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Practical levels of electricity from MFC stacks fed with urine

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MFCs represent a promising technology for simultaneous organic waste treatment and sustainable electricity production. The main idea of our work is to develop Microbial Fuel Cells into a mature sustainable energy technology with a direct application in everyday life.

The aims of the current study were to compare different designs and sizes of MFCs in terms of power production and BOD reduction, fed with artificial feedstock and real urine, with the long term objective of mass-manufacturable modular elements for inexpensive stack production. Power output was assessed not only in terms of temporal real-time data, but also in terms of practical implementation into energizing stand-alone electronic devices. Since power output and COD reduction are inherently linked, the higher the power production, then better the waste clean-up.

Materials and Methods: MFCs (6mL) were manufactured by 3D rapid prototyping using Nanocure® material and conventional PEM. Ceramic MFCs (45mL) were constructed in a cylindrical form, with the inside forming the anodic chamber, the ceramic material acting as the PEM and the cathode wrapped around the outside and exposed to air. Both types of MFC were fed with the same feedstocks and at the same hydraulic retention time per unit. In the case of urine, this was provided by healthy human volunteers and was always fed fresh. Polarization experiments, power output monitoring and calculations were performed as previously described [1]. COD was determined using the potassium dichromate oxidation method [2]. The electrode surface area of the Nanocure 6mL MFCs was 157cm^2, whereas the electrode surface area for the 45mL ceramic MFCs was 337cm^2.

Results and Discussion: In terms of organic loading reduction, and power production, the cascade/stack approach has proven to be superior, since (see Table 1) a total of 63% COD reduction was achieved from the 18-unit Nanocure stack. Considering that urea does not get bio-utilized for electricity production, the percentage reduction achieved of the biodegradable carbon in urine, is >90%.

Table 1. COD reduction and power production from the 18-unit MFC stack.

MFC cascade	COD [g/L]	% reduction	Power [μW]
Input	14.64	-	-
After 1st stage	12.95	11.54	63.82
After 2nd stage	11.08	14.41	88.23
After 3rd stage	10.37	6.45	103.13
After 4th stage	8.67	16.34	137.67
After 5th stage	6.73	22.32	75.90
After 6th stage	5.48	18.68	63.23
Total reduction: 63%			

The same 18-unit MFC stack, when put in the appropriate configuration for optimum power generation, produced a peak output of 1.5mW (absolute value) of power. Based on the carbon electrode footprint, this is the equivalent of 5.3mW/m^2.

Both types of MFC units and collective stacks performed far better on urine than they did on artificial feedstock of equivalent (or even higher) COD. This is best demonstrated in Figure 1 (bottom right), which shows a 3.4-fold steady-state improvement in power output after being fed with urine, from the ceramic MFCs.

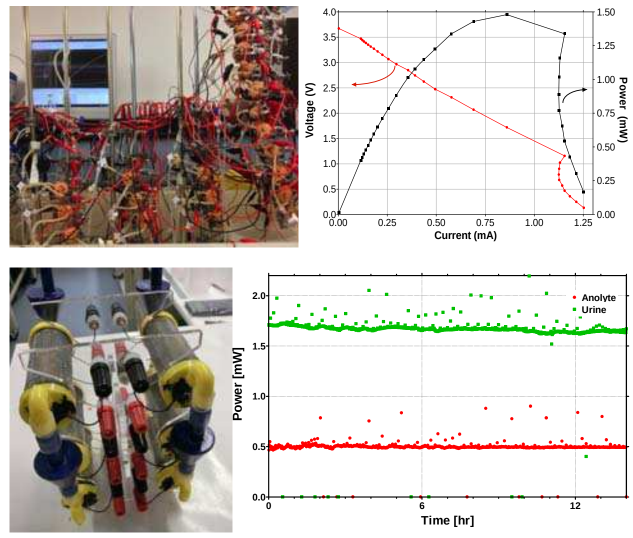

Figure 1. Different types of MFC stack. (i) 3D printed 6mL MFCs in a stack of 18 units & controls (top left); (ii) power and polarization data from the 18-unit stack (top right); (iii) ceramic 45mL MFCs in a half-stack of 6 units (bottom left); (iv) Power output from the 12-unit ceramic MFC stack when fed with either 25mM acetate + 0.1% YE (red lower line) or neat urine (green upper line).

Conclusions: The results clearly demonstrate that urine is particularly suited for high energy extraction in MFCs, and removes >90% of the organic bio-available carbon. Also, the findings confirm that our general approach to scale up (*miniaturisation & multiplication*) is both technically and scientifically sound. We have successfully implemented our MFC stacks in various practical applications, ranging from toy windmills, toy cars and digital wristwatches to complete robots and mobile phones.

It is of particular interest to pursue the construction of a single large stack of 1000 MFC units, for the purposes of revealing how best to mass-fabricate such systems, using low cost modular materials, as a “Lego-like” building-block approach and demonstrate the capabilities and performance of such a system.

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References

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2. Ledezma, P., Greenman, J. and Ieropoulos, I. 2013. MFC-Cascade stacks maximise COD reduction and avoid voltage reversal under adverse conditions, Bioresource Technology, Volume 134, April 2013, pp158–165.