Optimization of an electrochemical flow cell for pathogen disinfection in hydroponics

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Introduction

An optimized electrochemical flow cell (EFC) was developed for enhancing water treatment in closed-loop hydroponics. Benefits of this technology include no moving parts, no continual injection of disinfectants and no accumulation byproducts from disinfectants. Hypochlorite (ClO^-) is produced *in situ*, which eliminates the need for constant injection.

The research explores the optimization of the EFC system by modifying electrode spacing to increase the volume of water that can be treated. The previous system had electrodes spaced at 2 mm and we investigate whether spacing can be increased.

Methods

A fertilizer solution was prepared using 1.15 g/L of a 6-11-31 Master Plant Prod fertilizer, 0.85 g/L $Ca(NO_3)_2$ and 0.0426 g/L of KCl. The solution contained KCl to produce chlorine in solution when operating the EFC. A common plant pathogen, *Fusarium oxysporum lycopersisy*, was added in solution for electrochemical treatment.

To test electrode spacing, 5 single cells were 3D printed with variable spacings of 2, 3, 6, 9 and 10 mm (Figure 1). The irrigation solution with pathogens was passed through each cell and the solution was collected for monitoring microbial loads following treatment using various currents and flow rates. The solution was collected and cultured to monitor microbial loads inactivated when passing through the EFC at various electrode spacings. Surface response analysis was used to determine the ideal electrode spacing for a larger scale system. A large-scale system was developed to test the optimized electrode spacing (Figure 2).

Figure 1: 3D printed cells with variable spacings for testing pathogen inactivation

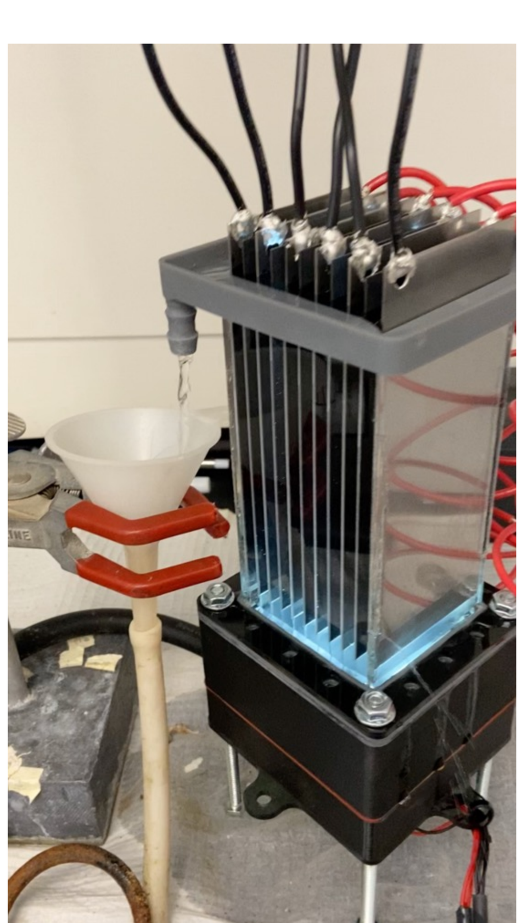
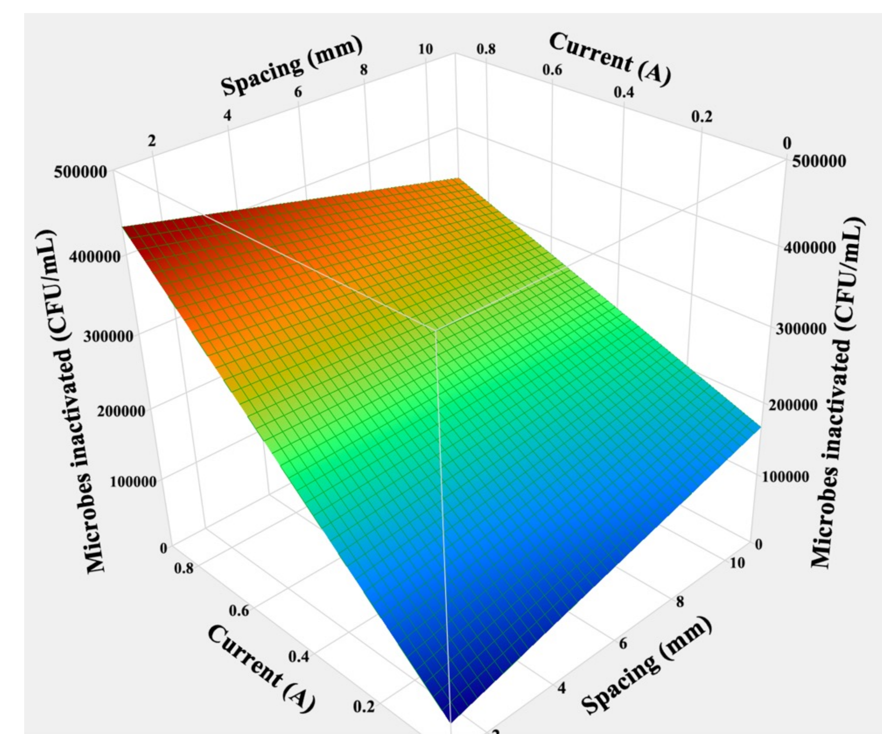


