Energy Minimization in the Electrochemical Disinfection of Human Liquid Waste Using Boron-doped Diamond Electrodes

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Previously we demonstrated total disinfection of synthetic urine spiked with E. Coli by employing electrochemical oxidation at boron-doped diamond electrodes (1). The chlorine species and reactive oxygen species (ROS) were responsible for the inactivation process. Very high overpotentials (> 6 V) resulted in faster disinfection while also leaving residual disinfectants sufficient to avoid recontamination of the processed urine. Voltage was applied to the electrodes for the time required to disinfect the urine, however, this led to relatively high energy consumption. Energy for disinfection is defined as the product of the cell voltage, the current and the time for which the current flows. The primary application driving these developments is the treatment of human waste for remote and off-grid applications. A balance between energy efficiency and process throughput is thus desired.

One approach to minimize energy consumed is to process for a shorter period of time, turn off the cell (refer to Figure 3) and allow the residual oxidants to disinfect the remaining colony-forming units (CFU). For instance, Figure 1 shows 2 L synthetic urine spiked with *E. Coli* treated for three different processing times – continuous processing for 15 minutes, 7.5 minutes on followed by continued monitoring, and 3 minutes on followed by continued monitoring. The CFU count drops below the disinfection threshold of 10 CFU/mL for both the full processing time (at 15 minutes) and 7.5 minutes (at around 90 minutes total). However disinfection was not achieved for 3 minutes. The energy saving for the 7.5 minutes on and off process was ~53% as compared to 15 minutes continuous treatment.

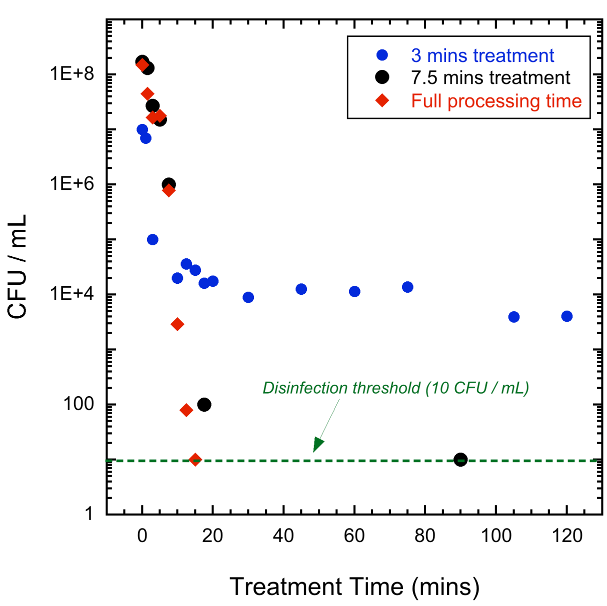

Figure 1: *E. Coli* CFU as a function of treatment time for urine and *E. Coli* at 8 V for different treatment times.

Based on these initial results, similar tests are planned for different voltages to achieve energy reduction by employing short processing times. Figure 2 shows a plot of energy consumption versus voltage. The solid line represents energy consumed at full processing. The dotted line represents the predicted lower limit when a stepped short processing time profile is applied. The green region indicates the energy that is saved or the available process window.

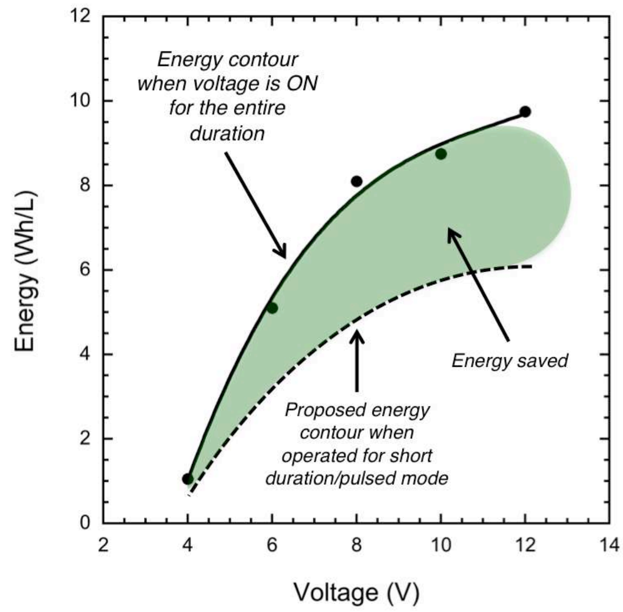

Figure 2: Disinfection energy as a function of voltage for full processing time and predicted energy for short processing time for disinfection of urine and *E. Coli*

Lower voltages are more energy efficient, however, if energy is stored in a standard 12 V batteries for these off-grid applications, a stepped or pulsed approach at 12 V may be more efficient than step-down circuitry operating at 4 V. Effects of pulsed voltage (Figure 3) will also be studied along with short processing time. The duty cycle of the pulses can be modified to control the total charge injected.

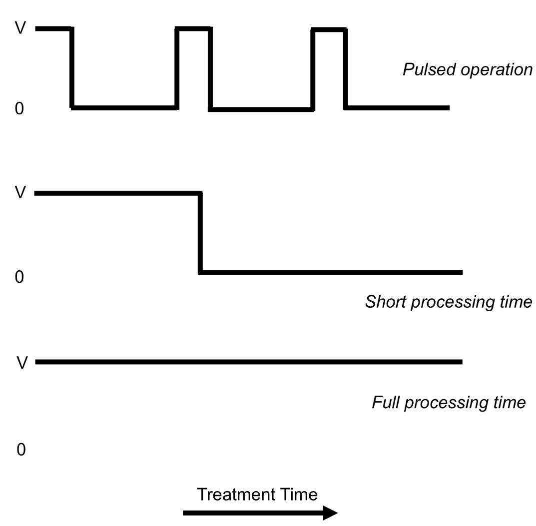

Figure 3: Different forms of electrode voltage to be used to achieve energy reduction in disinfection process

Financial support from The Bill and Melinda Gates Foundation and technical assistance from Barbara Raynal, Joan Colon Jorda and Advanced Diamond Technologies are gratefully acknowledged.

References

1. A. Raut, G.B. Cunningham, C.B. Parker, B.R. Stoner and J.T. Glass, in *223rd ECS Meeting (May 12-17, 2013).*