Novel Process Technologies for Disinfection of Potable Water

Wastewater Reclamation Using a Microplasma Ozone Source--E. Coli and Organic Dye Destruction.

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ABSTRACT

Ozone is a strong oxidizing agent that is capable of breaking down organic products into oxygen, water, and carbon dioxide. Using patented plasma source technology [KWJ Engineering], sources were constructed to produce ozone between 50-80 ppm at flows of 0.5 L/min. The ozone was introduced into water using three different delivery methods; a glass frit, a metal frit, and a Teflon tube. All delivery systems required a flow of air and the release of ozone into the water by effervescing. Tests were conducted on volumes between 25 and 50 ml, but the technique can be scaled for large volumes. The efficiency of each method was tested on an organic dye and on an *Escherichia coli* (*E. coli*) bacterial strain. Results showed a decrease in organic content and in living bacteria with all delivery systems, but the greatest decrease was observed with the use of the glass and metal frits.

INTRODUCTION

Ozone is increasingly being used for disinfecting and purifying water, air, and surfaces. It can be generated on site and leaves no chemical residue after use. It also is effective at destroying microbes and organic contaminants. Ozone acts by disintegrating the cell membranes and attacking their fatty acid constituents. Due to the rapid nature of cell lysis, ozone deactivates microbes faster than other disinfectants and microorganisms are unable to develop ozone specific resistance.

In drinking water systems, chemical treatment is more common because of the relatively high cost of ozone generation and the relatively low efficiency ozone generators. Wisconsin Lutheran College is collaborating with KWJ Engineering on a project funded by the National Aeronautics and Space Association (NASA) to design high-efficiency ozone generators and reactors for the introduction of ozone into water. The key in the development of drinking water technologies for small systems is not to make the systems fit the paradigm of a smaller version of large water treatment systems, but to start with a small, practical, and inexpensive treatment method that can be scaled to the necessary size.

