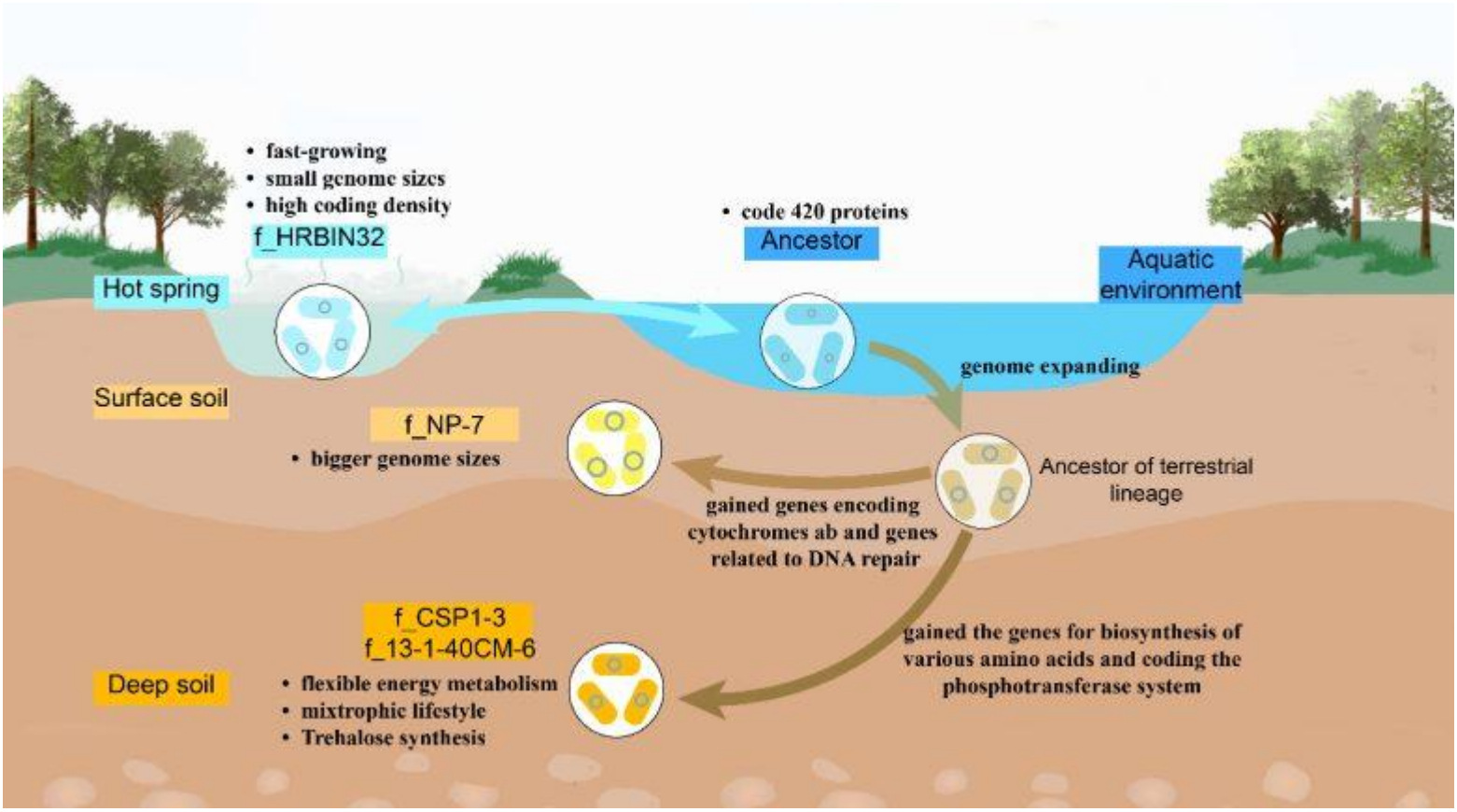
"The Critical Zone extends from the tops of trees down through the soil to depths up to 700 feet," Tiedje said. "This zone supports most life on the planet as it regulates essential processes like soil formation, water cycling, and nutrient cycling, which are vital for food production, water quality, and ecosystem health. Despite its importance, the deep Critical Zone is a new frontier because it's a major part of the Earth that is relatively unexplored."

What researchers found in the deep layers of the Critical Zone

Tiedje, a University Distinguished Professor Emeritus in the MSU Department of Microbiology, Genetics and Immunology and the Department of Plant, Soil and Microbial Sciences, discovered in this huge, unexplored microbial world a completely different phylum, or primary category, of microbe called CSP1-3. This new phylum was identified in soil samples from both Iowa and China at depths down to 70 feet. Why Iowa and China?

Because these two areas have very deep and similar soils we want to know if their occurrence is more general and not just in one area, Tiedje said.

Tiedje's team extracted DNA from these deep soils and found that CSP1-3's ancestors lived in the water — hot springs and fresh water — many millions of years ago. They underwent at least one major habitat transition to colonize soil environments — first topsoil and, later,



deep soils, during its evolutionary history.

A diagram showing the evolutionary history from an aquatic organism and adaptive traits of CSP1-3 phylum for each habitat. Credit: Michigan State University

Tiedje also found that the microbes were active. "Most people would think that these organisms are just like spores or dormant," he said. "But one of our key findings we found through examining their DNA is that these microbes are active and slowly growing."

Tiedje also was surprised to find these microbes were not rare members of the community, but were dominant; in some cases, they made up 50% or more of the community, which is never the case in surface soils.

"I believe this occurred because the deep soil is such a different environment, and this group of organisms has evolved over a long period of time to adapt to this impoverished soil environment," Tiedje added.

How the microbes purify water
Soil is our planet's biggest water filter. When water passes through soil, it is cleaned through physical, chemical, and biological processes. The surface soil, where most plant roots reside is often a very small volume of soil through which rainwater passes quickly. But the deep soil has a much larger volume. This is where CSP1-3 helps out. They live off the carbon and nitrogen that's washed down from the topsoil to complete the purification process.

"CSP1-3 are the scavengers cleaning up what got through the surface layer of soil," Tiedje said. "They have a job to do."

What's next?
The next step, Tiedje said, is to culture some of these microbes in the laboratory and if they grow, we can then learn more about their unique physiologies that allow them to be so successful in this deep soil environment. This is not easy. Most of the microbial world is not cultured because it's so difficult to replicate the conditions in which they live and grow.

For example, since CSP1-3's ancestors lived in hot springs, Tiedje's lab is trying to grow them at high temperatures as one example of testing new growth conditions based on information from their genomes.

