Solar purifier creates its own disinfectant from water and sunlight

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A hiker gets disoriented while on a desert trek when she comes upon a drying puddle left by a recent rain.

Consumed by thirst, miles from home, the hiker must decide whether to drink and risk infection from whatever bacteria are in the puddle, or endure dehydration. But that hiker might one day be able to drink worry free, thanks to a new kind of water purifier that uses sunlight and water to produce hydrogen peroxide, a powerful and common antiseptic.

The experimental water purifier, developed in the lab of Xiaolin Zheng, associate professor of mechanical engineering, is a variant of the better-known process of using solar energy to split water into hydrogen, a clean-burning fuel, and oxygen, a life-sustaining element. But, as the team describes in the journal *Advanced Energy Materials*, instead of fully splitting oxygen and hydrogen, the new process reduces oxygen and oxidizes water to produce hydrogen peroxide, or H_2O_2.

Even just a small amount will purify the water, she says. Hydrogen peroxide disinfects water at a level of tens of parts per million. That's about two tablespoons in 25 gallons of water. In tests using tap water, the Stanford system easily reached well over 400 parts per million of H_2O_2 in five hours.

Zheng says the team will have to change some of the materials in the process to make its blend of ordinary water and hydrogen peroxide safe to drink. But they think that one day, a person in desperate thirst could pull out their lightweight solar purifier, pour in some suspect H2O and, given enough time, produce enough H_2O_2 through the sun-activated process to turn any fresh water into a veritable oasis.

In addition to future drinking water applications, Zheng and Xinjian Shi, the graduate student leading the project, also imagine that their system might be adapted into self-sustaining swimming pools purified with solar-created hydrogen peroxide rather than chlorine, or solar-powered water purification stations for use in developing regions where fresh water is a precious commodity.

Plentiful raw materials

The prototype consisted of two electrodes, an anode and a cathode, thrust into water. The anode was made of bismuth vanadate ($BiVO_4$), a photosensitive semiconductor. Simple carbon served as the cathode. When exposed to sunlight, the bismuth vanadate semiconductor sent negatively charged electrons flowing toward the cathode, while positively charged carriers—or "holes" as they are known in physics—flowed back toward the anode. The flow of electrons turned oxygen into hydrogen peroxide while the holes acted to transform water into hydrogen peroxide, forming the purifying compound at both electrodes.

It is a new take on what is known in engineering circles as a photoelectrochemical (PEC) system. PEC systems have been much studied since the 1970s for their ability to convert sunlight to fuel and other useful chemicals, like hydrogen and oxygen. Prior PEC experiments have produced hydrogen peroxide but none of these previous experiments has been as successful as the present research.

"Ours is an unassisted system," Shi says, "It requires zero energy input and only light, water and oxygen to work. Water is the 'fuel' of our system. In fact, it works with tap water."

Intriguingly, the system produces hydrogen peroxide on both sides of the reaction, at the anode and the cathode. At the end of it all, there's even a small amount of electricity remaining, due to the efficiency of the chemical reactions. While not a great amount, that additional energy might be used to light an LED bulb as an indicator that the system is working properly, the researchers say, letting the thirsty owner drink with confidence.

"We think that this is a new direction in PEC water splitting, which usually requires additional energy inputs to work," Zheng says.

Work ahead

The researchers consider this paper as a proof of concept and say much work remains before hydrogen peroxide-producing purifiers can become commonplace. Most importantly, bismuth vanadate—the anode—is itself toxic and would need to be replaced by another equally photosensitive material.

Dr. Samira Siahrostami, a co-author on the study and a research engineer at the SUNCAT Center for Interface Science and Catalysis at Stanford, selected bismuth vanadate as the anode for this prototype due to its efficiency and ability to generate hydrogen peroxide. Going forward, the researchers plan to identify other anode materials that are stable, efficient and safe for water purification.

Zheng and Shi also suggest that they might replace the carbon cathode with a different material that is also photosensitive (carbon is not). Such a design would harness a greater range of solar light to further enhance efficiency of the system.

Provided by Stanford University

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