Enhanced Degradation of Perfluorooctanoic Acid (PFOA) Using Sequential Plasma and UV/H_2O_2 Processes

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Abstract: This study introduces a sequential plasma/UV-based approach for degrading perfluorooctanoic acid (PFOA). Plasma treatment achieved rapid degradation within the initial 30 minutes, while subsequent UV/H_2O_2 processing enhanced the breakdown of resistant compounds, achieving up to 80% defluorination.

1. Introduction

Poly- and perfluoroalkyl substances (PFAS) are synthetic chemicals widely used in industries and consumer products, causing groundwater contamination due to their persistence and toxicity. Advanced oxidation processes (AOP) based on ultraviolet (UV) light have shown potential for the removal of PFAS.[1] Similarly, low-temperature plasmas are highly effective at degrading organic pollutants due to their high production rates of reactive species and photons.[2] While standalone UV and plasma systems have demonstrated promise in degrading PFAS, they are unable to completely defluorinate the parent compound. Here, we combined the plasma with a UV-based system to treat perfluorooctanoic acid (PFOA). The key objective of this study is the complete or near-complete defluorination of the PFOA and its degradation intermediates which carry residual fluoride ions.

2. Methods

Plasma experiments were conducted using a gas-liquid discharge reactor with argon bubbling, operating at -30 kV and a discharge frequency of 60 Hz. A glass reactor equipped with a 400 W mercury UV lamp was used for the UV experiments. A 10 ppm PFOA solution was initially treated in a plasma reactor, then transferred into the UV/H_2O_2 reactor for further treatment, where 2.5 mM H_2O_2 was added every 15 minutes. Finally, the solution underwent a second plasma treatment, with the addition of a cationic surfactant (C12TAB) to enhance the transport of short-chain byproducts to the plasma-liquid interface.

3. Results and Discussion

As shown in Fig. 1, PFOA was rapidly degraded within the first 30 min of plasma treatment and the degradation was accompanied by the release of fluoride ions. In the UV/H_2O_2 reactor, the concentration of fluoride ions continued to increase, likely due to the oxidation of partially fluorinated PFOA decomposition byproducts by OH radicals generated through UV-induced H_2O_2 decomposition. The defluorination reached 76% following UV/H_2O_2 treatment. The final plasma treatment, which included the addition of C12TAB to target persistent short-chain PFAS intermediates, slightly increased the defluorination to 80%.

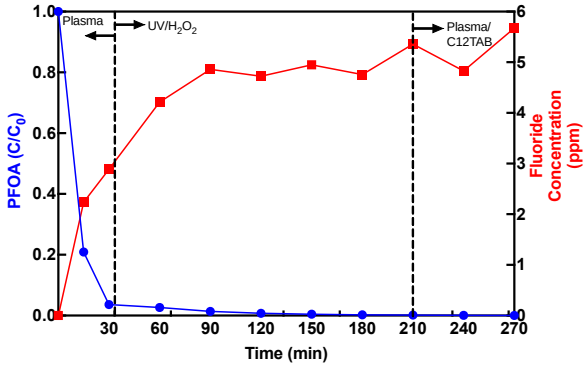

Fig. 1 – Time-dependent PFOA degradation and defluorination profile in sequential plasma and UV-H_2O_2 processes.

4. Conclusion

A sequence of advanced oxidation treatment methods has been used to defluorinate PFOA. Plasma alone was found to be effective at degrading PFOA, while OH generated from the UV/H_2O_2 system improved the defluorination of byproducts formed from PFOA degradation. The final plasma treatment with C12TAB resulted in an increase in overall defluorination efficiency to 80%. The lack of complete PFOA defluorination is most likely due to the fact that residual unoxidizable fluorinated compounds do not bind with C12TAB and thus remain undegraded in the bulk liquid.

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