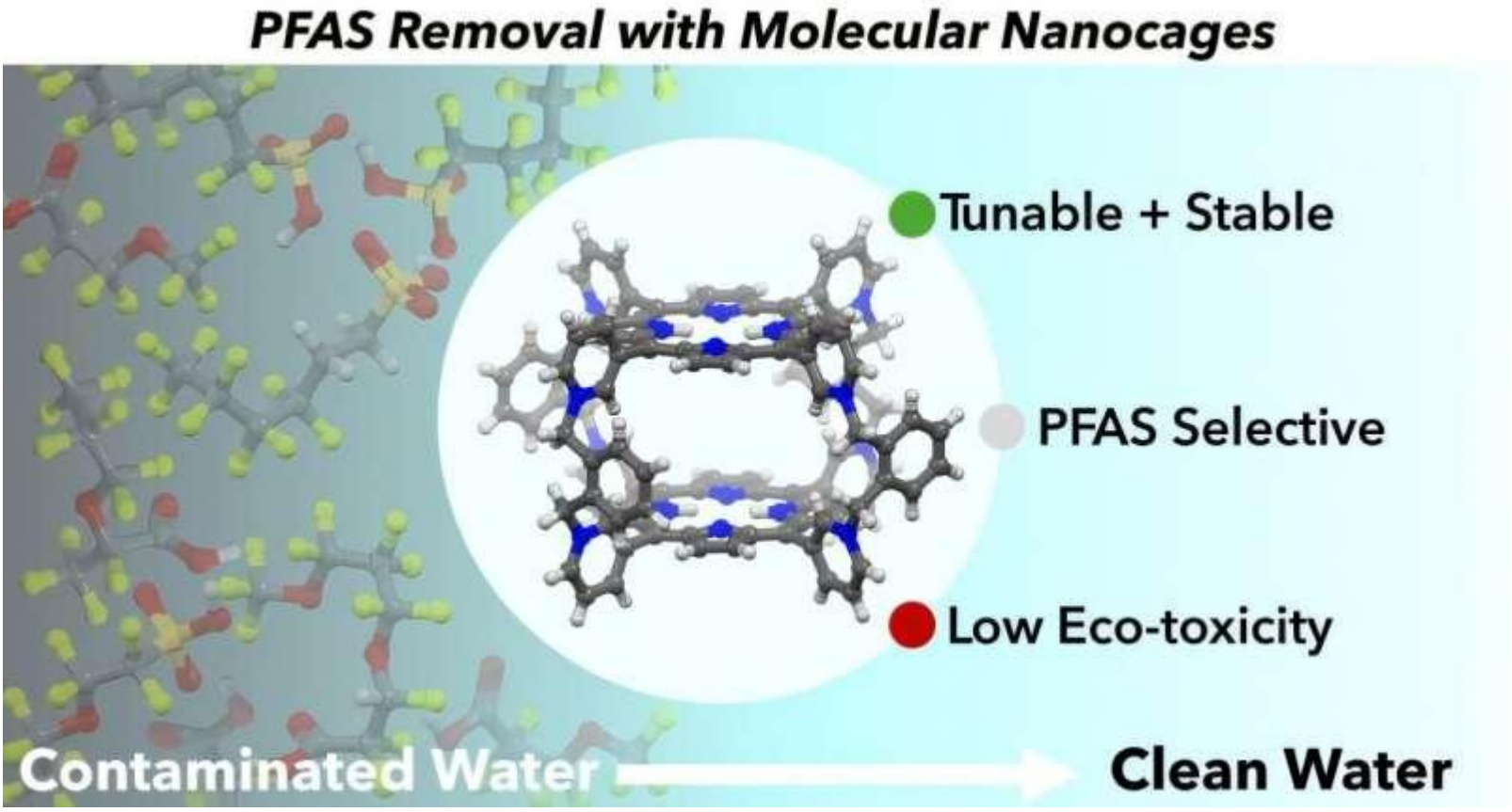
But if anyone can do it, Tiedje can, since he also discovered microbes that can dechlorinate chlorinated compounds.
"CSP1-3's physiology, driven by their biochemistry is different, so there may be some interesting genes of value for other purposes," he said. "For example, we don't know their capacities for metabolizing tough pollutants and, if we could learn that, we can help solve one of the Earth's most pressing problems."

Reference: "Diversification, niche adaptation, and evolution of a candidate phylum thriving in the deep Critical Zone" by Wenlu Feng, Xiaonan Wan, Yiran Zhang, John Quensen, Tom A. Williams, Michael Thompson, Matthew Streeter, Yang Zhang, Shuo Jiao, Gehong Wei, Yuanjun Zhu, Jie Gu, James M. Tiedje and Xun Qian, 18 March 2025, *Proceedings of the National Academy of Sciences*.
DOI: 10.1073/pnas.2424463122

APRIL 14, 2025

Molecular nanocages can remove 80–90% of PFAS from water

by National Science Foundation



An illustration of porphyrin-based molecular nanocages that are engineered for selectivity, water stability and fast sorption. These nanocages achieve on average 90% removal of 38 PFAS compounds from mixed water solutions. The material shows promise for more efficient, safer and sustainable water remediation. Credit: Karla Sanchez Lievanos/Research and Education in Energy, Environment and Water Institute (RENEW), University at Buffalo

Researchers have created a molecular nanocage that captures the bulk of per- and polyfluoroalkyl substances, or PFAS, found in water—and it works better than traditional filtering techniques that use activated carbon. Made of organic nanoporous material designed to capture only PFAS, this tiny chemical-based filtration system removed 80 to 90% of PFAS from sewage and groundwater during the study, respectively, while showing very low adverse environmental effects.

The study was led by scientists at the University at Buffalo and published in *ACS ES&T Engineering*.

PFAS are chemical compounds sometimes called "forever chemicals" and are commonly used in food packaging, nonstick coatings and other applications. PFAS do not degrade easily and are notoriously difficult to remove from water sources.

Studies show exposure to PFAS may cause a range of negative health impacts, including decreased fertility, developmental delays in children and increased risk for some cancers. The safe and effective removal of PFAS from groundwater, sewage and other water sources is a national challenge.

Molecular nanocages have been previously suggested as candidates for pollutant removal, including for PFAS. Their sturdy structures provide capabilities to capture, remove and chemically deactivate hazardous substances like PFAS and many others. They could also potentially filter out noxious gases from the air, the study authors say.

The researchers synthesized the nanocages from a group of organic chemicals called porphyrins. Previous studies have shown success with porphyrin nanocages in removing dyes, antibiotics, insecticides and chemicals that disrupt human hormone production from water.