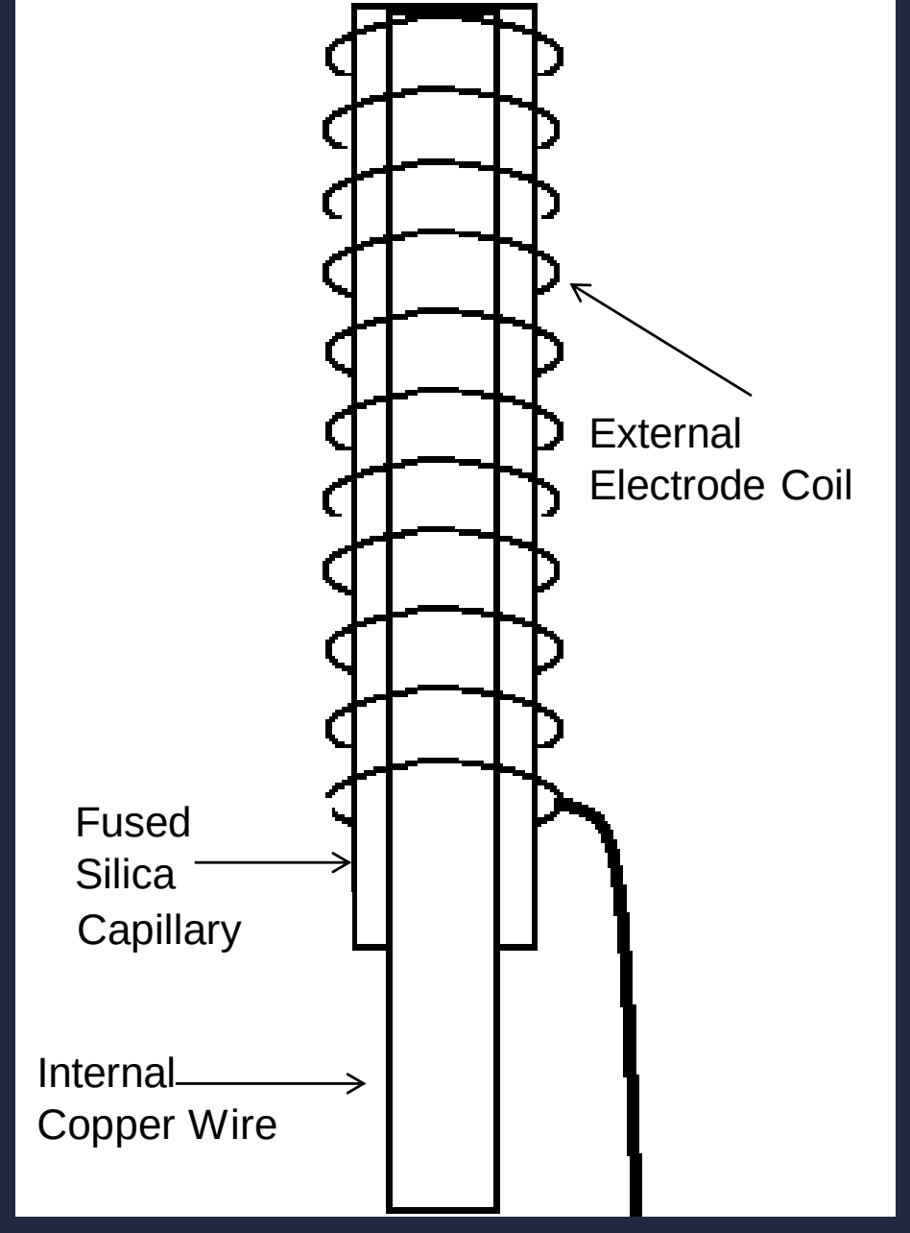

Figure 1. Diagram of microplasma generator.

Figure 2. Introduction of ozonated air into water by a metal frit.

Figure 3. Glass frit apparatus with Remazol Brilliant Blue dye.

EXPERIMENTAL PROCEDURE

Three methods were used in testing the sources ability to treat water. Each method involved flowing air over the plasma source. The first used a metal frit, submerged in water (**Figure 2**); the second passed ozonated air through a glass frit causing ozone to bubble through the water (**Figure 3**); and the third method completely submerged a porous Teflon tube containing a microplasma source into water.

Remazol Brtilliant Blue R (Fisher Scientific) dye (analytical wavelength of 592 nm) was used to study the effect of ozone on an organic molecule. The destruction of the dye was monitored by an HP 8452A Diode Array Spectrophotometer. *Escherichia coli* strain JM 109 was also used to test ozone's efficiency of breaking down a bacterial strain in water. An optical density of the starting solution at 600 nm (OD_{600}) gave an estimate of how many cells per milliliter the solution contained. Desired concentrations were obtained by dilutions. These dilutions were ozonated and samples were collected at selected time intervals. The samples were diluted further (if necessary to obtain countable colonies) and then plated on Plate Count Skim Milk Agar in Polystyrene disposable sterile petri dishes **(Figure 4).** After being left overnight in a warm room, the bacteria colonies of each sample were counted.

The ozone sources provided ~60 ppm ozone in air when run at 12 V with 0.5 L/min of airflow. Controls were run on each apparatus with normal airflow and no voltage applied to the ozone source. No significant change in dye concentration nor in the amount of living cells in water was observed over time during these controls.

Figure 4. *E. coli* colony growth agar plate.

RESULTS AND DISCUSSION

E. Coli tests with the metal frit suggest that most of the cells were destroyed after ten minutes (**Figure 5**). The Teflon tube did not perform nearly as well as the frit apparatuses. Not as much ozonated air was able to diffuse through the Teflon as with the metal and glass frits. When the flow rate was increased above a maximum, the efficiency of the Teflon apparatus began to drop. This is likely because significantly larger bubbles were released from the porous Teflon, causing less surface area between ozonated air and the water.

Both the metal frit and the glass frit apparatuses performed well. In experiments with varied airflow, higher flow rates showed more rapid dye degradation. The voltage was also varied to see effects of varying ozone concentrations. The rate of dye destruction on various concentrations of dye can be seen in **Figure 6 (below)**.

