# State of Knowledge on Cold Plasma Technology for PFAS Degradation

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**Abstract:** In this contribution, we summarized the state of knowledge of PFAs degradation by cold plasma, including the past efforts by the community, current status, and research gaps to fill in.

## 1. Introduction

Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals used in various industrial and consumer products due to their water and grease resistance. These compounds, characterized by their strong carbon-fluorine bonds, are highly persistent in the environment and accumulate in living organisms. According to the U.S. Geological Survey at least 45% of tap water in the U.S contains one or more PFAS types. In April 2024, the EPA designated PFOA and PFOS—two widely used PFAS—as hazardous substances under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This moves highlights concerns about their environmental persistence, bioaccumulation, and potential risks to human health and ecosystems.

Non-thermal plasma (cold plasma) is an assemblage of electrically stimulated atoms, molecules, electrons, photons, and ionic species in a high-energy state. This technology benefits from tuned plasma chemistry and the simultaneous action of oxidative and reductive species, space charge and UV radiation to degrade PFAS. During plasma, numerous highly energetic processes trigger the generation of highly reactive oxygen and nitrogen species (RONS) capable of directly activating the degradation process [1] (Fig. 1). Depending on the cold plasma's operational parameters, such as gas composition, power input, pulsed-plasma waveform, reactor design, and water matrix, each species contributes differently, making it vital to optimize plasma conditions for targeted PFAS degradation. While several reaction pathways and mechanisms have been proposed, the field lacks a comprehensive summary of the current state of knowledge and the key research gaps that need to be addressed.

## 2. Challenges in PFAS degradation by cold plasma

Plasma was developed in 1760s in France, not a new technique. But its application in water treatment was not explored until the 1970s [2]. It has been studied with increasing interest in the last decade, and results obtained in terms of both degradation efficiency, mechanisms, and versatility of treatment. Several types of discharge and electrodes configurations have been developed for PFAS degradation with the aim of increasing specific reactive species flux and PFAS-plasma interaction [3-6]. The literature data shows that plasma-liquid interface dynamics are influenced by interdependent factors, including gas-liquid interfacial area, reactive species

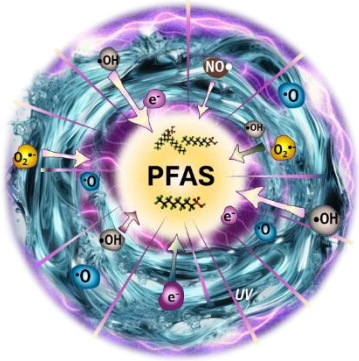


**Fig. 1.** Schematic representation of plasma-generated RONS's interaction with PFAS

flux, solution pH, electrical conductivity of liquid, and fluid renewal rates. Physical phenomena such as electrical double-layer formation and plasma sheath effects further contribute to the complexity, influencing the generation and transport of reactive species and subsequent degradation pathways. Additionally, standardized methods for calculating electrical energy per order (EEO) across diverse plasma systems are required to compare and enhance system performance meaningfully. Another significant gap is the need for improved PFAS mineralization to increase degradation efficiency and minimize the formation of persistent intermediates. Non-target analysis of degradation byproducts is essential to achieve a complete fluorine mass balance, ensuring effective mineralization and addressing concerns about residual toxicity.

Through this presentation, we will focus on the current research flow and main challenges and research gaps. The impact of such a synthesis would be substantial, providing clarity on existing challenges and guiding future research efforts to advance plasma-based PFAS remediation technologies.

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