The researchers then tested their nanocages' ability to absorb 38 different types of PFAS, including GenX, a type of PFAS commonly used in nonstick cookware and other materials. The results showed the nanocages removed 90% of PFAS from groundwater and 80% from unprocessed or "influent" sewage.

The organic molecular nanocages also outperformed the PFAS-filtering abilities of activated carbon, particularly in unprocessed sewage. Activated carbon and other purification or filtration methods, such as ion exchange resins and reverse osmosis, tend to interact weakly with PFAS, the researchers note. They are also costly, high-maintenance and energy-intensive in comparison to nanocages.

"Porphyrin-based nanocages offer a potentially practical solution to the challenges of PFAS removal," says Samy El-Shall, a program director in the NSF Division of Chemistry. "The material can also be mass-produced at scale, and the cages are modifiable to remove PFAS only while leaving other water contents alone."

More information: Karla R. Sanchez-Lievanos et al, Synthesis and Evaluation of Cationic Porphyrin-Based Organic Nanocages for the Removal of 38 PFAS from Water: Experimental, Theoretical, and Eco-toxicological Insights, *ACS ES&T Engineering* (2024). DOI: 10.1021/acsestengg.4c00639
Provided by National Science Foundation

This Wooden Cube Pulls Drinking Water From Thin Air, No Electricity Required

In a nutshell

- This wood-based material can pull water directly from air using only sunlight, working even in arid regions with humidity as low as 30% and in freezing temperatures down to -20°C.
- The device captured 2.5 milliliters of water per gram overnight in real-world testing, releasing it when exposed to sunlight with 94% efficiency.
- Made from affordable materials like balsa wood and lithium chloride, this technology could provide clean drinking water in areas lacking infrastructure or during emergencies.

MELBOURNE — Love a fresh glass of water? Someday soon, it could come straight from the air around you, collected by a small wooden cube sitting on your windowsill.

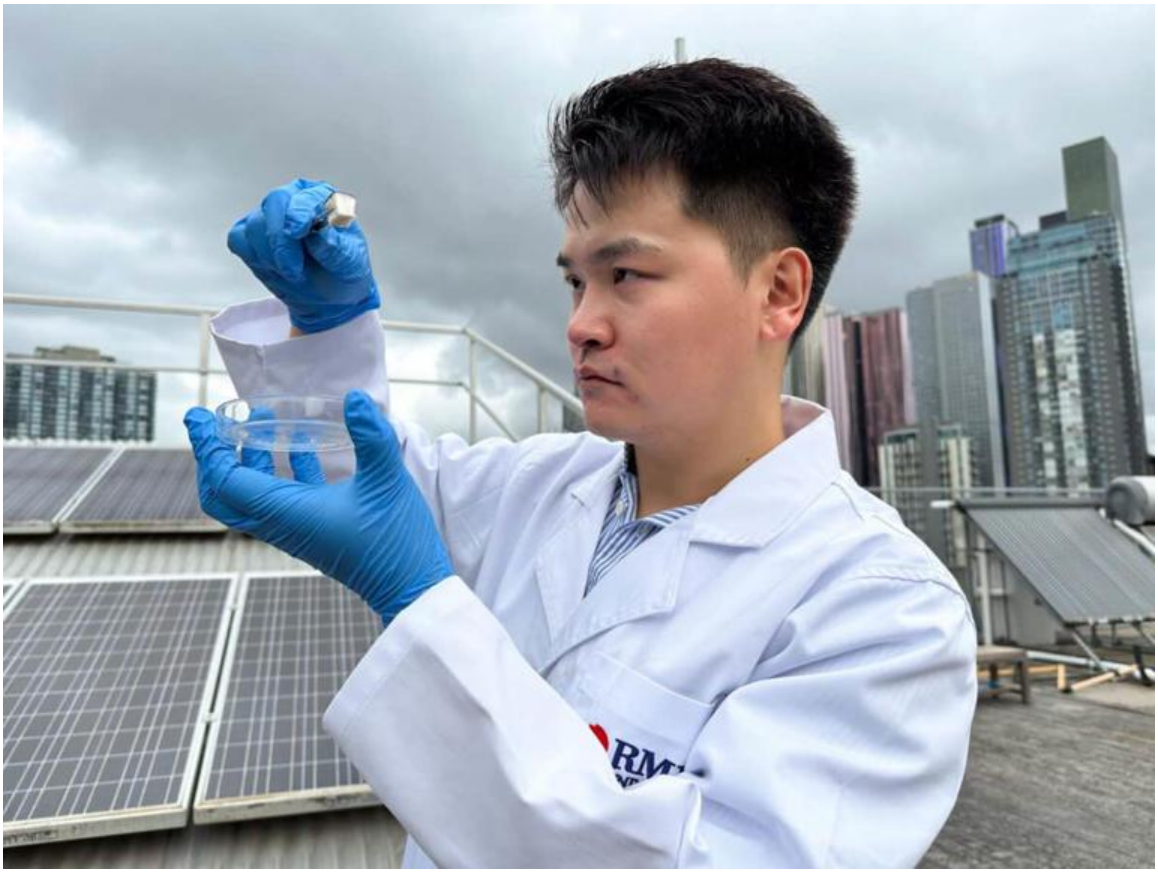
Scientists at The Royal Melbourne Institute of Technology (RMIT) in Australia have created a remarkable new material that does exactly this – it pulls moisture from the atmosphere and releases it as clean drinking water when exposed to sunshine. No pipes, no electricity, no infrastructure needed.

Nearly 80% of people worldwide now face serious water security issues, making this invention potentially life-changing for millions. The technology could help communities in water-scarce regions produce their own drinking water from nothing but air.

“Billions of people around the world lack access to drinkable water, and millions die from water-borne diseases every year,” said Dr. Derek Hao, a materials scientist and environmental engineer in RMIT University’s School of Science, in a statement. Hao and fellow RMIT researchers collaborated with Chinese scientists from Zhejiang A&F University, Yancheng Institute of Technology, and the Hangzhou Vocational & Technical College.

How It Works: Nature’s Design with a High-Tech Twist

The science behind it is cleverly simple. Researchers started with balsa wood, which naturally contains tiny channels that once carried water when it was a living tree. They removed lignin (the compound that makes wood rigid) to create a spongy structure packed with microscopic pores. This framework was loaded with lithium chloride salt, which strongly attracts water molecules from air. One side was then coated with carbon nanotube ink that converts sunlight into heat.



Dr Derek Hao, from RMIT University, holds the team’s spongy wood-based composite material that can absorb water from the atmosphere. (Credit: Shu Shu Zheng, RMIT University)

“Our team has invented a device comprising wood’s spongy scaffolding, lithium chloride, iron oxide nanoparticles, a carbon nanotube layer and other specialized features,” Hao said.

