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Artificial leaf: hydrogen from contaminated seawater, a reality check

An “artificial leaf” that turns contaminated seawater into hydrogen while destroying a toxic industrial chemical – that is the headline from Nanyang Technological University (NTU) Singapore this autumn. The result, published in Nature Communications, is scientifically solid. But it is a laboratory experiment on a few square centimetres, and it only works because the pollutant itself acts as fuel. Here is what the device actually does, and what it means for green hydrogen.

What the researchers showed

The team led by Prof. Lydia H. Wong at NTU’s School of Materials Science and Engineering built a self-powered photoelectrochemical device from two electrodes. The photocathode is a lead-halide perovskite solar cell, encapsulated with conductive silver-copper epoxy and titanium foil, with platinum as the catalyst for hydrogen evolution. The anode is a noble-metal-free spinel oxide of iron, cobalt and chromium ($Fe_{0.3}Co_{0.9}Cr_{1.8}O_4$) on nickel foam. Crucially, the anode does not split water into oxygen. It oxidises hydrazine – a toxic chemical used, among other things, to treat boiler feed water – into harmless nitrogen.

Without any external power supply, the photocathode reached a current density of around 25 mA/cm^2, corresponding to roughly 466 µmol of hydrogen per square centimetre per hour at close to 100 per cent Faradaic efficiency. The device ran stably for more than 72 hours in alkaline salt solution and in real seawater. At the same time, it reduced the hydrazine concentration from 0.5 mol/L to 0.5 parts per billion within about 30 hours – more than 20 times below the limit set by the US Environmental Protection Agency. Chlorine formation, the classic headache of seawater electrolysis, was suppressed. Tech Xplore and other outlets reported on the work in September 2026.

The trick: hydrazine instead of oxygen

In conventional electrolysis, the oxygen evolution reaction at the anode is the energy-hungry part: thermodynamically it needs at least 1.23 V. Hydrazine oxidation sits at −0.33 V. This principle of "hybrid" or hydrazine-assisted electrolysis is well established in the literature; reviews report systems that need only around 1 V to drive 500 mA/cm^2, saving more than 80 per cent of the energy compared with conventional water splitting. What is new in Singapore is the combination with a perovskite photocathode that is stable enough to run without any grid electricity.

That is also the main limitation. According to the study, the same photocathode paired with a conventional oxygen-evolving anode would deliver practically no current. A substantial share of the energy therefore comes from the chemical energy of the hydrazine, which is consumed in the process. Strictly speaking, this is not water splitting, and the figures cannot be compared with the solar-to-hydrogen efficiencies of conventional systems.

A reality check: lab result, not industrial process

Unrealistically high pollutant levels: The tests used 0.5 mol/L hydrazine, around 16 grams per litre. In power-plant boiler feed water, hydrazine is typically below 0.1 mg/L, and even in lay-up solutions for idle boilers it reaches at most around 200 mg/L. Whether the device still runs self-powered at real-world concentrations is an open question.

Alkalised seawater: The experiments ran in alkaline electrolytes based on potassium hydroxide. This is standard practice in seawater electrolysis research, but it requires chemicals and pre-treatment.

Small areas: The largest device shown delivered an absolute current of 40 mA with an anode area of 9.2 cm^2. Square-metre modules are still a long way off.

Lifetime and materials: 72 hours is a good result for perovskite photocathodes in an aggressive alkaline environment. Commercial electrolysers, however, have to last tens of thousands of hours. The device also contains lead and platinum.

Technology readiness: In our assessment, the device is at TRL 3–4. Photoelectrochemical systems in general sit around TRL 4–5, while PV-coupled electrolysis with PEM or alkaline electrolysers is commercially mature at TRL 9.

Water is not Switzerland's bottleneck – but it is for exporters

Stoichiometrically, producing one kilogram of green hydrogen takes about nine litres of water. Including treatment and cooling, IRENA and Bluerisk put the figure at around 18 litres per kilogram for PEM and 22 litres for alkaline electrolysis in their 2023 report "Water for hydrogen production". For water-rich Switzerland, this is not a limiting factor.

It becomes relevant for imports: in its national hydrogen strategy of December 2024, the Federal Council expects imports via the European network from around 2035. Many potential production regions for hydrogen, e-methanol and e-SAF are rich in sun but poor in fresh water. Robust seawater processes could therefore influence the cost and acceptance of the molecules Switzerland will need to buy for its defossilisation.

Swiss research is at the forefront of solar hydrogen

Switzerland has its own strengths in this field. At SPIN member EPFL, Prof. Sophia Haussener's laboratory built a concentrated photoelectrochemical pilot plant with more than 2 kW of hydrogen output, producing around half a kilogram of hydrogen per day along with usable heat and oxygen. The spin-off SoHHytec is taking the technology towards industrial use. Prof. Kevin Sivula's group, also at EPFL, works on photoelectrodes and transparent porous substrates that can even harvest hydrogen from humidity in the air. And the ETH spin-off Synhelion has been producing solar fuels on an industrial scale since 2024 – using concentrated solar heat rather than photoelectrochemistry.

E-fuels need volume, continuity and low cost

For e-fuels such as e-methanol or e-SAF, green hydrogen is the key feedstock – needed in large volumes, as continuously as possible and at low cost. The NTU artificial leaf will not make a relevant contribution to that in the foreseeable future. The approach is still worth watching, because it couples pollutant removal with hydrogen production and creates value twice. Such coupled processes could find a niche at industrial sites with contaminated wastewater, much like electrolysers at sewage treatment plants that supply oxygen for biological treatment.

Conclusion

The artificial leaf from Singapore is an elegant proof of concept. It shows that perovskite photocathodes can work stably for days in a salty, alkaline environment, and that pollutant removal can be coupled with hydrogen production. Anyone who reads it as an imminent alternative to PV-powered electrolysis is overestimating it: much of the energy comes from the hydrazine, the concentrations are far from practice, and the active areas measure only a few square centimetres. For the Swiss Power-to-X community, the verdict is to keep an eye on it – particularly for hydrogen imports from water-scarce regions and for niche wastewater applications. The scale-up of green hydrogen and e-fuels over the coming years will rely on proven electrolysis technologies.

Sources: Ahmed, M. G. et al., "Self-powered artificial leaf using perovskite photocathode for solar hydrogen production and hydrazine degradation", Nature Communications 17, 6641 (2026); Tech Xplore, "'Artificial leaf' generates clean hydrogen from contaminated seawater" (17 September 2026); Nanowerk / NTU Singapore press

release (14 September 2026); Holmes-Gentle, I. et al., “Kilowatt-scale solar hydrogen production system using a concentrated integrated photoelectrochemical device”, Nature Energy (2023); Swiss Federal Office of Energy, Hydrogen and Power-to-X.

https://power-to-x.swiss/2026/10/23/artificial-leaf-hydrogen-contaminated-seawater/