# Electrochemical disinfection of human urine for water-free and additive-free toilets using boron-doped diamond electrode

Akshay S. Raut, Garry B. Cunningham[1], Charles B. Parker, Brian R. Stoner[1], Jeffrey T. Glass

Electrical and Computer Engineering, Duke University, Durham, NC 27708, USA
(1) RTI International, Center for Materials & Electronic Technologies, RTP, NC 27709, USA

Developing a disinfection system for human waste that does not require water, added chemical reagents, or energy in excess of that which can be easily produced by solar panels would be advantageous to communities in developing nations. Electrochemical disinfection of water refers to the elimination of microorganisms present in water by using suitable electrodes to pass electric current through the water[1]. Our current work focuses on developing an electrochemical disinfection unit for human urine without using any additional water or added chemical reagents and deriving all its energy from solar panels. The unit will be part of a modular outdoor toilet for use in developing countries in South Asia and sub-Saharan Africa. The electrochemical disinfection method we have devised based on previous studies[2] produces hypochlorous acid/hypochlorite at the anode as a side reaction to oxygen evolution. In addition, other reactive oxygen species (ROS) such as ozone, hydrogen peroxide and hydroxyl radicals are also generated [1]. These ROS are responsible for deactivating microbial cells [3]. Such electrochemical disinfection techniques have been validated in the past[2].

Our prototype disinfection system consists of a two-electrode flow cell – Diamonox 40 OSG-1 manufactured by Advanced Diamond Technologies (Romeoville, IL) with a boron-doped diamond (BDD) anode and a tungsten cathode. The surface area of each electrode is 42 $cm^2$. Initial tests involved I L physiological saline (0.9% w/v NaCl in water) with 1 mL green food coloring. The ROS generated upon applying DC voltage to the electrodes electrochemically attacked the organic food coloring causing it to become transparent. Samples were drawn at regular intervals and relative color was measured optically. Figure 1 shows a plot of relative color concentration versus treatment time for saline with food coloring at various applied voltages from 4 – 12 V. Plotting the energy required to discolor 1 L of saline with 1 mL green food coloring at different voltages and target color concentrations (obtained optically) as shown in Figure 2 will allow for optimization of parameters such as electrode spacing and fluid flow rate.

Future work after optimization of the cell parameters as described above will include testing of synthetic urine spiked with *Escherichia coli* bacteria. Total colony forming units (CFUs) will be counted from samples taken before, during and after the treatment. Total colony forming units (CFUs) will be counted from samples taken before, during and after the treatment. Data showing effective microbial disinfection in synthetic urine and geometric optimization of the cell will be presented.

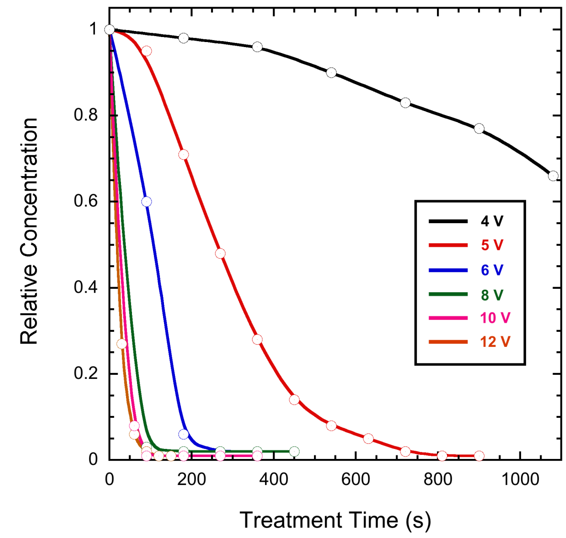


**Figure 1: Relative color concentration versus treatment time for 1 L saline with 1 mL green food coloring**

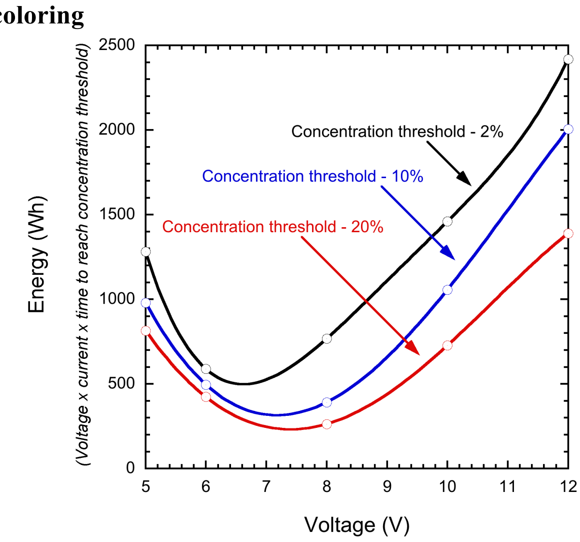


**Figure 2: Plot of energy required for treatment versus applied voltage for different target concentrations**

**Acknowledgements**
The authors would like to thank the Bill & Melinda Gates Foundation for funding this project, Prof. Marc Deshusses for helping with bacterial cultures, Barbara Raynal for assistance in lab work and Jason J. Amsden for helpful discussions.

**References**
1. Kraft, A., Electrochemical Water Disinfection: A Short Review. *Platinum Metals Review* **2008,** *52* (3), 177-185.
2. Stoner, G. E.; Cahen Jr, G. L.; Sachyani, M.; Gileadi, E., The mechanism of low frequency a.c. electrochemical disinfection. *Journal of Electroanalytical Chemistry and Interfacial Electrochemistry* **1982,** *141* (3), 229-243.
3. Jeong, J.; Kim, C.; Yoon, J., The effect of electrode material on the generation of oxidants and microbial inactivation in the electrochemical disinfection processes. *Water Research* **2009,** *43* (4), 895-901.
4. Barker, L. M.; Pallante, S. L.; Eisenberg, H.; Joule, J. A.; Becker, G. L.; Howard, J. E., Simple synthetic and natural urines have equivalent anticalcifying properties. *Invest Urol* **1974,** *12* (1), 79-81.
5. Burns, J. R.; Finlayson, B., Proposal for a Standard Reference Artificial Urine in in vitro Urolithiasis Experiments. *Investigative Urology* **1980,** *18* (2).