At night, the material absorbs moisture from the surrounding air. When the sun rises, the coating heats up, forcing the absorbed water to evaporate and condense as liquid water that can be collected for drinking.

Most atmospheric water harvesters only work in humid environments, but this new device functions in relative humidity as low as 30% – dry enough for desert regions where water shortages hit hardest. It continues working even in freezing temperatures down to -20°C (-4°F), something no previous material could manage.

"The device retained its flexibility and water-absorbing function even after being stored at −20 degrees Celsius for 20 days, demonstrating excellent freeze resistance," Hao noted.

Breaking Records: Performance That Surprises Experts

The scientists used artificial intelligence to refine their creation. They analyzed over 600 data points with machine learning algorithms to identify which factors most affected water collection efficiency. Their models revealed that absorption time, salt concentration, and humidity were the key variables to optimize.

The wood-based composite developed by the team for their research fit snugly into a cup with a dome lid and anti-pollution tray, a cooling mechanism and an activation system powered by the sun.

The invention with a sponge-like material, developed by researchers in Australia and China, absorbs water from the atmosphere and then releases it in a cup using the sun's energy. (Credit: Shu Shu Zheng, RMIT University)

When tested outside by the Chinese team, a small prototype pulled impressive amounts of water from air with 65.9% humidity. "In outdoor tests, our device captured 2.5 milliliters of water per gram overnight and released most of it during the day, achieving a daily water collection efficiency of 94%," said Dr. Junfeng Hou from Zhejiang A&F University.

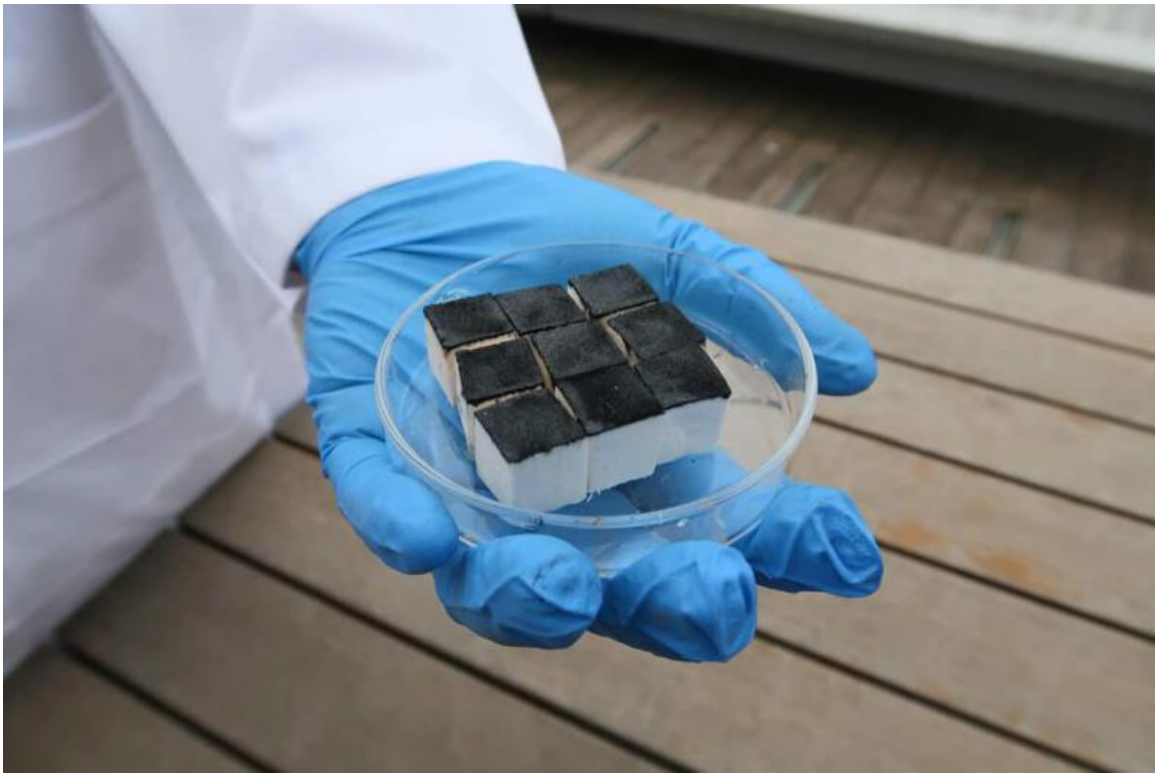
"At 30% humidity, our device absorbed water at about 0.6 milliliters per gram. These results highlight its potential use in off-grid, solar-driven water harvesting systems," added Hou, who led the Chinese research team.

Lab tests showed even better performance. Under controlled conditions with 90% humidity, the material absorbed 2.18 grams of water per gram of its own weight. When exposed to concentrated sunlight, it released up to 99.9% of the collected water.

The wooden framework prevents a persistent problem with salt-based water collectors: leakage. Previous designs struggled because moisture-absorbing salts would dissolve and drip away after capturing enough water. This new design holds the salt in place through repeated wet-dry cycles.

“Its moisture absorption–release performance was stable across 10 consecutive cycles, with less than 12% decline in efficiency,” Hao said.

The material also shows surprising toughness. It can be compressed repeatedly and return to its original shape, maintaining 87% of its height even after 20 compression cycles. This resilience indicates it could withstand rough handling in real-world settings.



With nine sponge cubes, each weighing 0.8 grams, 15 millilitres of water can be absorbed from the atmosphere. (Credit: Shu Shu Zheng, RMIT University)

Beyond Drinking Water: Wide-Ranging Applications

This technology opens possibilities beyond just drinking water. It could potentially irrigate crops in arid regions, control humidity in buildings, or even cool solar panels to improve their efficiency.

Hao said the device would be particularly valuable in emergency scenarios: “Its ability to harvest potable water from the atmosphere using only sunlight makes it invaluable in disaster-stricken areas where traditional water sources are

compromised. The system's portability and reliance on renewable energy further enhance its applicability in such contexts."

The researchers are already looking toward scaling up production. "The current demonstration unit size is 15 cubic millimeters. It would be very easy to prepare a larger unit, or we can use the units to form an array," Hao explained. "The main component, balsa wood, is widely available, biodegradable and cheap, and the manufacturing process is not complex, which could enable mass production."

With climate change and population growth occurring simultaneously, innovations like this water-from-air harvester provide a glimmer of hope. With further development, this unassuming wooden cube could help communities leapfrog traditional water infrastructure altogether—producing clean drinking water literally out of thin air.

