POTENTIAL PFAS DESTRUCTION TECHNOLOGY: MECHANOCHEMICAL DEGRADATION

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 U.S. 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. Mechanochemical degradation (MCD) has been identified as a promising technology that may be able to remediate PFAS-contaminated solid or semi-solid matrices.

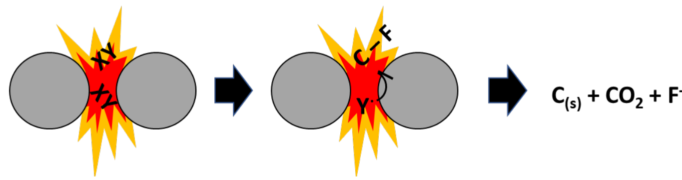

Figure 1. *Ball impacts create radicals from co-milling materials and localized high temperatures that mineralize PFAS.*

Mechanochemical Degradation: Technology Overview

MCD describes the mechanism of destruction that persistent organic pollutants undertake in a high-energy ball-milling device (Cagnetta et al., 2016). MCD does not require solvents or high temperatures to remediate solids and can be considered a "greener" method compared to alternatives (Bolan et al., 2020). Co-milling reagents like silica, potassium hydroxide, or calcium oxide are added to help react with fluorine and to produce highly reactive conditions. The crystalline structures of the co-milling reagents are crushed and sheared by high energy impacts from stainless-steel milling balls in the rotating vessel (Figure 1). Research has found that these collisions produce radicals, electrons, heat, and even plasma (Nakayama, 2010) that react with PFAS to produce inorganic fluoride compounds and graphite (Wang et al., 2019).

Potential for PFAS Destruction

MCD has shown promise at the benchtop and pilot scale and has the potential to be an alternative to incinerating solids containing persistent organic pollutants. A recent study by one commercial company showed destruction of greater than 99 percent of persistent organic pollutants in about six tons of soil in an hour with a transportable MCD setup (Bolan et al., 2020), but their work with PFAS is still in its preliminary stages. MCD also has the potential to produced gaseous PFAS emissions but these products of incomplete destruction have not yet been assessed. MCD could also be a unit operation in series with other treatment technologies, processing ash from an incineration unit or treated biosolids from a pyrolysis/gasification unit.

Research Gaps

Further research into the destruction of PFAS with MCD is needed to understand the effects of various matrices, the function of different co-milling reagents, the potential for loss of volatile PFAS, and performance at field application scales. MCD methods for destruction of persistent organic pollutants perform best with dry, sandy soil and the efficiency decreases as the soil becomes more clay-like. Co-milling reagents and other conditions can be modified to provide high efficiencies, but the destruction of PFAS in a variety of soils has not been fully studied yet. A large scale PFAS remediation project has not yet been undertaken, so design projections from laboratory- and pilot-scale testing have not been verified.

Next Steps

MCD is one of the technologies being evaluated by EPA researchers for PFAS destruction. EPA researchers are conducting laboratory- and pilot-scale testing to evaluate PFAS destruction under a variety of conditions. EPA expects to publish the results of this work in 2021.

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Contacts

- Erin Shields, PhD - shields.erin@epa.gov
- Andrew Whitehill, PhD - whitehill.andrew@epa.gov

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