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POTENTIAL PFAS DESTRUCTION TECHNOLOGY: SUPERCRITICAL WATER OXIDATION

In Spring 2020, the EPA established the PFAS Innovative Treatment Team (PITT). The PITT was a multi-disciplinary research team that worked full-time for 6-months on applying their scientific efforts and expertise to a single problem: disposal and/or destruction of PFAS-contaminated media and waste. While the PITT formally concluded in Fall 2020, the research efforts initiated under the PITT continue.

As part of the PITT's efforts, EPA researchers considered whether existing destruction technologies could be applied to PFAS-contaminated media and waste. This series of Research Briefs provides an overview of four technologies that were identified by the PITT as promising technologies for destroying PFAS and the research underway by the EPA's Office of Research and Development to further explore these technologies. Because research is still needed to evaluate these technologies for PFAS destruction, this Research Brief should not be considered an endorsement or recommendation to use this technology to destroy PFAS.

Background

Various industries have produced and used per- and polyfluoroalkyl substances (PFAS) since the mid-20th century. PFAS are found in consumer and industrial products, including non-stick coatings, waterproofing materials, and manufacturing additives. PFAS are stable and resistant to natural destruction in the environment, leading to their pervasive presence in groundwater, surface waters, drinking water, and other environmental media (e.g., soil) in some localities. Certain PFAS are also bioaccumulative, and the blood of most US citizens contains detectable levels of several PFAS (CDC, 2009). The toxicity of PFAS is a subject of current study and enough is known to motivate efforts to limit environmental release and human exposure (EPA, 2020).

To protect human health and the environment, EPA researchers are identifying technologies that can destroy PFAS in liquid and solid waste streams, including concentrated and spent (used) fire-fighting foam, biosolids, soils, and landfill leachate. These technologies should be readily available, cost effective, and produce little to no hazardous residuals or byproducts. The capability to decompose an array of complex molecular structures simultaneously makes supercritical water oxidation (SCWO) a promising technology for PFAS destruction that warrants further investigation.

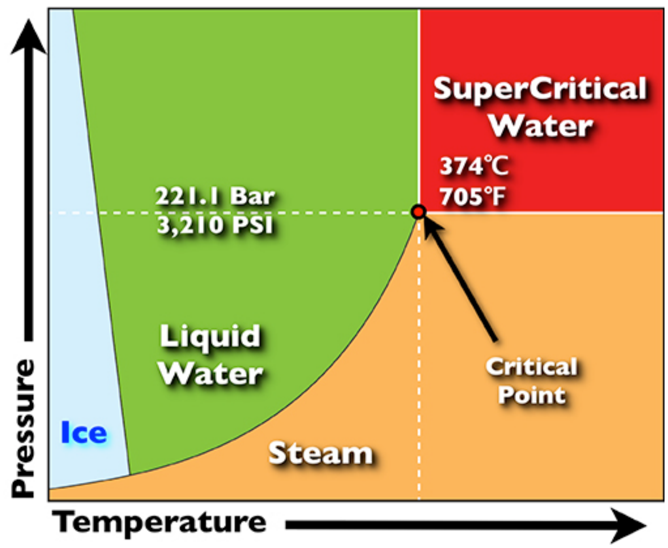

Figure 1. *SCWO reactions occur above the critical point of water. Image credit: Jonathan Kamler.*

Supercritical Water Oxidation: Technology Overview

SCWO is a process that can be utilized to destroy hazardous waste compounds. Water above a temperature of 705 °F and pressure of 221.1 bar is considered "supercritical" (Figure 1), a special state of water where certain chemical oxidation processes are accelerated. Since the 1980s, SCWO has been used successfully to treat halogenated waste materials (containing fluorine, chlorine, bromine, or iodine), including polychlorinated biphenyls (PCBs) (Abeln et al., 2001; Kim et al., 2010). Organic compounds, usually insoluble in liquid water, are highly soluble in supercritical water. In the presence of an oxidizing agent (such as oxygen), supercritical water dissolves and oxidizes various hazardous organic pollutants. Implementation of SCWO at scale has been limited by several technical challenges, including the buildup of corrosive gases during the oxidation reaction, the precipitation of salts, and the high energy requirements.

Potential for PFAS Destruction

As an alternative to disposal of PFAS-laden material in a landfill or combustion in an incinerator, SCWO purports to destroy PFAS by breaking the strong carbon-fluorine bonds and decomposing the material into a non-toxic waste stream. SCWO's previous applications to destroy chemical warfare agents, PCBs, and halogenated compounds makes it a potential, but currently unproven, alternative for PFAS destruction (Marrone et al., 2004; Mitton et al., 2001). Jama et al., (2020) reported greater than 99% destruction of 12 PFAS, from 3.6 µg/L to <0.036 µg/L, from a landfill leachate. These data are preliminary, and future experiments analyzing for more PFAS will help to understand if high destruction efficiencies can be expected for complex liquid wastes.

Research Gaps

Technical challenges to implementation of SCWO are presented by the high pressures and temperatures, causing potential system degradation and maintenance issues (Vadillo et al., 2013). In addition, the requirement for elevated and stable temperatures demand a large and expensive energy input. The breakdown of PFAS in aqueous film-forming foams and other wastes produces fluoride salts. Although fluoride salts are not toxic, they create reactor plugging issues and reduce system performance, requiring careful attention to system maintenance (Voisin et al., 2017). Additionally, the transformation of fluorine to corrosive hydrofluoric acid (HF) may require protections for worker health, emission controls, and reactor care. The use of chemical additives, such as alkaline substances, to neutralize an acidic environment could significantly mitigate these issues.

Next Steps

SCWO is one of the technologies being evaluated by EPA researchers for treatment of PFAS-containing wastes. EPA researchers are partnering with commercial entities to conduct pilot-scale SCWO studies. EPA expects to publish the results of this work in 2021.

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Note: This research brief is a summary of research conducted by EPA's Office of Research and Development and does not necessarily reflect EPA policy.