Paper Summary

Methodology

The researchers created their wood-based atmospheric water harvesting material through several steps. First, they treated balsa wood with sodium chlorite to remove lignin, creating a porous wood sponge. This sponge was then impregnated with lithium chloride (LiCl) solutions at different concentrations (0-30%). They also developed a photothermal ink containing multi-walled carbon nanotubes, iron oxide, and cellulose nanofibrils, which was applied to one surface to create a solar-thermal interface. The team tested the material's performance in absorbing moisture under varied conditions (humidity 30-90%, temperature 5-55°C) and releasing water under different light intensities (0.6-1.5 times natural sunlight). They built a solar-powered atmospheric water harvesting device to evaluate real-world performance in natural day/night cycles. Additionally, the researchers employed machine learning techniques, including random forest models and long short-term memory (LSTM) networks, to analyze and predict the material's absorption-desorption behavior based on over 600 data points.

Results

The wood-based material demonstrated exceptional water harvesting capabilities across a range of conditions. At 90% relative humidity, it absorbed 2.18 grams of water per gram of its own weight within 600 minutes. When exposed to simulated sunlight, it released up to 99.9% of the absorbed water when illuminated at 1.5 times natural sunlight intensity. The material functioned effectively at humidity levels as low as 30% and maintained performance even at temperatures as low as -20°C due to the salt's ability to prevent water from freezing. In outdoor testing under natural conditions (65.9% humidity), the prototype device absorbed moisture overnight and released it during the day with approximately 94% efficiency. After 10 absorption-desorption cycles, the material maintained about 80% of its initial water collection capacity. The machine learning models achieved high prediction accuracy (R^2 of 0.988) for moisture absorption rate, enabling optimization of the material's composition and performance.

Limitations

The research has several practical limitations. The outdoor tests were conducted in relatively humid conditions (65.9% relative humidity), so performance in extremely arid environments remains untested over extended periods. While the researchers optimized the lithium chloride concentration to minimize leakage, there could still be long-term concerns about salt loss after extended use beyond the 10 cycles tested. The water production rate might be insufficient for larger-scale applications without significant scaling up. Additionally, economic feasibility and environmental impact of large-scale production weren't addressed, which would be critical factors for real-world implementation. The researchers also noted that at higher salt concentrations, excessive water absorption led to leakage issues, limiting the optimal concentration to 15% lithium chloride.

Funding and Disclosures

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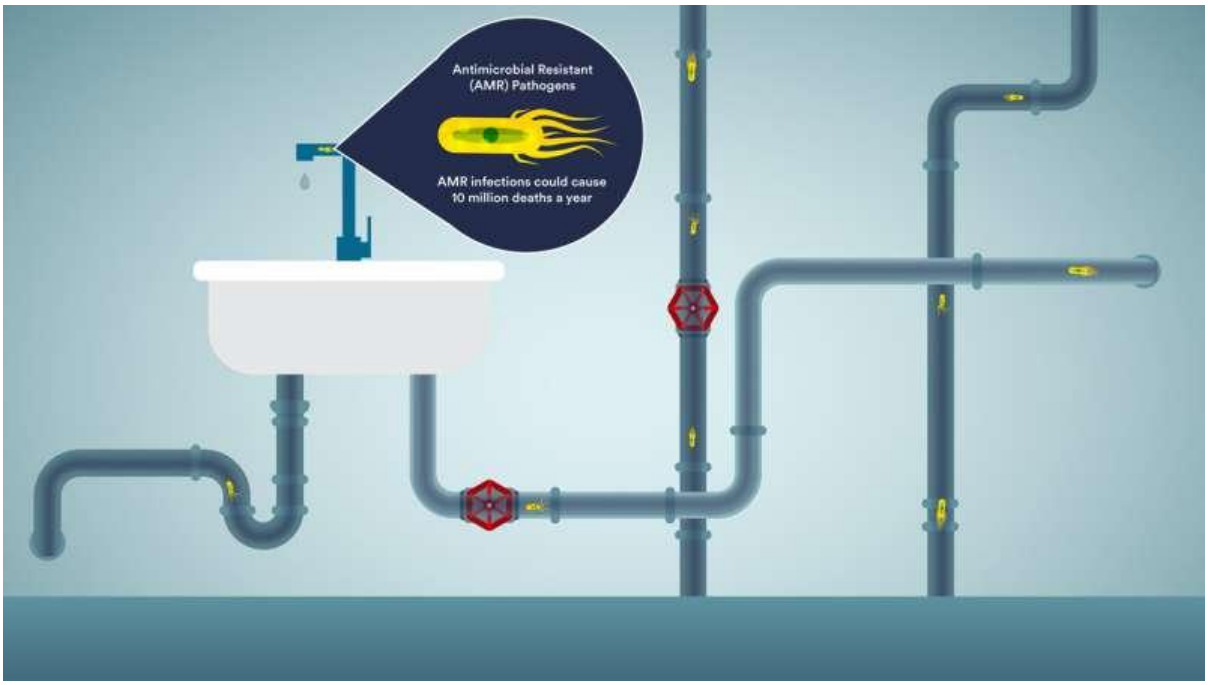
Publication Information

The study, titled “Development and characterization of novel wood-based composite materials for solar-powered atmospheric water harvesting: A machine intelligence supported approach,” was published in the *Journal of Cleaner Production* (Volume 497, February 2025). The research was conducted by a team led by Xingying Zhang, Yangyang Xu, and Junfeng Hou from Zhejiang A&F University in China, with collaborators from Yancheng Institute of Technology, Hangzhou Vocational & Technical College, and RMIT University in Australia. The article was received in November 2024, accepted in February 2025, and published online on February 28, 2025.

MAY 1, 2025

Drinking water plumbing a hotspot for superbugs

by Flinders University



Credit: Flinders University

A growing threat of antimicrobial resistant (AMR) pathogens poses a critical public health threat—and drinking water plumbing systems serve as significant but overlooked reservoirs of these problematic microbes.

Despite international efforts to combat AMR, surveillance has primarily focused on clinical cases, while environmental reservoirs—such as drinking water plumbing systems—remain poorly understood.

A recent study by researchers from Flinders University and other leading institutions revealed alarming findings about bacterial persistence in Australian drinking water plumbing, and identified significant transmission risks in both hospital and residential environments.

"The presence of these antimicrobial-resistant bacteria in residential and hospital plumbing systems highlights a pressing public health concern that requires immediate attention," says Flinders University's Professor Harriet Whiley.

Published in the *Journal of Hospital Infection*, the study assessed the prevalence of key AMR threats—being methicillin-resistant Staphylococcus aureus (MRSA), plus carbapenem-resistant Pseudomonas aeruginosa and Acinetobacter baumannii—in hospital and residential drinking water and biofilm samples across Australia.

