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Hot from the press!

A New Technology Breaks Through: 1000-Litre Microbial Fuel Cell Generates Pure Water and Electricity

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Abstract: For years, researchers led by Professor Fabian Fischer at HES-SO Valais have been concentrating on microbial fuel cells, also called bio-electrochemical systems, which use electrogenic bacteria to generate electricity. Their latest innovation is a device consisting of about 14 metres of joined-up microbial fuel cells, housed in the 'catacombs' – a series of underground tunnels – beneath the wastewater treatment plant in Sion. It uses bio-electrogenic rather than aerobic microbes for the primary purpose of producing energy and purified water, but also to save electricity.

The Origins of Microbial Bioelectricity

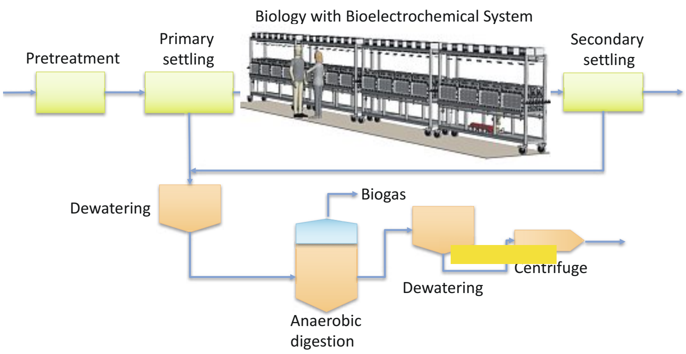
The scientists at HES-SO in Sion based their work on the fact that water supply and wastewater purification consume 1–2% of Switzerland's electricity output. It comes as no surprise, therefore, that wastewater treatment plants are the biggest energy consumers in any local community. "50–70% of total power consumption in a wastewater treatment plant occurs in the aerated lagoon. You have to force air through the sewage to help the microbes digest the organic matter in it", Fabian Fischer notes. "You can do that in microbial fuel cells too, with the major difference that they invert energy consumption into energy production. As things stand today, the theoretical potential of microbial fuel cells has been demonstrated, and there are plenty of projects aiming for real-life implementation, but the big challenge now is to scale up microbial fuel cells."

Bioelectrochemical phenomena are often thought to be extremely rare. However, there may have been summer nights when you have seen male insects trying to attract a mate using bioluminescence. Or maybe you have been in a zoo aquarium when an electric eel is hunting its prey. In these cases, you can understand bioelectricity because you can see and explain it. But it is much more difficult to find a simple and convincing explanation of why bioelectric microbes are electric. The sticking point is that you need a microscope, voltmeter or ampèrmeter to see their bioelectric effects. These instruments would show you that they breathe through their outer cell wall.

Fully electrogenic microbes were only found to exist about 30 years ago. Three articles describing their properties were published in 1988. One dealt with Oneida Lake, a manganese-rich lake in New York State. With no industrial or other potential manganese resource available, a scientist carried out microbial analyses after all chemical approaches had failed. On the manganese dioxide-rich bed of the lake, he discovered a bacterial species called *Shewanella* with electrogenic properties. The *Shewanella* bacteria performed a form of manganese respiration through their extracellular membrane, by which they transferred electrons to the oxidized manganese. This electrochemical process solubilized some manganese, which had previously been insoluble in water. This was the prelude to intensified research into microbial fuel cells, but it was only 10 years later that they were generally acknowledged as being suitable for this purpose. Today, we know that there are numerous other naturally occurring electrogenic microbes, and that they are even present in wastewater.

The 'Trick' with Up-scaling

The major issue facing the HES-SO researchers is scaling up the microbial fuel cells, as Professor Fabian Fischer explains: "We have been working on the problem at the HES-SO Valais laboratory for many years, and during that time we have increased the size of the reactors from 20 ml at the outset, then to one litre, and finally to the current 1000-litre unit. We developed a large number of new operating methods, tested materials and substrates, and developed electronic components that would make it possible to use these systems efficiently in sewage purification plants." A microbial fuel cell creates a maximum voltage of 0.5 V. In operating mode, that voltage quickly sinks to 0.2 V. To increase system performance, several microbial fuel cells can be connected together in series. However, in order to drive a typical 220 V electrical appliance, the HES-SO scientists would need to connect about 440 microbial fuel cells in series. "Using modern commercially available electronics, we can produce and store biological electricity with much smaller series of connected microbial fuel cell units. This has been facilitated by the rapid progress in research into electronic devices for low-power circuits, such as those in transparent solar cell panels. It is possible to charge polymer lithium batteries rated at 3.7 V or more with three or four microbial fuel cell units. This voltage is more than many smart phone batteries provide. The 1000-litre reactor charges several stacks of lithium batteries at the same time. Fabian Fischer and his group are now close to being able to charge lithium batteries for computers, electric cars and other devices using microbial energy. Examining ways of simplifying microbial fuel cell architecture so that the cells can be scaled up to plant-size reactors is another important issue. As yet, however, there is a long way to go before the technology can be implemented in a full-scale wastewater treatment plant.



