Water remediation of toxic bisphenol chemicals by cold atmospheric pressure plasmas

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Abstract: In this contribution, we report water remediation of toxic compounds that potentially threaten the environment and public health. Here we report the use of cold atmospheric pressure plasma (CAP) generated in ambient air to remove bisphenol A (BPA) and bisphenol S (BPS) from aqueous systems. Our study shows that CAP can effectively remove bisphenols from water, with more than 75% of BPA and over 48% of BPS after 480 seconds. Findings demonstrate nitrification with further cleavage, demethylation, carboxylation, and the coupling of minor bisphenol intermediates. Finally, the lower toxicity of the transformation products (TP) mixture also suggests that CAP is an effective water treatment technology

1. Introduction

Bisphenols, including BPA and BPS, are prevalent environmental contaminants with estrogenic, genotoxic, and cytotoxic effects. These compounds are widely used in industrial applications and are challenging to remove through conventional water treatment processes. CAP has emerged as an advanced oxidation process capable of generating RONS that degrade organic pollutants. This study investigates CAP's efficacy in degrading BPA and BPS under conditions simulating environmental scenarios. [1,2]

2. Methods

The study utilized a surface dielectric barrier discharge system to generate CAP for treating BPA and BPS solutions. The plasma system was operated with a sinusoidal waveform at a frequency of 23 kHz and a voltage of 12 kV. Samples were treated for varying durations, up to 480 seconds, with and without the addition of methanol as a radical scavenger to simulate natural conditions. The degradation efficiency and TP formation were analyzed using high-resolution mass spectrometry, adopting a non-targeted screening approach. Toxicological characterization involved cytotoxicity and genotoxicity assays conducted on HepG2 cells, which were exposed to BPA, BPS, and their TPs for 24 hours. The expression of genes associated with metabolic processes and DNA damage responses was also analyzed through quantitative PCR, providing insights into the molecular impacts of the plasma-treated compounds.

3. Results and Discussion

CAP treatment significantly enhanced the degradation of BPA compared to BPS, with observed half-lives of 210 seconds and 4700 seconds, respectively. The inclusion of a radical scavenger notably suppressed the formation of critical RONS, such as hydroxyl radicals and hydrogen peroxide, thereby reducing the degradation efficiency. Despite this, the CAP system successfully produced multiple TPs for both BPA and BPS, including previously unreported nitrification and demethylation products. The proposed degradation pathways revealed complex mechanisms involving aromatic ring cleavage and coupling of smaller intermediates. Toxicological assays showed that the mixtures of TPs had a reduced impact on cell viability and DNA integrity compared to their parent compounds. Gene expression analysis further indicated that while BPA and BPS activated stress-related metabolic pathways, their TPs elicited comparatively subdued responses, highlighting CAP's ability to mitigate the toxicological risks associated with these pollutants.

4. Conclusion

This presentation underscores the potential of CAP as an advanced and environmentally sustainable water treatment technology. By effectively degrading bisphenols and reducing the toxicity of their byproducts, CAP addresses key limitations of conventional treatment methods. The findings also emphasize the influence of environmental factors, such as radical scavengers, on degradation efficiency and transformation product formation. While the lower toxicity of TPs is promising, further research is needed to optimize CAP systems for large-scale applications and to investigate long-term environmental impacts. CAP represents a significant step forward in the development of innovative solutions for managing water pollution and safeguarding ecosystem health.

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