Key findings showed:

- 73% of residential water and biofilm samples tested positive for at least one AMR pathogen, compared to 38% of hospital samples.
- 45% of residential drinking water plumbing fixtures had at least two of the targeted AMR pathogens, highlighting the risks in home environments.
- Drain biofilms were identified as a major reservoir for AMR bacteria, contributing to their persistence even after disinfection efforts.
- Carbapenem resistance genes were found in biofilm samples that tested negative for P. aeruginosa, suggesting biofilms may act as long-term reservoirs for AMR genes, which will allow resistance to spread even after the original bacteria have died.
- MRSA, typically associated with dry, high-touch surfaces such as bed rails and doorknobs, was detected in both water and biofilm samples. This indicates that AMR pathogens that are not traditionally considered waterborne may thrive in plumbing systems.

Antimicrobial resistance is among the most pressing 21st century global health challenges. The World Health Organization (WHO) warns that by 2050, AMR infections could cause 10 million deaths a year, and would therefore surpass cancer as the leading cause of death worldwide.

Resistant infections already lead to prolonged hospital stays, higher medical costs and an increasing reliance on last-resort antibiotics, which are becoming less effective.

"Our research underscores the urgent need for enhanced surveillance and targeted interventions to mitigate the risks posed by AMR pathogens in drinking water systems, especially in home health care settings," said lead researcher Dr. Claire Hayward.

This study calls for improved strategies to manage AMR risks in water infrastructure, particularly in environments housing vulnerable populations, such as hospitals and aged care facilities.

Strengthening water system hygiene, routine monitoring, and innovative biofilm control methods could play a crucial role in addressing this growing threat.

More information: C. Hayward et al, Drinking water plumbing systems are a hot spot for antimicrobial-resistant pathogens, *Journal of Hospital Infection* (2025). DOI: 10.1016/j.jhin.2025.02.018
Provided by Flinders University

JUNE 11, 2025

Window-sized device taps the air for safe drinking water

by Massachusetts Institute of Technology

edited by Sadie Harley, reviewed by Robert Egan

Credit: Unsplash/CC0 Public Domain
Today, 2.2 billion people in the world lack access to safe drinking water. In the United States, more than 46 million people experience water insecurity, living with either no running water or water that is unsafe to drink. The increasing need for drinking water is stretching traditional resources such as rivers, lakes, and reservoirs.

To improve access to safe and affordable drinking water, MIT engineers are tapping into an unconventional source: the air. The Earth's atmosphere contains millions of billions of gallons of water in the form of vapor. If this vapor can be efficiently captured and condensed, it could supply clean drinking water in places where traditional water resources are inaccessible.

With that goal in mind, the MIT team has developed and tested a new atmospheric water harvester and shown that it efficiently captures water vapor and produces safe drinking water across a range of relative humidities, including dry desert air.

The new device is a black, window-sized vertical panel, made from a water-absorbent hydrogel material, enclosed in a glass chamber coated with a cooling layer.

The hydrogel resembles black bubble wrap, with small dome-shaped structures that swell when the hydrogel soaks up water vapor. When the captured vapor evaporates, the domes shrink back down in an origami-like transformation. The evaporated vapor then condenses on the glass, where it can flow down and out through a tube, as clean and drinkable water.

The system runs entirely on its own, without a power source, unlike other designs that require batteries, solar panels, or electricity from the grid. The team ran the device for over a week in Death Valley, California—the driest region in North America. Even in very low-humidity conditions, the device squeezed drinking water from the air at rates of up to 160 milliliters (about two-thirds of a cup) per day.

The team estimates that multiple vertical panels, set up in a small array, could passively supply a household with drinking water, even in arid desert environments. What's more, the system's water production should increase with humidity, supplying drinking water in temperate and tropical climates.

"We have built a meter-scale device that we hope to deploy in resource-limited regions, where even a solar cell is not very accessible," says Xuanhe Zhao, the Uncas and Helen Whitaker Professor of Mechanical Engineering and Civil and Environmental Engineering at MIT.

"It's a test of feasibility in scaling up this water harvesting technology. Now people can build it even larger, or make it into parallel panels, to supply drinking water to people and achieve real impact."

Zhao and his colleagues present the details of the new water harvesting design in a paper appearing in the journal *Nature Water*. The study's lead author is former MIT postdoc "Will" Chang Liu, who is currently an assistant professor at the National University of Singapore (NUS). MIT co-authors include Xiao-Yun Yan, Shucong Li, and Bolei Deng, along with collaborators from multiple other institutions.

Carrying capacity

Hydrogels are soft, porous materials that are made mainly from water and a microscopic network of interconnecting polymer fibers. Zhao's group at MIT has primarily explored the use of hydrogels in biomedical applications, including adhesive coatings for medical implants, soft and flexible electrodes, and noninvasive imaging stickers.

"Through our work with soft materials, one property we know very well is the way hydrogel is very good at absorbing water from air," Zhao says.

Researchers are exploring a number of ways to harvest water vapor for drinking water. Among the most efficient so far are devices made from metal-organic frameworks, or MOFs—ultra-porous materials that have also been shown to capture water from dry desert air. But the MOFs do not swell or stretch when absorbing water, and are limited in vapor-carrying capacity.

Water from air

The group's new hydrogel-based water harvester addresses another key problem in similar designs. Other groups have designed water harvesters out of micro- or nano-porous

hydrogels. But the water produced from these designs can be salty, requiring additional filtering.

Salt is a naturally absorbent material, and researchers embed salts—typically, lithium chloride—in hydrogel to increase the material's water absorption. The drawback, however, is that this salt can leak out with the water when it is eventually collected.

The team's new design significantly limits salt leakage. Within the hydrogel itself, they included an extra ingredient: glycerol, a liquid compound that naturally stabilizes salt, keeping it within the gel rather than letting it crystallize and leak out with the water.

The hydrogel itself has a microstructure that lacks nanoscale pores, which further prevents salt from escaping the material. The salt levels in the water they collected were below the standard threshold for safe drinking water, and significantly below the levels produced by many other hydrogel-based designs.

In addition to tuning the hydrogel's composition, the researchers made improvements to its form. Rather than keeping the gel as a flat sheet, they molded it into a pattern of small domes resembling bubble wrap that act to increase the gel's surface area, along with the amount of water vapor it can absorb.

The researchers fabricated a half-square-meter of hydrogel and encased the material in a window-like glass chamber. They coated the exterior of the chamber with a special polymer film, which helps to cool the glass and stimulates any water vapor in the hydrogel to evaporate and condense onto the glass. They installed a simple tubing system to collect the water as it flows down the glass.