Flow chart of a typical plant: The 1000-litre microbial fuel cell: its function in a typical wastewater treatment plant (Photo: HES-SO Valais).

What about Profitability?

There is currently insufficient data to correctly predict the profitability of large-scale microbial fuel cells. This is why the electrodes currently being used are probably the most expensive. However, once demand for them rises, their prices will drop, along with the prices of other essential parts and materials.

The current estimates are therefore rooted in basic assumptions, operating principles and a few known parameters. In fact, a lot of biological and organic mass is currently available for conversion into an appropriate useful product or at least into fully digested sewage sludge. "Look at the 1000-litre project currently in progress: it focuses particularly on municipal wastewater, which is available in large quantities and completely free of charge!" says Fabian Fischer. "But how much energy does municipal wastewater contain? Let us work it out. One person consumes about 2000 calories per day – enough energy to power a 100-Watt light bulb for 24 hours. However, 24 Watts of this energy are not used and go into the sewage."

It takes 7.5 Watts to purify the sewage produced by one person. Processing this water in a microbial fuel cell would save 50–70% of this energy. Consequently, it will only take 2.3 Watts of electricity per inhabitant to operate the bioelectrochemical sewage treatment plants of the future. The electricity generated by the process should further reduce the amount of electricity required. As a result, 20 Watts remains for conversion into bioelectricity. If half of this energy were converted into electricity, it would be possible to save 10 Watts per inhabitant. Given a price of 20 centimes per kWh, a sewage treatment plant for 100,000 inhabitants would generate annual income of 1.75 million francs – assuming that no electricity would have to be bought to clean the waste water.

Microbial fuel cells also work with other waste. Using the fifty percent of food production that is thrown away would increase output per person from 10 to 60 Watts. In this case, and again omitting any power that the purification plant might consume, annual income rises to up to 10.5 million francs. All in all, large-scale microbial fuel cells represent a promising way of reducing the cost of operating wastewater treatment facilities.

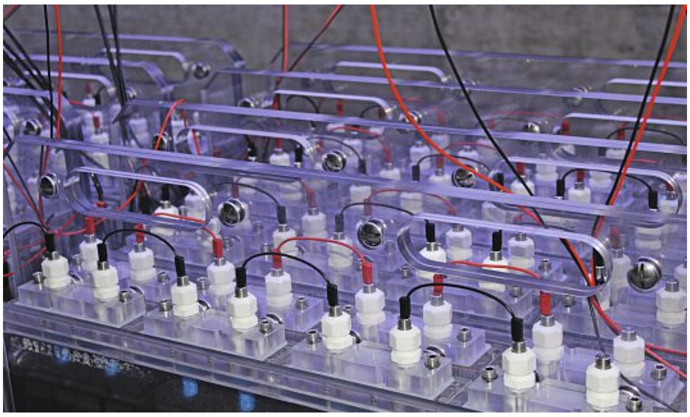
64-unit microbial fuel cell block for treating wastewater and generating electricity (Photo: Elsbeth Heinzelmann).

The microbial fuel cell arrives at the Châteauneuf wastewater treatment plant in Sion. Photo: HES-SO Valais

The Step into Practice

"We have been working with the wastewater treatment plant in Sion for many years. It therefore made sense to ask if we could use the 'catacombs' there to install one of the longest-ever 1000-litre reactors", says Fabian Fischer. The reply was positive, but brought a number of transportation challenges because the installation was more than 14 metres long. Today, the system is running satisfactorily, as Fabian Fischer is keen to point out. "With appropriate operating conditions, the system cleans wastewater to legal standards, and the purified water can be discharged into the nearby river Rhone. The system even works with cold sewage during winter. The positive results obtained to date are also attributable to the use of state-of-the-art electronic technology. The electronic circuits employed in the system optimize power production and enable the generated electricity to be saved in four lithium battery packs. We are now concentrating on further developing the current system and calculating the dimensions of a future large-scale microbial fuel cell that will clean the entire

Research Assistant Maxime Blatter of the HES-SO uses electronic circuits to monitor the process and optimize electricity production and wastewater purification (Photo: Elsbeth Heinzelmann).



The stacked multiple microbial fuel cells assembly enhances power generation (Photo: Elsbeth Heinzelmann).

wastewater output of a sewage plant all year round. In addition, we are estimating the associated investment costs.” There is more work on the way for Fabian Fischer and his team in Sion, supported by colleagues in St. Imier.

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Professor Fabian Fischer

Fabian Fischer works in chemical biotechnology and bioelectrochemistry at the School of Engineering (HEI) of the University of Applied Sciences and Arts Western Switzerland (HES-SO) in Sion. He is a member of the Life Technologies Institute and the newly founded Institute for Renewable Energy, both located in Sion (VS).

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