Electrically Active Microbes Clean Wastewater and Produce Energy

Municipalities charge industrial customers high annual fees for sewer discharge. These treatment facilities are overloaded with incoming industrial wastewater and sometimes are not able to adequately treat all of the wastewater to meet the requirements set by the U.S. Environmental Protection Agency (EPA).

Industrial wastewater is rich with organics, which create problems for municipal treatment facilities. When waste containing high concentrations of organic material is released to surface water, aerobic microbes consume both dissolved oxygen and organic compounds, depleting the water of oxygen needed for fish and other wildlife and eroding local ecosystems.

The chemical process industries (CPI) traditionally employ aerobic wastewater treatment technologies, for which energy, operating labor, and sludge disposal are the largest cost drivers. However, anaerobic treatment options provide additional benefits. They are net energy positive and achieve high treatment efficiencies, making them an economically viable option for onsite treatment. They can also enable wastewater reuse, helping the CPI hedge against water supply and pricing concerns. However, the microbiological, technological, and economical challenges associated with full-scale implementation of anaerobic wastewater treatment technologies have prevented their practical use — until now.

With funding from the National Science Foundation, Boston-based Cambrian Innovation has developed the EcoVolt Reactor, a modular anaerobic wastewater treatment system. The reactor uses an electromethanogenic process in which microbes convert organic matter into biogas with a high methane fraction. The methane can be used to generate clean electricity and heat.

The EcoVolt Reactor operates as a fixed-biofilm anaerobic system. Inside the reactor are two electrodes coated with electrically active microbes. The anode is seeded with electrogenic bacteria, which produce electrons as they consume organic materials, and the cathode is seeded with electrotrophic species, which metabolize electrons. When the wastewater contacts the anode, the electrogens digest the organic components and produce electrons, CO_2, and H^+. An external voltage source allows the electrons to travel through a circuit to the cathode. At the cathode, the electrotrophs fix the electrons, CO_2, and H^+ into water and methane. Starches, sugars, alcohols, and other compounds go through hydrolysis, fermentation, acidogenesis, and acetogenesis before they are finally fixed into methane in the methanogenesis stage.

▲ The first EcoVolt Reactor was installed at Lagunitas Brewing Co. in Petaluma, CA.

The EcoVolt Reactor significantly reduces the concentration of organics (by more than 80%) in the effluent and discharges a stream fit for sewer discharge or for additional polishing to allow onsite reuse, while generating methane gas. The methane and excess CO_2 bubble out of the solution, making them easy to capture. This high-quality, renewable biogas is piped to a cogeneration system. Combined heat and power (CHP) turbines transform the biogas into electricity and heat, which are returned to the facility.

The microorganisms in the EcoVolt Reactor are highly efficient at organic decomposition and produce high-quality biogas (70–80+% methane) for energy generation. The current produced between the two electrically active microbes provides continuous feedback regarding the health of the system, which is monitored and used to automate operational aspects of treatment.

The EcoVolt Reactor offers advantages over traditional wastewater treatment technologies. It operates reliably and robustly, handling fluctuations in wastewater flow and concentration, and requires a smaller footprint than its counterparts. It can be used as a standalone unit, or it can be combined with Cambrian's EcoVolt MBR (membrane bioreactor) to facilitate water reuse.

Cambrian Innovation has installed one demonstration plant and four commercial plants, and is currently installing two additional plants that are comprised of multiple EcoVolt modules. As of December 2016, EcoVolt systems had treated over 15 million gal of wastewater and reclaimed over 3 million gal of recycled water, with investment payback periods of as little as two years. The EcoVolt Reactor is poised to clean up waste streams across industry while lowering costs and carbon footprints. CEP

This technology was funded through the NSF Small Business Innovation Research Program.

This article was prepared by the National Science Foundation in partnership with *CEP*.