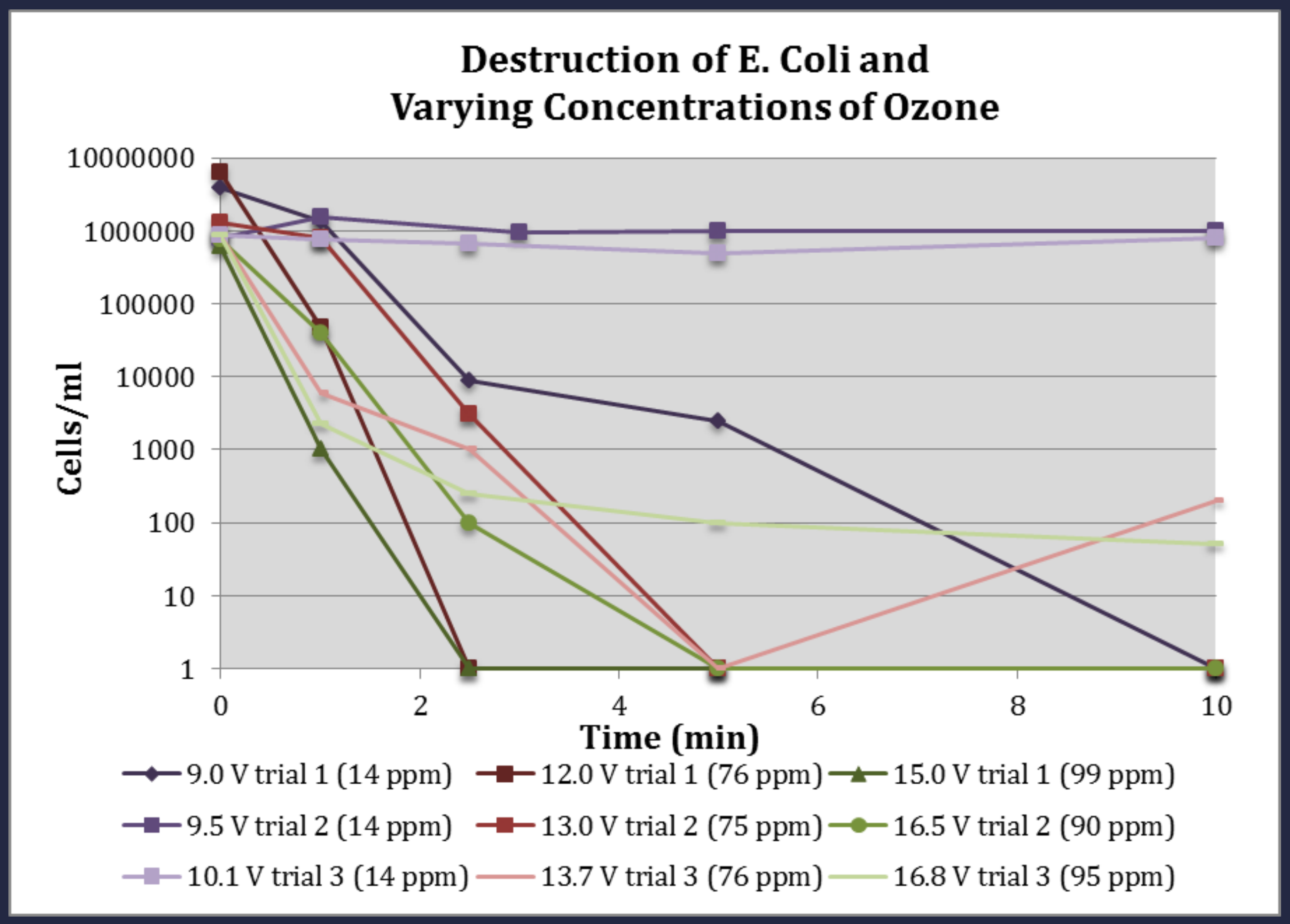

Figure 6. Decrease in *E. coli* with metal frit apparatus while varying ozone concentration. NOTE: The 16.8 V Trial 3's last two data points, along with 13.7 V Trial 3's final data point are based on one counted colony per plate and essentially indicate complete destruction of bacteria.

