POTENTIAL PFAS DESTRUCTION TECHNOLOGY: PYROLYSIS AND GASIFICATION

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. Pyrolysis and gasification have been identified as promising technologies that may be able to meet these requirements with further development, testing, and demonstrations.

Figure 1. *Biosolids beneficial use.*

Pyrolysis/Gasification: Technology Overview

Pyrolysis is a process that decomposes materials at moderately elevated temperatures in an oxygen-free environment. Gasification is similar to pyrolysis but uses small quantities of oxygen, taking advantage of the partial combustion process to provide the heat to operate the process. The oxygen-free environment in pyrolysis and the low oxygen environment of gasification distinguish these techniques from incineration. Pyrolysis, and certain forms of gasification, can transform input materials, like biosolids, into a biochar while generating a hydrogen-rich synthetic gas (syngas).

Both biochar and syngas can be valuable products. Biochar has many potential applications and is currently used as a soil amendment that increases the soil's capacity to hold water and nutrients, requiring less irrigation and fertilizer on crops. Syngas can be used on-site as a supplemental fuel for biosolids drying operations, significantly lowering energy needs. As an additional advantage, pyrolysis and gasification require much lower air flows than incineration, which reduces the size and capital expense of air pollution control equipment.

Potential for PFAS Destruction

PFAS have been found in effluent and solid residual (sewage sludge) streams in wastewater treatment plants (WWTPs) (Sinclair and Kannan, 2006; Schultz et al., 2006; Yu et al., 2009; EGLE, 2020; Maine PFAS Task Force, 2020), prompting increasing concern over managment of these materials. In the United States, WWTP solids have typically been managed in one of three ways: (1) treatment to biosolids followed by land-application; (2) disposal at a lined landfill; or (3) destruction (burning) in a sewage sludge incinerator. WWTP solids are rich in nutrients and the most common U.S. practice is to aerobically or anaerobically digest it to produce a stabilized biosolid product that can be land-applied as fertilizer (EPA, 1994; EPA, 2019). This is done because the nutrients in biosolids deliver nitrogen, phosphorous, and other trace metals that are beneficial for crops and soil (Figure 1).

Some states are beginning to test biosolids for PFAS contamination and to prevent land application if concentrations exceed state-specific screening levels. An increase in rejected biosolids may lead to an increased use of incineration or landfilling of wastewater solid residuals, with increased cost burdens to communities. Currently, approximately 16% of wastewater solids are incinerated (EPA, 2019). This increased amount of incineration could introduce additional costs and other environmental considerations.

New options for the treatment of PFAS-impacted WWTP solids may be found in non-incineration thermal processes, such as pyrolysis and gasification. These approaches may show promise to reduce PFAS loadings from biosolids, in some cases without destroying the beneficial use potential of the material. Gasification may also become an attractive alternative to sewage sludge incineration for reduction of WWTP solids to inert ash, with potential uses as input material in cement production and fine aggregate applications (Lynn et al., 2015).

The high temperatures and residence times achieved by pyrolysis or gasification followed directly by combustion of the hydrogen-rich syngas stream in a thermal oxidizer (or afterburner) could potentially destroy PFAS by breaking apart the chemicals into inert or less recalcitrant constituents. However, this mechanism, as well as evaluation of potential products of incomplete destruction, remain a subject for further investigation and research. It is possible that this combination of processes may be more effective at PFAS destruction than some lower temperature sewage sludge incineration processes.

The end products of both gasification and pyrolysis result in material volume reductions of over 90% compared to the input solids, making transport and use or disposal more energy efficient and lessening the environmental impacts (e.g., lower landfill leachate PFAS loadings compared to biosolids disposal).

Limitations and Research Gaps

Pyrolysis and gasification of biosolids are emerging treatment technologies. In the United States, one biosolids pyrolysis company is permitted for operation with three similar biosolids systems units operating in Europe (PYREG, 2019). Several biosolid gasification projects are in development in the United States, but long-term operation on this feedstock has yet to be commercially demonstrated.

Pyrolysis and gasification represent a significant financial investment compared with direct biosolid land application alternatives, and there are a number of challenges and data gaps with these technologies. However, if these issues can be overcome, these systems could provide effective means of treating PFAS in WWTP solid residuals and PFAS-impacted biosolids.

Next Steps

The pervasiveness and resistance to degradation of PFAS have become a motivating factor to identify methods to safely manage these substances to prevent bioaccumulation within humans or the environment. Identification and validation of safe and effective approaches to reduce PFAS levels in biosolids is an important research area for EPA.

In August 2020, EPA researchers conducted a field test at a WWTP employing pyrolysis. The purpose of this limited-scope field test was to improve understanding of target PFAS levels in the pyrolysis-produced biochar compared to the input material. EPA researchers are currently analyzing samples collected during the field test and expect to publish the results in a peer-reviewed scientific journal in 2021.

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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.