Plasma Activated Water Generation in Pin-to-Plate Gas Phase DBD-based Plasma Source for Enhanced Biochemical Activity

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Abstract: Plasma-activated water (PAW) exhibits strong biochemical activity due to reactive oxygen and nitrogen species. This study explores how electrode and dielectric material, liquid conductivity, and gap distance affect PAW generation in a pin-to-plate DBD source. The operation at 5 kV and 20 kHz produces significant hydroxyl radicals (108.5 µM), linked to electrode erosion. Despite minor electrode loss, the reactive species effectively eliminate bio-contaminants, achieving a 3-log reduction in E. coli. Optimization of plasma sources is crucial for practical PAW applications.

1. Introduction

The development of Plasma-Activated Water (PAW) has attracted attention for its potential in agriculture, food safety, and medical disinfection due to the strong oxidative and antimicrobial properties of its reactive oxygen and nitrogen species (RONS) [1,2]. Various plasma sources, including pin-to-liquid discharge and dielectric barrier discharge (DBD), have been studied for PAW generation, with factors like electrode materials, liquid conductivity, gas type, voltage, and gap distance influencing PAW composition. Previous research has shown the impact of electrode materials and gap distance on microbial inactivation and plasma discharge efficiency. However, there is a limited exploration of how these factors interact to optimize RONS production. This work presents a pin-to-plate gas-phase DBD (P2PDBD) system that enhances biochemical activities. The study investigates the effects of electrode and dielectric materials, along with operating conditions, on plasma discharge characteristics and PAW efficacy for water treatment.

2. Methods

The experimental setup uses a P2PDBD plasma source to activate water, driven by a bipolar pulsed power supply. A pin electrode enclosed with Teflon dielectric is used for the high-voltage electrode, while rectangular plates serve as the ground electrode.

3. Results and Discussion

The conductivity of water affects plasma-water interactions, influencing chemical reaction pathways. The minerals in tap (TW) and seawater (SW) can interact with plasma-generated species, causing precipitate formation and pH changes due to buffering effects. DI water (DIW) and SW show a significant pH decline upon plasma exposure, while TW maintains a stable pH due to the buffering effect of carbonates and bicarbonates. The gap distance between the plasma source and the water surface also affects plasma chemistry as shown in Fig. 1(a). A 0.5 cm gap increases evaporation and humidity, promoting hydroxyl radical and hydrogen peroxide formation, and enhancing biochemical activity. At a 2 cm gap, minimal changes in water properties are observed with higher voltage as shown in Fig. 1(b). E. coli inactivation studies show PAW-12 min is highly effective, outperforming artificial solutions, demonstrating the bactericidal potential of PAW as shown in Fig. 1(c).

4. Conclusion

This study examines the dynamics of PAW generation in a P2PDBD system, focusing on parameters like electrode material, liquid conductivity, and gap distance. It highlights how high-voltage electrode erosion influences hydroxyl radical formation. The findings offer valuable insights for optimizing PAW generation and its physicochemical properties for future applications.

References

[1] S. Pandey et al., Phys Lett A (2023) 128832.

[2] R. Montalbetti et al., Plasma Processes and Polymers (2024).

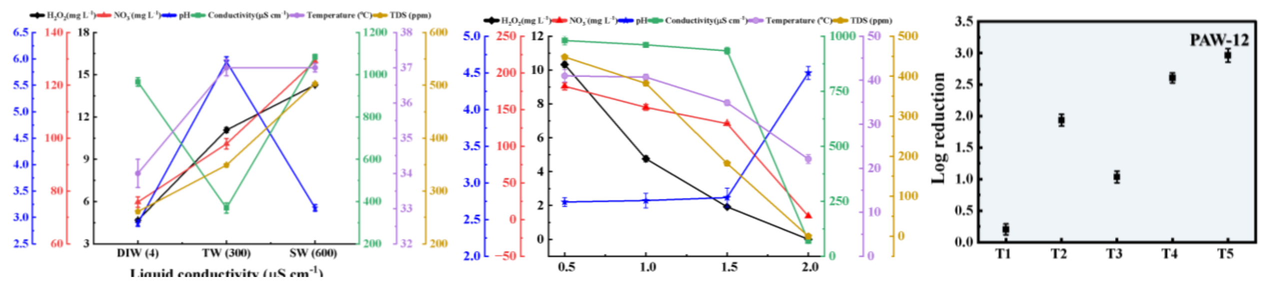

Fig. 1. Variation of physicochemical properties of PAW with (a) liquid conductivity and (b) gap distance, (c) Efficacy of different treatment solutions for *E. coli*