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Translated from Spanish

An “artificial leaf” produces hydrogen using sunlight while decontaminating seawater

Researchers at Nanyang Technological University in Singapore have developed a leaf-inspired photoelectrochemical device that directly uses sunlight to produce hydrogen from seawater and simultaneously remove hydrazine, a toxic contaminant found in certain industrial effluents.

Nanyang Technological University (NTU Singapore) released the results on September 17, 2026. The scientific work that supports the development had been previously published in the journal *Nature Communications* and allows for a more precise analysis of both the possibilities and the current limitations of this technology.

The device operates without an external power source. A perovskite-based photocathode absorbs solar radiation and generates the current needed to drive the electrochemical reactions. At the other electrode, a catalyst oxidizes the hydrazine present in the water, transforming it primarily into nitrogen and hydrogen.

The result is an experimental system that combines two processes: solar hydrogen production and treatment of an industrial pollutant.

The challenge of producing hydrogen directly from seawater

Using seawater directly to produce hydrogen presents difficulties that do not arise in the same way when using previously purified water. The high concentration of salts, especially chloride ions, can interfere with electrochemical reactions, promote the formation of chlorine compounds, and accelerate the corrosion of materials.

In conventional electrolysis, the reaction at the anode typically produces oxygen. This process requires a certain amount of energy and, in the presence of chlorides, can compete with unwanted reactions.

NTU researchers adopted a different strategy: to take advantage of the presence of hydrazine to replace that anodic reaction with an oxidation that requires less energy.

Hydrazine is used in various industrial and energy applications, but it is a highly toxic substance. Its disposal in wastewater constitutes an environmental problem in itself.

The device seeks to transform that problem into part of the solution: the oxidation of hydrazine reduces the energy needed for the process, largely avoids the reactions associated with chlorine, and further contributes to the generation of hydrogen.

Perovskite to directly transform light into chemical energy

The so-called "artificial leaf" belongs to the family of photoelectrochemical devices. Unlike an installation consisting of photovoltaic panels connected to a separate electrolyzer, the device itself absorbs light and uses that energy to directly drive the chemical reactions.

The photocathode developed by the team uses a lead halide perovskite as the semiconductor material. To protect it from the chemically aggressive environment of the electrolyte, the researchers incorporated a conductive epoxy resin with silver and copper particles and a titanium sheet.

The anode uses an oxide catalyst based on iron, cobalt, and chromium, developed without noble metals to promote the oxidation of hydrazine.

This combination made it possible to achieve a photocurrent density of approximately 25 mA per square centimeter under illumination equivalent to a sun, both in laboratory-prepared saline solutions and in real seawater samples.

More than 72 hours of stable operation

One of the historical problems with perovskite-based devices is their stability in the face of humidity, temperature, and chemically aggressive environments. For this reason, the test duration is one of the relevant data points of the study.

The system maintained stable operation for over 72 hours under illumination equivalent to the solar radiation of a clear day. Researchers also recorded a hydrogen production rate of approximately 466 micromoles per square centimeter per hour.

This is still a relatively short experimental duration compared to the thousands of hours a commercial installation should achieve. The result demonstrates stability under laboratory conditions, but does not yet allow for direct projection of an industrial lifespan.

This distinction is especially important in emerging photoelectrochemical technologies: good performance over several days constitutes a relevant proof of concept, but does not equate to demonstrating economic operation over years.

The pollutant fell to 0.5 parts per billion

The second function of the device was evaluated by measuring the degradation of hydrazine. According to NTU, the initial concentration used in the assay was 0.5 molar, equivalent to approximately 1.6% by weight.

After about 30 hours of operation, the concentration was reduced to approximately 0.5 parts per billion.

In this way, the experiment not only produced hydrogen, but also demonstrated the possibility of using solar energy to simultaneously treat a chemical pollutant.

The concept is particularly interesting for certain industrial processes because it combines the generation of an energy vector with effluent treatment. However, the current application is specifically linked to the presence of hydrazine and should not be interpreted as a system capable of indiscriminately decontaminating any type of wastewater.

The next goal is to work with other industrial waste.

Researchers are already working on catalysts that will allow the principle to be extended to other pollutants. The goal is for future versions to be able to treat different waste streams and, at the same time, transform some of those compounds into usable fuels or chemicals.

This approach introduces a difference compared to most traditional wastewater treatment technologies, where removing a contaminant primarily represents an energy and operational cost.

The research aims to involve certain waste products in reactions that reduce energy consumption and simultaneously yield a valuable product, such as hydrogen.

James Durrant, a professor of photochemistry and sustainable energy at Oxford University who was not involved in the study, highlighted when commenting on the results that the interest of these multifunctional systems lies precisely in combining solar fuel production with environmental benefits.

It's still research, not a commercial technology.

The results do not mean that it is already possible to commercially install hydrogen plants based on this “artificial leaf.” The device remains in the research stage and will have to overcome several challenges before it can compete with industrial technologies.

These include the scaling up of active surfaces, the durability of perovskites, the manufacturing cost, hydrogen recovery and separation, the overall efficiency of the

process, and the behavior in the face of real effluents with varying chemical compositions.

The use of lead-containing materials must also be considered. In future industrial applications, it will be necessary to ensure encapsulation, stability, recovery, and proper management of the materials throughout their entire life cycle.

For these reasons, the development should be understood as a scientific demonstration of a new technological route and not as a currently available alternative to replace commercial electrolyzers.

A line of research of interest to Uruguay

Singapore's experience may be of interest to Uruguay due to the convergence of three areas that are part of its productive and energy agenda: renewable generation, future hydrogen production, and treatment of industrial streams.

Uruguay has abundant wind and solar resources and has analyzed the development of hydrogen and its derivatives for industrial activities, transportation, and export. Water availability and the environmental characteristics of each project are relevant variables when evaluating these technologies.

The direct use of seawater could, in certain future applications, reduce dependence on freshwater, although this does not eliminate the challenges associated with water resources. Collection, pretreatment, brine or effluent management, materials, facility location, and environmental protection remain factors that must be evaluated for each process.

NTU's technology adds another possibility: integrating hydrogen production with the treatment of certain industrial waste. For Uruguay, its current interest is primarily technological and prospective, since there is not yet a commercial application that can be directly transferred to national projects.

To produce energy and simultaneously solve an environmental problem

The main contribution of this research lies not only in obtaining hydrogen using sunlight. Its distinguishing feature is combining, in a single process, the direct capture of energy, the production of a fuel, and the degradation of a pollutant.

If this principle can be extended to other waste and overcome the challenges of durability and scalability, it could open a technological avenue in which certain industrial effluents cease to be treated exclusively as waste and become part of energy or chemical recovery processes.

For now, Singapore's "artificial leaf" is an experimental demonstration. But it points to a relevant research direction: developing energy technologies that not only reduce emissions during operation, but can also integrate energy production, efficient resource use, and environmental treatment within the same process.

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