Using microbes and wastewater to desalinate water

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Unlikely as it may seem, microbes and wastewater are key components of a new technology capable of desalinating water without any additional energy. In a paper recently published in Environ. Sci. Technol. (2009, DOI 10.1021/es901950j), a team of researchers explains how this new technology can remove the salts from waters with a wide range of salinities, including ocean water.

The technology is based on microbial fuel cells (MFCs), which use microorganisms as catalysts to convert chemical energy to electrical energy. The paper’s authors, including Bruce Logan of Pennsylvania State University and Xiaoxin Cao of Tsinghua University (China), are among the small group of researchers worldwide trying to improve MFCs—or bioelectrochemical systems, as they are beginning to be called—and extend their utility. As it happens, says Logan, he and Cao independently conceived of the same innovation last year: a technology they call a microbial desalination cell (MDC).

Developing new technologies to improve the energy efficiency of water desalination is one of this century’s grand engineering challenges, according to the National Academy of Engineering. The MDC requires no external energy source.

The main difference between this technology and a conventional MFC is that the MDC uses two membranes rather than one (or none). Salty water is placed between an anion exchange membrane and a cation exchange membrane. When bacteria on the MDC’s anode produce current and protons, the salty water’s anions migrate through the membrane to the anode, and the cations are drawn to the cathode. In addition to producing power, the MDC can remove 90% of the salt from water with up to 35 grams of salt per liter, which is roughly the equivalent of seawater.

The new MDC actually solves many problems at once, explains Xia Huang, who was Cao’s Ph.D. advisor when the research was conducted. She says that Cao’s invention grew out of a discussion about how to decrease internal membrane resistance during one of the group’s weekly meetings in September 2008. Cao suddenly realized that by using two membranes and putting salty water between them, MFCs could desalinate water, she recalls. Logan says that a similar idea came to him one month later, when he was sitting on a plane catching up on his reading. “It hit me that we could. . .modify electrodialysis [a conventional technology for desalinating water] and essentially do the same thing [by] using the MFC as the integrated power source.” When Logan visited Tsinghua University a few weeks later, he heard Cao make a presentation about the MDC concept. “So, we decided to collaborate,” says Logan.

Researchers from other groups that are actively trying to improve MFCs’ commercial viability agree that the new work represents an important step forward. “This technology yet again demonstrates that bioelectrochemical systems are a very versatile type of technology for wastewater treatment,” says René Rozendaal, a research fellow at the University of Queensland’s (Australia) Advanced Water Management Center. Lars Angenent of Cornell University’s Department of Biological and Environmental Engineering lauds MDCs for making “smart use” of ion exchange membranes.

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However, the high cost of ion exchange membranes also makes the MDC comparatively expensive. The MDC's potential to use sewage and other wastewater as a low-cost fuel could help reduce its price and increase its efficiency, according to the authors.

The technology's ability to simultaneously generate electricity, desalinate water, and clean wastewater fits with the general trend in MFCs, says Bert Hamelers of Wageningen University's (The Netherlands) environmental technology department, a leading MFC research group.

Industries that must continually reuse process water may find the MDC particularly attractive, Hamelers adds. Angenent, Hamelers, and Rozendal agree that the technology could have utility for desalinating irrigation water. Huang says that it could also prove useful for treating brackish water in some areas of China.

Although bioelectrochemical systems cost more than other wastewater treatment systems, they also “offer many more opportunities for product formation that can potentially offset these higher costs,” Rozendal says. Such systems have already been proven capable of generating electricity, methane, hydrogen, hydrogen peroxide—and now desalinated water, he points out. “What will the future bring?” he asks.

Penn State researchers are already at work on the next generation of MDCs, which will be based on air cathodes. DAVID JONES