Figure 2: EFC design after electrode spacing was determined

Results

Microbial inactivation increased with current applied to the solution, as well as smaller spacing (Figure 3a). However, microbial inactivation was increased with slower flow rates and larger spacing (Figure 3b). This indicates that larger spacing between electrodes can be permitted if the solution flows through the system at slower flow rates. Higher microbial inactivation with larger spaces can be the result of diminishing the amount of chlorine that is reduced at the cathode. This provides higher concentrations of chlorine for pathogen inactivation.

3A



3B

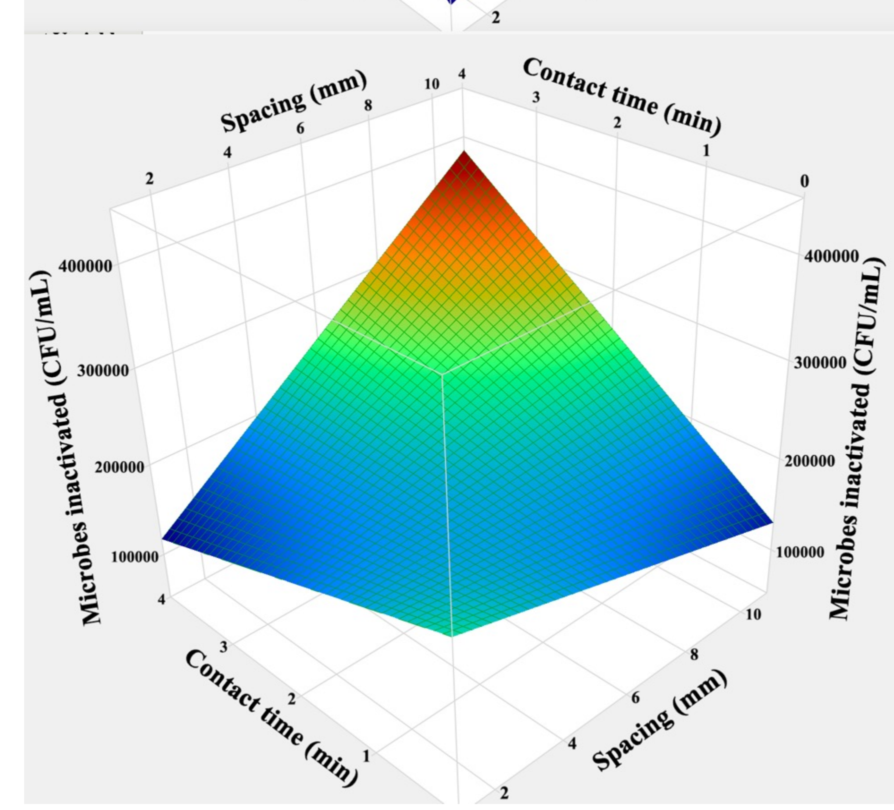


Figure 3: Response surface analysis of electrode spacing with a) current applied to solution and b) flow rate used in the cells

After conducting the response surface analysis, canonical analysis was performed to identify the optimal electrode spacing. It was identified that 6 mm spacing was the most optimized and a new cell was built to compare between the previous system. It was found that the new cell achieved higher inactivation rates than the previous cell design (Figure 4).

