Organic wastewater purification from bacteria and viruses by cold atmospheric plasmas

A. Lavrikova, F. Avino, R. Agus, Y. Asnis, I. Furno
Swiss plasma center (SPC), École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

Abstract: Antimicrobial and antiviral effects of two air dielectric barrier discharges are studied for wastewater purification. The energy consumption as well as the log reduction are measured as a function of various experimental parameters. The kinetics of the reactive oxygen and nitrogen species are measured in plasma-activated water and plasma-activated media. Post-treatment incubation reveals a high potential of cold atmospheric plasmas for organic wastewater treatment.

1. Introduction

Cold atmospheric plasmas are one of the most promising bio-decontamination techniques in clinical, food processing, and environmental practices [1]. Yet, current solutions remain unsatisfactory for organic wastewater purification (e.g., [2, 3]). The presence of organic matter in a liquid, such as proteins and sugars, causes a reduction of the microbial inactivation. Along with target microbial cells, plasma–generated reactive oxygen and nitrogen species (RONS) interact with biomolecules thus shielding microbial cells [4].

The physicochemical properties of plasma-activated Luria-Bertani broth (PALB) and plasma activated water (PAW) are compared to explore the shielding effect of plasma activated medium reactivity. Evaluation of bacterial membrane and RNA destruction helps to understand certain plasma-cell interaction pathways.

2. Methods

Surface dielectric barrier discharge (SDBD) [5] and volume dielectric barrier discharge (VDBD) are used for direct treatment of a liquid sample. Antimicrobial effects are studied on *Micrococcus luteus* (*M. luteus*) and *Escherichia coli* (*E. coli*) through bacterial survival, cell membrane permeabilization, membrane potential, and RNA degradation. Antiviral effects are studied on adeno-associated virus (AAV) by digital PCR and transduction assay. RONS in PAW and PALB are measured by vis-spectrophotometry and high-performance liquid chromatography.

3. Results and Discussion

M. luteus and *E. coli* suspensions in water are completely inactivated immediately after 3- and 5-min treatment by the SDBD. However, plasmas do not cause significant inactivation in the presence of LB broth. Figure 1 demonstrates the survival of *M. luteus* in LB broth immediately after 3-, 5-, and 10-min treatment, and after 24- and 48-h post-treatment incubation. Treatment for 10 min with 24-h post-treatment incubation causes complete inactivation. The absence of viable but non-culturable bacteria is confirmed by live/dead staining. Bacteria survival correlates with the amount of LB broth in a suspension. Post-treatment incubation facilitates the formation of secondary RONS in PALB, which are required for bacteria inactivation.

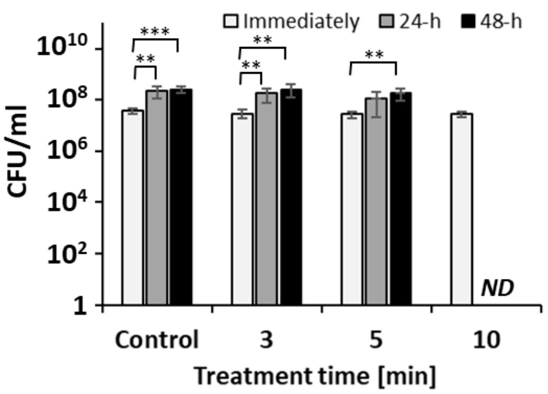

Fig. 1. Reduction of *M. luteus* population upon direct SDBD treatment in LB broth as a function of treatment time and post-treatment incubation. *ND* = not detected.

4. Conclusion

The findings reveal distinct bacteria and virus responses to plasma based on the surrounding liquid contents. Acidity is an important but not indispensable factor in plasma microbial inactivation. VDBD is found to be more energy efficient than SDBD for wastewater treatment. High antimicrobial and antiviral effects in a culture media provides a practical solution for organic wastewater purification by cold atmospheric plasma.

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References

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