In November 2023, the team traveled to Death Valley, California, and set up the device as a vertical panel. Over seven days, they took measurements as the hydrogel absorbed water vapor during the night (the time of day when water vapor in the desert is highest). In the daytime, with help from the sun, the harvested water evaporated out from the hydrogel and condensed onto the glass.

Over this period, the device worked across a range of humidities, from 21% to 88%, and produced between 57 and 161.5 milliliters of drinking water per day. Even in the driest conditions, the device harvested more water than other passive and some actively powered designs.

"This is just a proof-of-concept design, and there are a lot of things we can optimize," Liu says. "For instance, we could have a multipanel design. And we're working on a next generation of the material to further improve its intrinsic properties."

"We imagine that you could one day deploy an array of these panels, and the footprint is very small because they are all vertical," says Zhao, who has plans to further test the panels in many resource-limited regions. "Then you could have many panels together, collecting water all the time, at a household scale."

More information: A Meter-scale Vertical Origami Hydrogel Panel for Atmospheric Water Harvesting in Death Valley, *Nature Water* (2025). doi.org/10.1038/s44221-025-00447-2
Journal information: Nature Water
Provided by Massachusetts Institute of Technology

MIT's Window-Sized Device Pulls Drinking Water From Thin Air, Even in the Desert

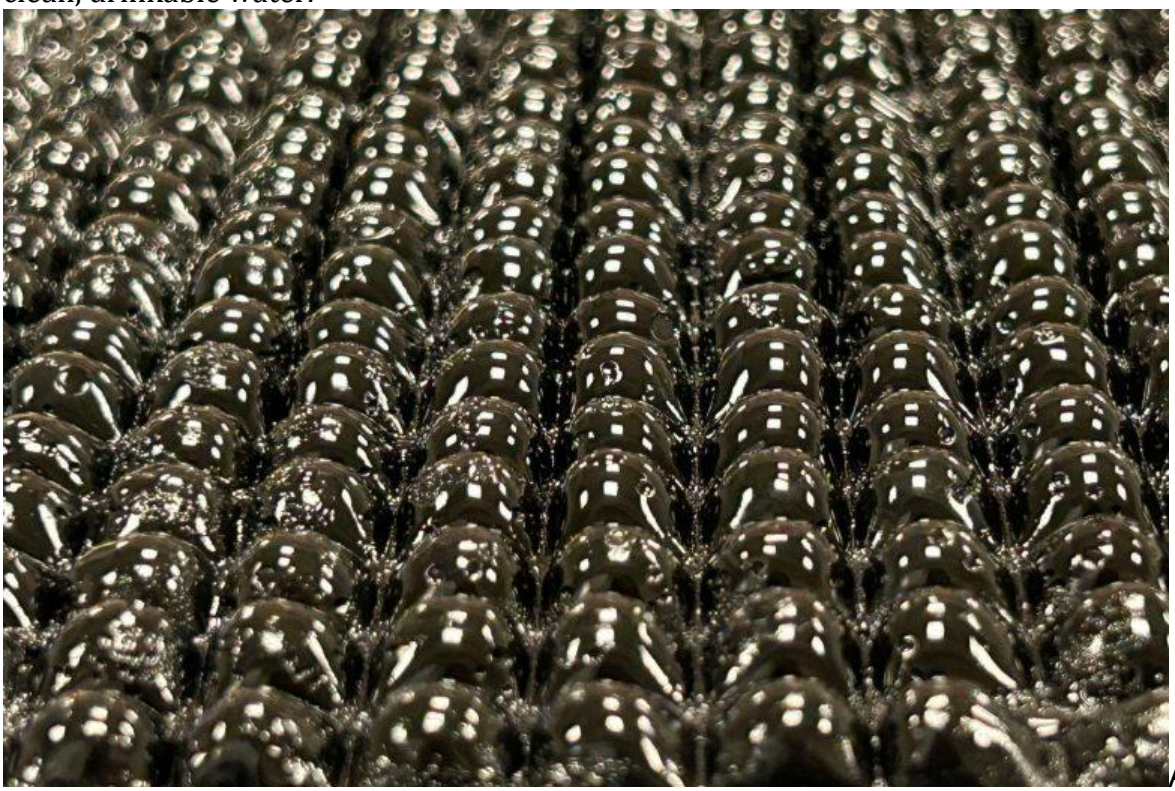
BY JENNIFER CHU, MASSACHUSETTS INSTITUTE OF TECHNOLOGYJUNE 20, 2025

A new passive water harvester, developed by MIT engineers, harvests water from air. The team showed the device can collect water even in dry environments such as Death Valley, pictured here. Credit: Shucong Li, Chang "Will" Liu, and Xiao-Yun Yan (MIT)

MIT engineers have created an atmospheric water harvester that can generate fresh water in any location, including extreme environments like Death Valley, California.

Today, 2.2 billion people around the world do not have access to safe drinking water. In the United States, over 46 million people face water insecurity, living without running water or relying on supplies that are unsafe to drink. As demand for clean water grows, traditional sources like rivers, lakes, and reservoirs are being pushed to their limits.

To help address this challenge, MIT engineers are exploring an alternative source: the air. Earth's atmosphere holds trillions of gallons of water in the form of vapor. If this vapor can be captured and condensed efficiently, it could provide clean drinking water in areas where traditional supplies are unavailable. Working toward that goal, the MIT team has developed and tested a new atmospheric water harvester that successfully captures vapor and produces safe drinking water across a range of humidity levels, including extremely dry desert air. The device is a black, vertical panel about the size of a window. It is made of a water-absorbing hydrogel and enclosed in a glass chamber coated with a cooling material. The hydrogel, which looks like black bubble wrap, features small dome-like shapes that swell as they absorb water vapor. When the vapor evaporates, the domes shrink in an origami-like motion. The vapor condenses on the glass surface and flows through a tube as clean, drinkable water.



A close-up of a new origami-inspired hydrogel material, designed by MIT engineers, that swells to absorb water from the air. When water condenses out of the material to be collected, the individual hydrogel spheres shrink back down to capture more moisture. Credit: Shucong Li, Chang "Will" Liu, and Xiao-Yun Yan (MIT)

Unlike other systems that rely on batteries, solar panels, or electricity, this device operates entirely on its own. The team tested it for more than a week in Death Valley, California—the driest area in North America. Even under low-humidity conditions, it produced up to 160 milliliters of drinking water per day, roughly two-thirds of a cup.