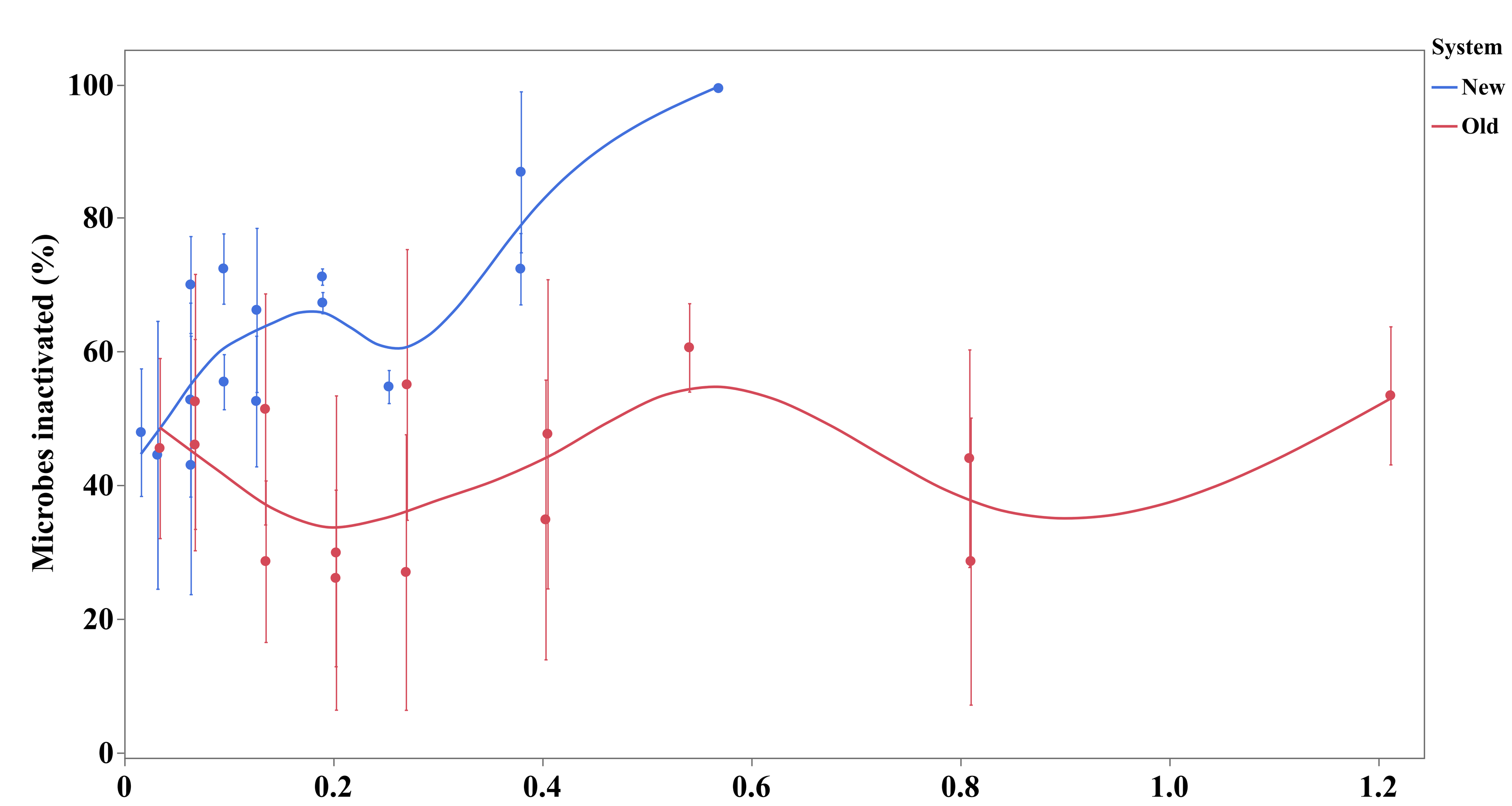


Figure 4: Charge volume density comparison between the previous and the optimized modules.

Conclusion

The new optimized flow cell was shown to inactivate more pathogens than the previous system. Furthermore, the research provides a baseline for the optimization of electrochemical systems and provides a novel technology for protecting crops in Controlled Environment Agriculture.