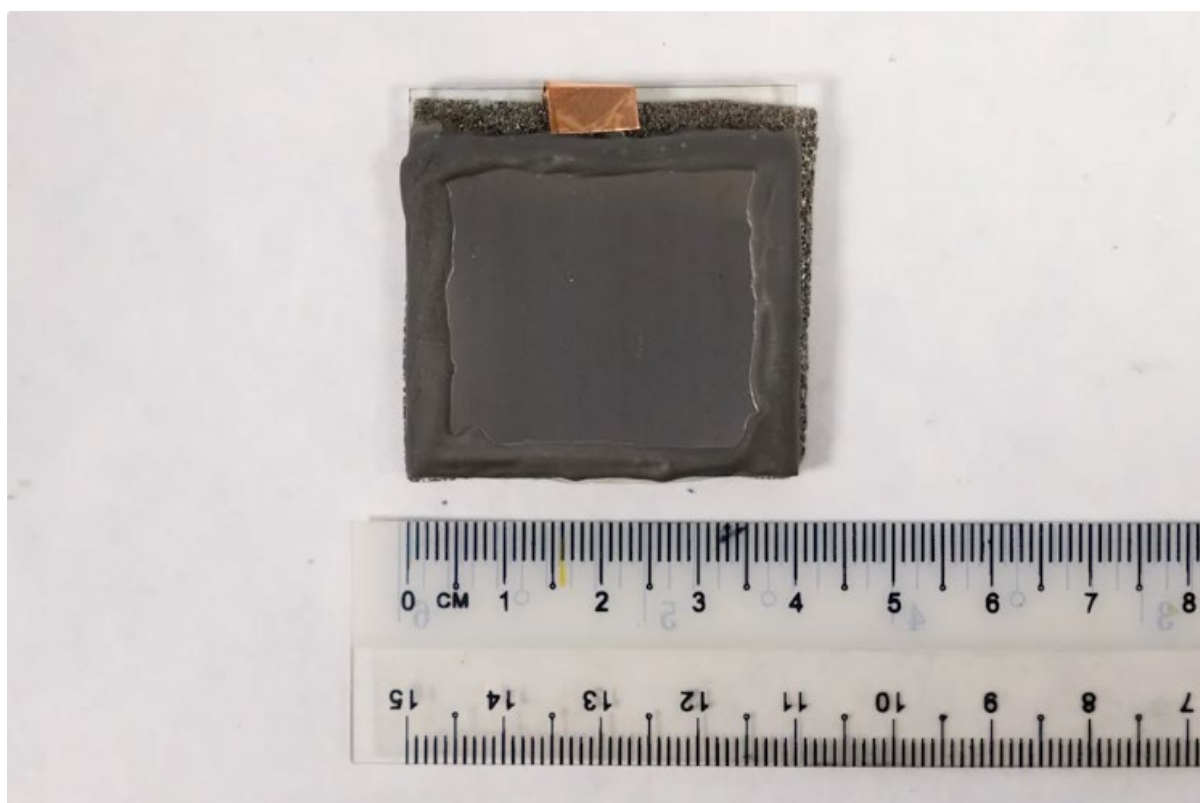


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Translated from German

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Artificial leaf produces hydrogen from seawater - without an external power source



The artificial leaf uses sunlight to produce hydrogen and simultaneously breaks down toxic hydrazine in the water. © NTU Singapore.

Seawater is plentiful, as is sunlight. So why not combine the two and produce hydrogen? Unfortunately, it's not that simple. The salt can corrode parts of the electrolyzer needed to produce hydrogen, unwanted chlorine compounds can form – and the process usually requires a lot of additional energy.

Researchers at Nanyang Technological University in Singapore (NTU) have developed an unusual approach. Their small "artificial leaf" uses sunlight directly as an energy source and links hydrogen production to the degradation of hydrazine, a highly toxic industrial pollutant. The work by Mahmoud G. Ahmed, Anupam Sadhu, and colleagues was published in Nature Communications.

Hydrogen from seawater: Hydrazine reduces energy requirements

In electrolysis, water is split into hydrogen and oxygen using electricity. The oxygen production at the anode, in particular, requires a comparatively large amount of energy. The researchers are therefore replacing this reaction with the oxidation of hydrazine.

This is interesting for two reasons. Hydrazine is highly toxic and is used in industrial processes, among other things. At the same time, it oxidizes to oxygen much more easily than water. This drastically reduces the required voltage – and also largely avoids the problematic formation of chlorine compounds from seawater.

The experimental setup only works with hydrazine. Without this substance, the coupled system did not generate a measurable photocurrent. Therefore, the artificial leaf is not an electrolyzer that could simply be placed in the sea. Instead, it utilizes an additional chemical reaction to enable hydrogen production with significantly less energy.

Sunlight provides the necessary energy

The core component on the light-facing side is a photocathode made of perovskite. The material absorbs light and generates electrical charges. Because perovskite is sensitive to water and the alkaline environment, the team encapsulated the layer with conductive epoxy resin and titanium foil.

On the opposite side, a catalyst made of iron, cobalt, and chromium accelerates the degradation of the hydrazine, primarily producing nitrogen. A small portion of the hydrazine also decomposes, producing hydrogen at this electrode as well.

