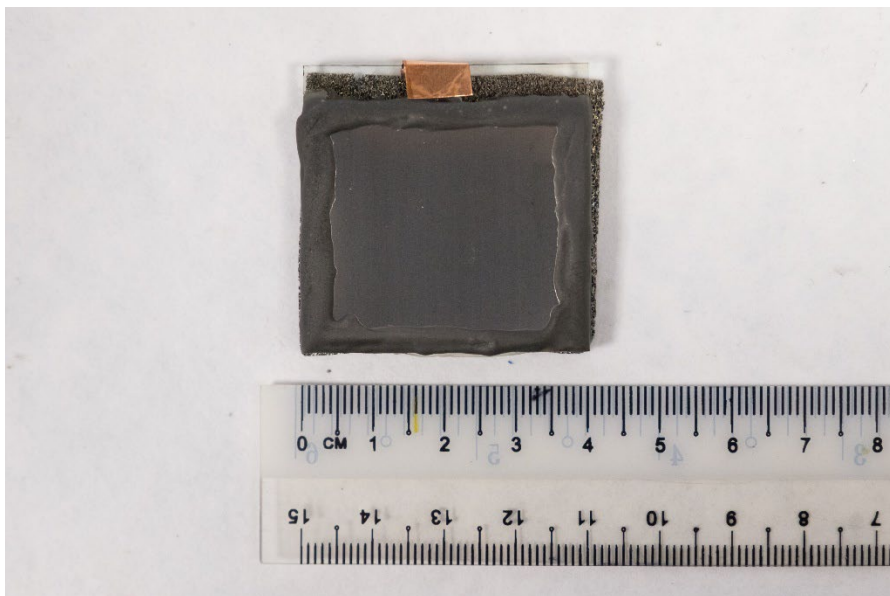




17 September 2026

‘Artificial leaf’ generates clean hydrogen from contaminated seawater



The device generates clean fuel and removes pollutants at the same time. Credit: NTU Singapore

Scientists from Nanyang Technological University, Singapore, have designed a device that harvests sunlight to generate clean hydrogen from seawater and simultaneously degrades hydrazine, a highly toxic contaminant from industrial wastewater.

Inspired by leaves, the device directly captures sunlight and converts it into electricity to drive the reaction without the need for external power sources. The innovation is published in Nature Communications.

Two-in-one green solution

To produce green hydrogen from water, an electric current is passed through water between two electrodes, splitting the water molecules into hydrogen and oxygen—a process known as electrolysis.

In electrolysis, electrons flow to the cathode (negative electrode), where they combine with water molecules to produce hydrogen gas.

Producing hydrogen directly from seawater instead of freshwater improves sustainability because additional steps to remove salt from the seawater are not required. However, seawater presents its own challenges. Chloride ions in seawater interfere with the reaction and reduce its efficiency. Additionally, corrosive and toxic chlorine compounds are generated that can damage the electrodes.

To boost the efficiency of hydrogen production from seawater, the researchers, led by Professor Lydia Wong of NTU's School of Materials Science and Engineering, designed an anode (positive electrode) containing a catalyst that breaks down hydrazine into hydrogen and nitrogen.

This reaction requires less energy than the oxygen-producing reaction usually involved in water electrolysis. As a result, the sunlight-powered cathode can generate hydrogen from water more efficiently and with lower energy requirements, while the anode removes hydrazine and produces additional hydrogen.

The catalyst, containing iron, cobalt and chromium, is also resistant to corrosion, and its electrical, physical and chemical properties can be easily customized. At the same time, the production of corrosive and toxic chlorine compounds is suppressed.

Catalyzing a sustainable future

To generate the electricity required to power the device, the researchers fabricated the cathode from lead halide-based perovskites—a semiconductor material that captures light and converts it to electricity. The cathode was coated with a conductive epoxy resin containing silver and copper particles, as well as titanium foil, to protect it from degradation.

In simulated and real seawater samples, the device generated a stable electric current from light. The photocurrent density (25 mA cm^{-2})—the amount of current generated per illuminated area of the device—was one of the highest reported for lead-based perovskite cathodes, an indication of the device's effectiveness at converting sunlight to electricity.

The device maintained stable performance for more than 72 hours under illumination equivalent to sunlight reaching Earth's surface on a clear day, generating hydrogen at a high rate of $466 \text{ } \mu\text{mol cm}^{-2} \text{ h}^{-1}$, comparable with similar solar-powered devices. It effectively degraded hydrazine without the need for separation from water within 30 hours, reducing its concentration from 0.5 M (equivalent to about 1.6% by weight) to 0.5 parts per billion (ppb), more than 20 times below the U.S. Environmental Protection Agency's permissible limit of 10 ppb.

“This dual-function device represents a major leap forward for environmental technology. By efficiently harvesting solar energy to break down a toxic industrial

pollutant while simultaneously harvesting clean fuel, we are solving both an energy problem and a pollution problem,” said Wong.

“The breakthrough here lies not simply in producing solar hydrogen but in demonstrating a practical route toward multifunctional photoelectrochemical systems. Such dual-purpose approaches are likely to play an increasingly important role in the future deployment of solar fuels technologies, where economic value and environmental impact must go hand in hand,” said James Durrant, professor of photochemistry and sustainable energy in the Department of Chemistry at the University of Oxford, who was not involved in the research.

The researchers are now working to develop catalysts that can expand the device’s applications beyond hydrazine degradation, including the treatment of other pollutants and the conversion of waste materials into useful products such as fuels and industrial chemicals.

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