The team estimates that multiple vertical panels, set up in a small array, could passively supply a household with drinking water, even in arid desert environments. What's more, the system's water production should increase with humidity, supplying drinking water in

temperate and tropical climates. “We have built a meter-scale device that we hope to deploy in resource-limited regions, where even a solar cell is not very accessible,” says Xuanhe Zhao, the Uncas and Helen Whitaker Professor of Mechanical Engineering and Civil and Environmental Engineering at MIT. “It’s a test of feasibility in scaling up this water harvesting technology. Now people can build it even larger, or make it into parallel panels, to supply drinking water to people and achieve real impact.”

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Members of the team (from left to right), Shucong Li, “Will” Chang Liu, and Xiao-Yun Yan, with two water harvesters. Credit: Massachusetts Institute of Technology

Researchers are exploring a number of ways to harvest water vapor for drinking water. Among the most efficient so far are devices made from metal-organic frameworks, or MOFs — ultra-porous materials that have also been shown to capture water from dry desert air. But the MOFs do not swell or stretch when absorbing water, and are limited in vapor-carrying capacity.

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Reference: "A metre-scale vertical origami hydrogel panel for atmospheric water harvesting in Death Valley" by Chang Liu, Xiao-Yun Yan, Shucong Li, Hongshi Zhang, Bolei Deng, Nicholas X. Fang, Youssef Habibi, Shih-Chi Chen and Xuanhe Zhao, 11 June 2025, *Nature Water*.
DOI: 10.1038/s44221-025-00447-2
This work was supported, in part, by the MIT J-WAFS Water and Food Seed Grant, the MIT-Chinese University of Hong Kong collaborative research program, and the UM6P-MIT collaborative research program.

JUNE 23, 2025

Light-as-a-feather nanomaterial extracts drinking water from air

by ARC Centre of Excellence for Carbon Science and Innovation

edited by Lisa Lock, reviewed by Robert Egan

First author Xiaojun Ren holding the graphene oxide aerogel. Credit: University of New South Wales
An international scientific collaboration has developed a novel nanomaterial to efficiently harvest clean drinking water from water vapor in the air. The nanomaterial can hold more than three times its weight in water and can achieve this far quicker than existing commercial technologies, features that enable its potential in direct applications for producing potable water from the air.

The collaboration is led by the Australian Research Council Center of Excellence for Carbon Science and Innovation (ARC COE-CSI) UNSW Associate Professor Rakesh Joshi and Nobel Laureate Professor Sir Kostya Novoselov. Prof Joshi is based at the School of Materials Science and Engineering, University of New South Wales (UNSW). Prof Novoselov is based at the National University of Singapore.

A United Nations report estimates that 2.2 billion people lack safely managed drinking water.

On Earth, there are about 13 million gigaliters of water suspended in the atmosphere (Sydney harbor holds 500 gigaliters). While that is only a fraction of the total water on Earth, it still amounts to a substantial source of fresh water.

"Our technology will have application in any region where we have sufficient humidity but limited access to or availability of clean potable water," Dr. Joshi says.

Prof Novoselov says, "This is an excellent example of how interdisciplinary, global collaboration can lead to practical solutions to one of the world's most pressing problems—access to clean water."

The research is published in the *Proceedings of the National Academy of Sciences*.

Finding magic in the bonding

The novel nanomaterial is based on the well-studied form of the graphene oxide, which is a single-atom-thick carbon lattice functionalized with oxygen-containing groups. Graphene oxide has good water adsorption properties, which are properties that enable water to bond to the surface of a material.

Calcium also has good water adsorption properties. The research team decided to see what happened if you intercalate calcium ions (Ca^{2+}) into the graphene oxide.

What happened was unexpected.

An important characteristic of materials that effectively adsorb water is strong hydrogen bonds between the water and the material it adsorbs onto, something that graphene oxide and calcium each have. The stronger the hydrogen bond, the more a material can adsorb water.

But some magic happens when you intercalate calcium to the oxygen in the graphene oxide.

In calcium-intercalated graphene oxide, it is the synergy between calcium and oxygen that facilitates the extraordinary adsorption of water.

What the research team discovered is that the way the calcium coordinates with the oxygen in the graphene changes the strength of the hydrogen bonds between the water and the calcium to make those bonds even stronger.

"We measured the amount of water adsorbed onto graphene oxide by itself and we measured X. We measured the amount of water adsorbed onto calcium itself and we got Y. When we measured the amount of water adsorbed onto the calcium-intercalated graphene oxide we got much more than X+Y. Or it is like 1+1 equals a number larger than 2," says

Xiaojun (Carlos) Ren, UNSW School of Materials Science and Engineering and first author on the paper.

"This stronger-than-expected hydrogen bonding is one of the reasons for the material's extreme ability to adsorb water," he says.

It's also light as a feather

There was one more design tweak the team did to enhance the material's water-adsorbing ability—they made the calcium-intercalated graphene oxide in the form of an aerogel, one of the lightest solid materials known.

Aerogels are riddled with micro- to nanometer-sized pores, giving them a massive surface area, which helps this aerogel form adsorb water far quicker than the standard graphene oxide.

The aerogel also gives the material sponge-like properties that make the desorption process, or release of the water from the membrane, easier.

"The only energy this system requires is the small amount needed to heat the system to about 50 degrees to release the water from the aerogel," says Professor Daria Andreeva, the co-author of the paper.

The power of the supercomputer

The research is based on experimental and theoretical work that relied on the Australian National Computational Infrastructure (NCI) supercomputer in Canberra.

Professor Amir Karton from the University of New England led the computational work to provide the crucial understanding of the underlying mechanism.

"The modeled simulations done on the supercomputer explained the complex synergistic interactions at the molecular level, and these insights now help to design even better systems for atmospheric water generation, offering a sustainable solution to the growing challenge of fresh water availability in regional Australia and in water-stressed regions across the globe," says Professor Karton.

The power of science without borders

This is still a fundamental research discovery that needs further development. Industry have collaborated on this project to help scale up this technology and develop a prototype for testing.

"What we have done is uncover the fundamental science behind the moisture adsorption process and the role of hydrogen bonding. This knowledge will help provide clean drinking water to a large proportion of those 2.2 billion people that lack access to it, demonstrating the societal impact by collaborative research from our Center," says COE-CSI Director and one of the co-authors on the paper, Professor Liming Dai.

The research is a global collaboration between research groups from Australia, China, Japan, Singapore and India.

More information: Xiaojun Ren et al, Synergetic hydrogen-bond network of functionalized graphene and cations for enhanced atmospheric water capture, *Proceedings of the National Academy of Sciences* (2025). DOI: 10.1073/pnas.2508208122
Journal information: Proceedings of the National Academy of Sciences
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