Under simulated sunlight, the system achieved a photocurrent density of approximately 25 milliamperes per square centimeter. This resulted in the production of approximately 466 micromoles of hydrogen per square centimeter per hour at the photocathode.

The structure achieved three points that are important for further development:

- * It operated without externally applied voltage.
- * Performance remained comparable even in real seawater.
- * Under continuous lighting, the system ran stably for more than 72 hours.

The fact that seawater barely impaired performance is due to the hydrazine reaction. It occurs at such a low voltage that the otherwise competing chlorine chemistry is largely avoided.

Toxic hydrazine drops to 0.5 parts per billion.

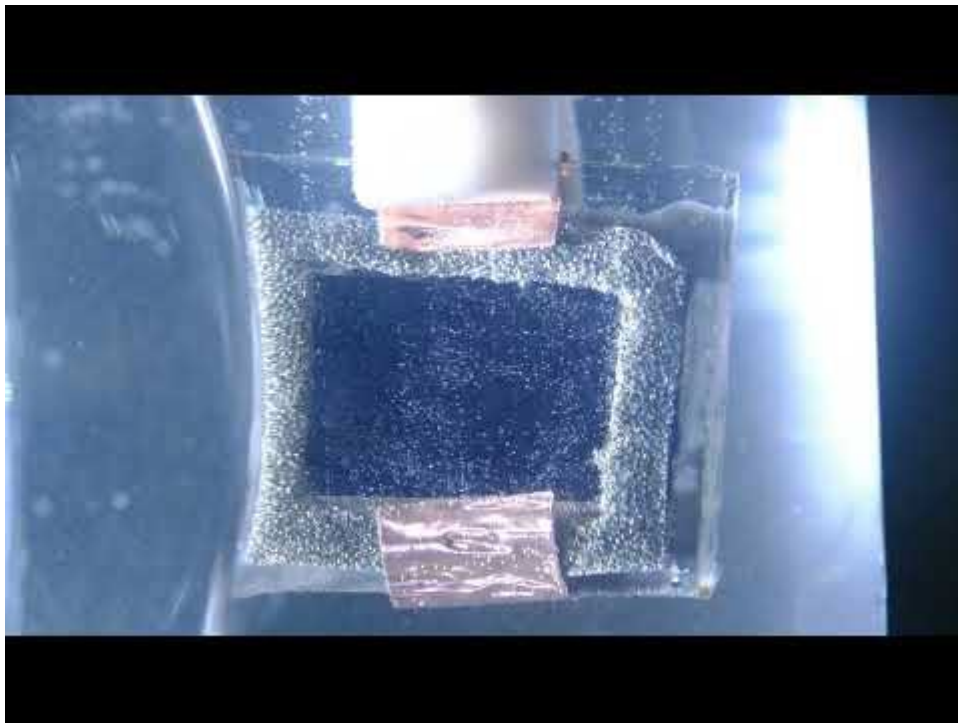
For a larger demonstrator, the scientists fabricated a photocathode with an active area of 6.25 square centimeters. This was combined with a nickel foam electrode coated with the iron-cobalt-chromium catalyst.

After approximately 30 hours, the hydrazine concentration had dropped from an initial 0.5 moles per liter to only 0.5 parts per billion. The initial value corresponded to about 1.6 percent hydrazine by weight, which was very high.

The setup also worked in natural sunlight. During an outdoor test in Singapore on a cloudy day, the team observed gas bubbles consisting of hydrogen and nitrogen.

"This dual-function device represents a major step forward for environmental technologies," says [Lydia H. Wong](#) of Nanyang Technological University. The approach combines two processes that are normally considered separately: the degradation of a toxic substance and the production of an energy carrier.

As soon as light falls on the artificial leaf, hydrogen is produced at both electrodes – the anode and the cathode.



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For large-scale plants, crucial steps are still missing.

The setup is still a long way from industrial-scale hydrogen production from seawater. The active area of the larger demonstrator was only a few square centimeters, and its stability has so far only been studied over days rather than months or years.

In addition, there are the special experimental conditions. The system operates in a highly alkaline environment and requires hydrazine. Real seawater or wastewater, on the other hand, contains many other substances, and the pH value can also fluctuate significantly. Future systems will first have to be able to handle such conditions.

The materials used are also not yet ideal. The photocathode contains lead-based perovskite, which must be carefully shielded from contact with water. Platinum is also used on the cathode side as a catalyst for hydrogen production.

The researchers therefore want to develop further catalysts and apply the approach to other pollutants. If successful, such systems could combine water treatment and energy production in the future: a problematic substance would be broken down while hydrogen is produced simultaneously. Until then, the artificial leaf remains a small laboratory demonstrator with an unusual principle.

In short:

- * The "artificial leaf" uses sunlight to produce hydrogen from alkaline seawater while simultaneously breaking down highly toxic hydrazine.
- * The crucial trick: The hydrazine reaction requires significantly less energy than the usual oxygen production during electrolysis and largely avoids problematic chlorine compounds.
- * The process is still in the laboratory research phase: It only works under specific conditions with hydrazine and small test areas, but could potentially combine water treatment and hydrogen production in the future.

Incidentally , hydrogen can also be extracted from seawater in a completely different way – researchers in Sydney are using light and liquid gallium instead of classic electrolysis. You can find out more about how the metal can be reused and release hydrogen in the process in our [article](#).

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