7th Asia-Pacific Conference on Plasma Physics, 12-17 Nov, 2023 at Port Messe Nagoya

Removal Kinetics of PFAS utilizing Bubble Flotation and Non-Thermal Plasma Streamer Discharges in Argon

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The pollution of the environment and drinking water with trace quantities of per- and polyfluoroalkyl substances (PFAS) has increasingly come under scrutiny as these compounds are bioaccumulative and have links to adverse health effects in humans such as kidney and testicular cancer.[1] These pollutants have been dubbed "Forever Chemicals" due to their recalcitrance to degradation by biological processes and persistence in the environment.[2] A growing need therefore exists to develop low-cost and energy-efficient technologies capable of achieving a high level of destruction of this class of pollutants at concentrations in the µg/L (ppb) as detected in the environment.

A non-thermal plasma discharge generates a field of highly energy electrons and ionised species that when interfaced with a liquid surface, collide with water molecules and introduce a range of highly reactive species (e.g. ·OH, ·O, H, O_3, O_2^-).[3] These radicals and solvated electrons have been shown be effective at destroying any PFAS molecules adsorbed at the plasma-liquid interface.[4]

The efficacy of a synergistic treatment reactor utilizing non-thermal plasma streamer discharges in an argon atmosphere and bubbles to transport the PFAS molecules to the plasma-liquid interface was investigated to destroy a structurally diverse suite of PFAS shown in Figure 1. These compounds were plasma treated in individual solutions of 2 L at 10, 25 and 50 ppb and in contaminated groundwater for up to 120 min.

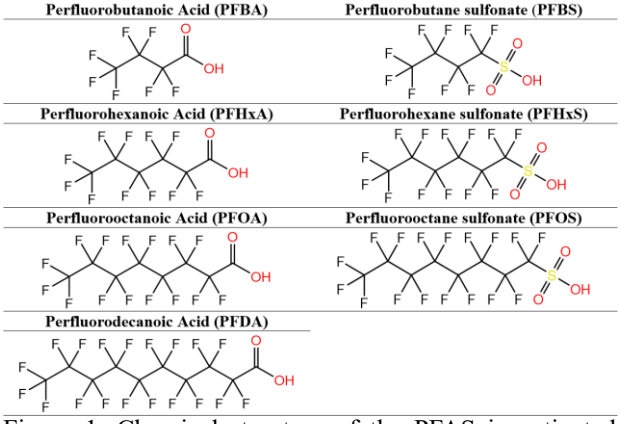

Figure 1. Chemical structure of the PFAS investigated using non-thermal plasma

The trends in removal kinetics showed the treatability of the PFAS investigated correlated with the length of the perfluorinated carbon chain, with high removal rates (>99%) achievable for longer chain PFAS species such as perfluorooctane sulfonate (PFOS) in contaminated groundwater after 120min of plasma treatment. Quantification of breakdown products detected inorganic fluoride ions (F^-) as the primary breakdown product accounting for up to 60% of the total fluorine initially in the reactor with shorter chain species accounting for <5% of the total fluorine. The conductivity and ion composition of the solutions influenced the degradation rate by influencing the transport of PFAS to the plasma-liquid interface and surface coverage of the argon plasma discharge.

The synergy between the highly active radicals produced by the non-thermal plasma and bubbles as a transport vector to the plasma-liquid interface was shown to be effective remediation strategy applicable for destroying a diverse range of PFAS pollutants present at low concentrations in water.

References

1. European Environment Agency. *Emerging chemical risks in Europe—"PFAS."* https://www.eea.europa.eu/themes/human/chemicals/emerging- chemical-risks-in-europe (2019) doi:10.18356/e2f0ac16-en.
2. Jansen, K. 'Forever chemicals' no more? *C&EN Glob. Enterp.* **97**, 28–32 (2019).
3. Locke, B. R., Sato, M., Sunka, P., Hoffmann, M. R. & Chang, J. S. Electrohydraulic discharge and nonthermal plasma for water treatment. *Ind. Eng. Chem. Res.* **45**, 882–905 (2006).
4. Takeuchi, N. *et al.* Plasma-liquid interfacial reaction in decomposition of perfluoro surfactants. *J. Phys. D. Appl. Phys.* **47**, (2014).