

Degradation of perfluorooctanesulfonic acid (PFOS) through cold plasma-based wastewater treatment

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INTRODUCTION

Perfluorooctanesulfonic acid (PFOS) is chemically very stable due to strong covalent bonds of carbon and fluorine, and it also shows hydrophobicity and oleophobic properties. Therefore, it has been widely used in various chemical products such as surfactants, fire extinguishing agents, fiber coating agents, and lubricants. However, its persistence and stability are too strong to destroy thus the conventional treatment facilities have shown the limitations of their management. Accordingly, the effluent of the facilities contains a significant amount of PFOS and it is discharged into the receiving water. PFOS is very biologically resistant and does not biodegrade naturally. This may lead to bioaccumulation in organisms. Additionally, experimental studies have demonstrated the toxicity of PFOS through the impedance of cell-to-cell communication and peroxisome proliferation, which are both mechanisms for hepatocarcinogenesis (Haukas et al. 2007). Therefore, this study testes a cold plasma process, one of the advanced oxidation processes, to degrade PFOS in water. Using a batch experiment, a degradation kinetic study reveals how the operating condition of cold plasma is associated with the rate of PFOS decomposition.

MATERIALS AND METHODS

Experimental set-up of the CP

The reactor was filled with 3.0 L of 8.0 mg/L of PFOS solution. It was treated for the reaction time of 1, 3, 6 and 10 hr. The details of the operating conditions of the CP were shown in Table 1.

Table 1 Details of the operating conditions of the CP in this study

Experimental conditions	Unit	Value
Working volume	L	3
Total operating time	Hour	10
Air flow rate for CP	L/min	5
Electrical power for CP	kW	0.15

Acute toxicity test by *Daphnia magna*

Daphnia magna was used to test acute toxicity of the liquid samples according to OECD test guidelines as shown in Table 2.

Table 2. Details of the operating conditions of the CP in this study

Parameter	Unit	Properties
Dilution ratio of PFOS solution	%	Control (0), 6.25, 12.5, 25, 50, 100
Number of <i>Daphnia magna</i>	EA	20
Test repetition	times	4

RESULTS AND DISCUSSION

PFOS removal by CP and Evaluation of acute toxicity

Figure 1(a) shows the variation of PFOS over time by CP. The initial concentration of PFOS (8.0 mg/L) decreased to approximately 3.0 mg/L after 1 hr, comparable to other AOPs. The kinetic constant estimated by regression was 3.1 hr^{-1} . Interestingly, CP treatment present no further rapid degradation after 1 hr. PFOS concentration demonstrates very slow degradation throughout the experiment after 1 hr. Detected fluoride and sulfate concentration confirm the degradation of PFOS. Figure 1(b) shown that.

Figure 1(c) shows the variations in the acute toxicity of the PFOS over time. There was no change in acute toxicity within the first hour of CP exposure, but at around 3 hr the TU value had sharply increased to 3.0. After that, acute toxicity gradually decreased, until TU value reached 1.4. This result suggests that the intermediates of PFOS degradation may pose more significant toxicity than that of original PFOS though the toxicity gradually decreases with the continuous exposure to CP.

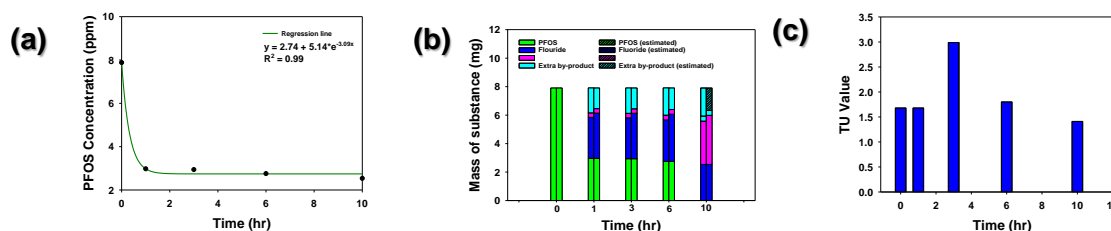


Figure 1. (a) PFOS concentration and regression line, (b) Mass balance of fluoride and sulfur according to reaction time, (c) Variations of PFOS's acute toxicity according to reaction time

CONCLUSION

This study demonstrates the aptness of CP in a PFOS degradation and verifies the rapid initial decomposition rate of PFOS. After 1 hr of exposure, PFOS's removal efficiency was as high as 62.5% though further degradation was very slow later. The regressed kinetic constant (3.1 hr^{-1}) further demonstrates CP's superiority than other AOPs. Although PFOS degradation was revealed by its building blocks, sulfate and fluoride, acute toxicity data further illustrates the significant toxicity potential in the remaining intermediates of PFOS. Finally, these results improve the understanding of the PFOS degradation in a plasma-based water treatment process.

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