Electrifying bacteria: microbial fuel cells and pee powered toilets

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There are many aspects of our lives that we take for granted, and one that is not often discussed is the fate of our bodily waste as it disappears down the pan. I’m sure it’s not long since you, the reader, last visited the toilet or perhaps you’re just about ready to go? Whenever you do spend that penny, do you wonder where it’s off to or is it out-of-sight, out-of-mind? Just this once, I’m suggesting you do consider the millions of gallons of dirty liquid that are flowing beneath our feet. These underground streams are off to the wastewater treatment company to be cleaned, a process that is very expensive. But what if I was to tell you that the act of cleaning the waste could actually generate power rather than consuming energy? As you have probably guessed I am now about to present to a technology that can do these things.

The technology is called the microbial fuel cell (MFC) and uses bacteria to transform chemical energy locked up inside organic matter (the stuff that makes the wastewater dirty) into electricity. Just like a battery the MFC consists of a negative and positive electrode, but unlike a battery the MFC begins life as a group of inert materials producing zero power. The action starts when bacteria are fed into the chamber that houses the negative electrode. The ‘electro-active’ bacteria are found everywhere including in soil, wastewater and marine sediments, in our labs we normally use wastewater sludge as the source of microbe. As the bacteria colonise the electrode they are fed dirty liquids and breakdown and consume the bits we consider undesirable (the organic matter). Within the bacterial cell as the organic matter is broken down, electrons are released that are bounced along a chain of chemical reactions called the electron transport chain, a process that generates energy for the bacteria. During this process it is vital that the ‘used’ electron is deposited in a final reaction and transferred out of the cell to enable more reactions to proceed. For the majority of animals on the planet, oxygen is involved in this final reaction as within our human cells and all aerobic organisms. In MFCs, oxygen is not present and some special bacteria are able to use the surface of the negative electrode to ‘dump’ their electrons. Clad in our lab coats and gloves we are ready for this, because we ensure that an electrical circuit is connected between the two electrodes. The electrons leave the bacteria, are deposited onto the negative electrode and flow around the circuit to the positive electrode as electricity! We can control the amount of electrons that flow and essentially how hard the bacteria work by fixing the resistance of the circuit. So, just to recap… as the bacteria break down the organic matter (pollutants) they generate electricity and this production of power is a direct consequence of the cleaning of the liquid!

You’re probably wondering how much power is produced and can anything useful be done with it? You must remember that bacteria are not the biggest of organisms and to this end the power output is low. individual MFCs can produce on average between 0.2 – 0.5V with power measured in the scale of micro to milliwatts. This may seem insignificant but the ethos of our centre is to focus on developing the technology so that the power of the microbe can be used for real life application, furthermore we strive to do this without incorporating expensive materials such as platinum. We’ve realised that if you connect lots and lots of small MFCs together (as opposed to individual large ones) you can maximise output and can power useful things. This was started back in 2002 by Prof. Ieropoulos who built a series of ‘Eco-Bot’ robots that were powered by bacteria and could perform useful tasks such as moving towards light, broadcasting signals, self-feeding and even ejecting their own waste. This was done in a pulsed manner so that the energy generated by the bacteria was stored until when sufficient amounts had accumulated, the robot would be activated and could perform its tasks. Since then, our group of researchers here at Bristol BioEnergy Centre (B-BiC) have demonstrated a number of applications and had fun on the way for example we’ve used the bacteria to power remote control helicopters, motorised air-refreshers and to charge mobile phones. All this with the help of electro-active bacteria who are fed unwanted liquids such as urine. It goes without saying that those of us who work in the labs at B-BiC do think differently about our own urine, and we never seem to have enough for all our experiments! The examples I’ve listed were all carried out in the confines of our labs but there comes a point when critics pose the question; ‘is this just a novelty, a technology that’s interesting on the surface but one that will forever be consigned as a laboratory curiosity’?

The detectives amongst you will have worked out that we have indeed managed to move the technology from the lab to the outside world and it is truly an exciting area to be working in at the moment. Our first successful field trial was funded by Oxfam and was a Pee Powered © urinal positioned at our Frenchay campus next to the Student Union bar, a place where there wouldn’t be any shortage of fuel! Beneath the urinal were 8 boxes containing nearly 300 MFCs. Fed by student urine these powered motion sensors and lighting, the sensors would detect the ‘fuel-giver’ and illuminate them until they left.

This trial ran for 1 year and the bacteria happily provided power over all four seasons with the simple requirement that they were continuously fed the valuable golden fuel. Following on from this, larger urinals were operated at Glastonbury music festival in 2015 and 2016. The MFCs in these scenarios powered the lighting throughout the night and again the bacteria dealt admirably with high volumes of revellers pee. Much of our work is funded by the Bill and Melinda Gates foundation and we are currently in the process of determining areas in a number of developing countries where similar urinals can be installed in locations such as refugee camps where power and sanitation are in urgent need.

In addition to preparing for the overseas field trials we will be at Glastonbury festival again (2017); if you happen to be there this year be sure to look out for us next to the Cider bus. A few weeks before Glastonbury, I’ll be attending the Small is Beautiful Festival where I’ll be chatting about the technology and although I can’t show off the urinals I’ll bring a few MFCs and we can see if it’s possible to extract some power from the Welsh landscape. As far as our centre is concerned we’ll continue to focus on many aspects of research in order to find better materials, improve the power output, better treatment efficiency, find alternative fuels and to use MFCs for additional services such as pathogen removal and other types of pollutant control. Finally, it is our hope that it won’t be too long before microbial fuel cells are a part of our lives, perhaps we’ll have charging ports in our toilets? So back to you, the reader’s bladder movements… perhaps you’re ready to go now… when you do … just remember that what you’re producing and flushing down the pan could one day be a means for lighting your yard or charging your phone!

B-BiC Bio.

The Bristol BioEnergy Centre is a centre of excellence based at University of the West of England. It was founded by Prof. Ioannis Ieropoulos in 2014 following 12 years of research into microbial fuel cells starting with his PhD where he developed the Eco-Bot series of robots. He is the director of B-BiC and is responsive for the incredible growth of the centre. Dr Jonathan Winfield began his MFC journey in 2008 where his PhD looked at MFCs for wastewater treatment. He is now senior researcher and lecturer.