Wastewater Produces Electricity and Desalinates Water

By Andrea Mossor

A process that cleans wastewater and generates electricity all at once, removing 90% of salt from brackish water or seawater, according to an international team of researchers from China and the U.S.

Clean water for drinking, washing, and industrial uses is a scarce resource in some parts of the world. In availability to the future will be even more problematic. Many locations already desalinate water using either a reverse osmosis process—one that pushes water under high pressure through a membrane that allows water to pass but retains salt—or an electrolysis process that uses electricity to draw salt ions out of water through a membrane. Both methods require large amounts of energy.

"Water desalination can be accomplished without electrical energy input or high water pressure by using a source of organic matter in the feed to desalinate water," the researchers report in a recent online issue of "Environmental Science and Technology.

"The key selling point is that it currently yields a lot of electricity to desalinate water and use the microbial desalination cells, we could actually desalinate water and produce electricity while removing organic material from wastewater," said Bruce Logan, Krupp Professor of Environmental Engineering, Penn State.

The team modified a microbial fuel cell—a device that uses naturally occurring bacteria to convert wastewater into clean water producing electricity—and it could desalinate salty water.

"Our main intent was to show that using bacteria we can produce sufficient current to do this," said Logan. "If we used 200 milliliters of an artificial wastewater—acetate acid in water—to desalinate three milliliters of salty water. This is not a practical system yet as it is not optimized, but it is proof of concept.

A typical microbial fuel cell contains two chambers, one filled with wastewater or other nutrients and the other with water, each containing an electrode. Naturally occurring bacteria in the wastewater consume the organic material and produce electricity.

The researchers, who also included Xiaoxin Cao, Xue Huang, Peng Liang, Kang Xiao, Yinpao Zhou, and Xianyuan Zhang, at Tsinghua University, Beijing, changed the microbial fuel cell by adding a third chamber between the two existing chambers and placing certain ion specific membranes—barriers that allow either positive or negative ions through, but not both—between the central chamber and the positive and negative electrodes. Salty water to be desalinated is placed in the central chamber.

Seawater contains about 35 grams of salt per liter and brackish water contains five grams per liter. Salt not only depletes its water, it dissolves into positive and negative ions. When the bacteria in the cell consume the wastewater it releases charged ions—protons—into the water. These protons cannot pass the porous membrane, so the negative ions move from the salty water into the wastewater chamber. At the other electrode, protons are consumed, so positively charged ions move from the salty water to the other electrode chamber, desalinating the water in the middle chamber.

The desalination cell releases ions into the water chambers that help to improve the efficiency of electricity generation compared to microbial fuel cells.

"When we try to use microbial fuel cells to generate electricity, the conductivity of the wastewater is very low," said Logan. "If we could add salt it would work better. Rather than just add salt, however, if we place where brackish or salt water is already abundant, we could use the process to additionally desalinate salty water, clean the wastewater and desalinate the resulting salty brackish water back into the ocean.

Because the salt in the water helps the cell generate electricity, the central chamber becomes less salty. The conductivity decreases and the desalination and electrical production decrease, which is why only 90% of the salt is removed. However, a 90% decrease in salt in seawater would produce water with 3.5 grams of salt per liter, which is less than brackish water. Brackish water would contain only 0.5 grams of salt per liter.

Another problem with the central cell is that as protons are produced at one electrode and consumed at the other electrode, these chambers become more acidic and alkaline. Mixing water from the two chambers together when they are discharged would once again produce natural, salty water, so the acidity and alkalinity are not an environmental problem assuming the discharged wastewater is dumped into brackish water or seawater. However, the bacteria that run the cell might have a problem living in highly acidic environments.

For this experiment, the researchers periodically added a pH buffer avoiding the acid problem, but this problem will need to be considered if the system is to produce reasonable amounts of desalinated water.

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