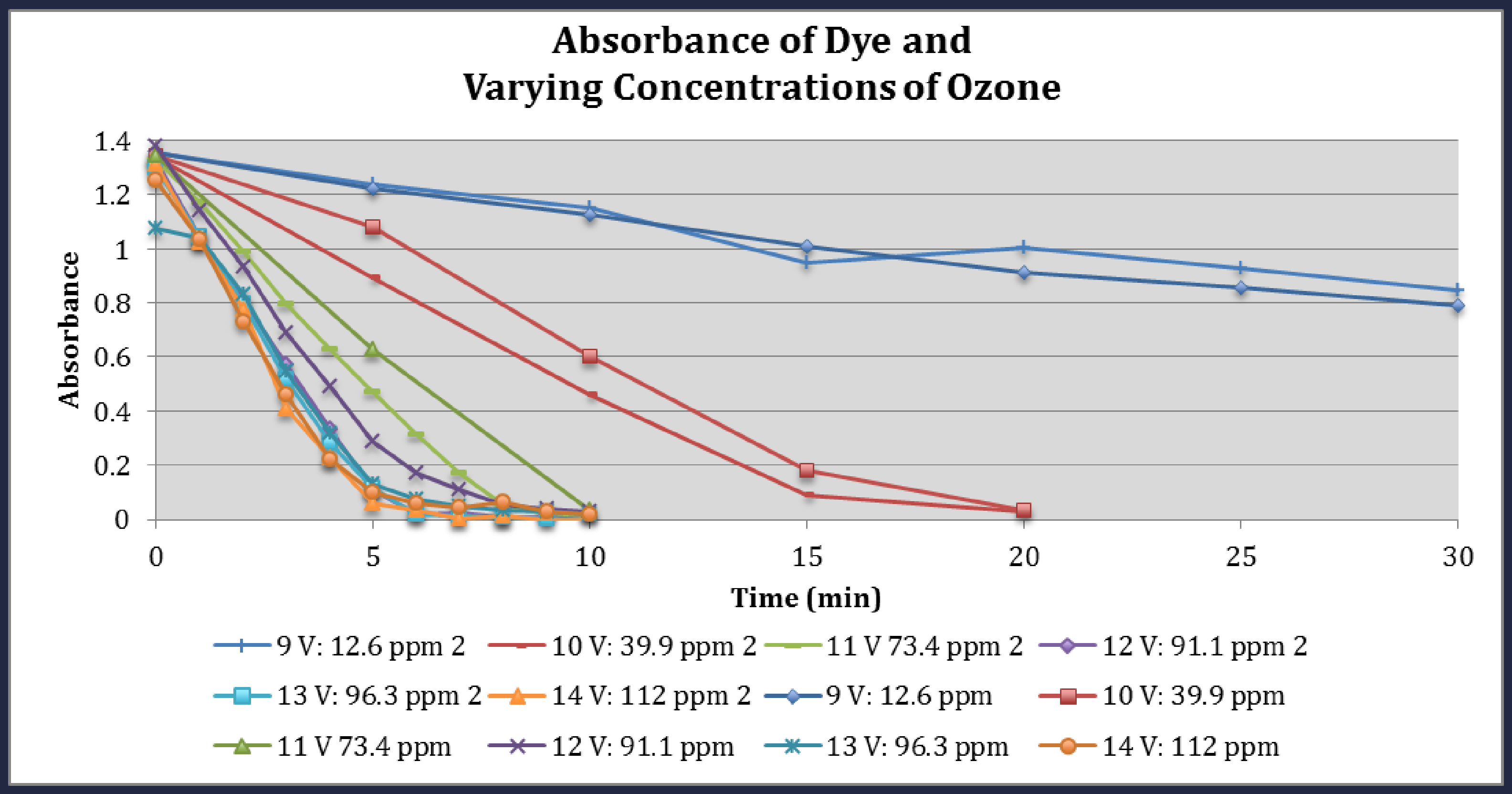

Figure 5. The absorbance of dye over time with varying ozone concentration. The flow rate was 0.5 L/min with a liquid volume of 28 mL in the glass frit apparatus.

CONCLUSION

Ozone is increasingly being used in today's modern sanitation practices because of its ability to be generated on site and its lack of residual chemicals. Introduction of ozone into water by effervescing proved effective at destroying organics and removing viable bacteria cells on a small scale within a matter of minutes. Continued work should be done in order to further characterize the ability and efficiency of the microreactors and in applying them to larger systems.

References

Pascual, A., Llorca, I., and Canut, A. Use of ozone in food industries for reducing the environmental impact of cleaning and disinfection activities, *Trends in Food Science & Technology*, **18**: S29-S35 (2007).

"Novel Process Technologies for Disinfection of Potable Water", NSF PROPOSAL NUMBER: 10-1 X3.01-8064, September, 2010.

United States Patent # 7.157,721 B1, William C. Blanchard, 2007 to KWJ Engineering concerning the DPIS – distributed Plasma Ion Source.

Gertsch, J, Armstrong, A, Ebeling, D, Shirke, A, Stetter, J. "Water Reclamation Using a Microplasma Ozone Source—E. coli and Organic Dye Destruction" International Ozone Association—Pan American Group Proceedings, Milwaukee, WI, Sept. (2012).

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