

PFAS Innovative Treatment Team (PITT)

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US EPA Office of Research and Development, Center for Environmental Measurement and Modeling

National Association of Clean Air Agencies
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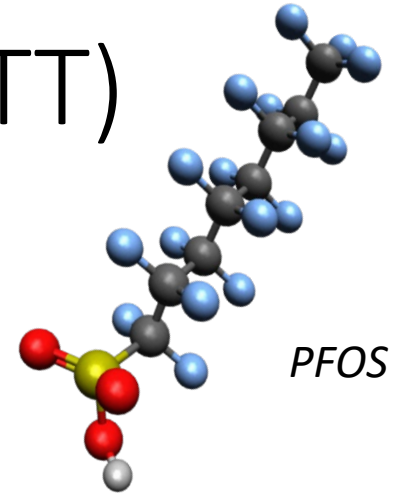
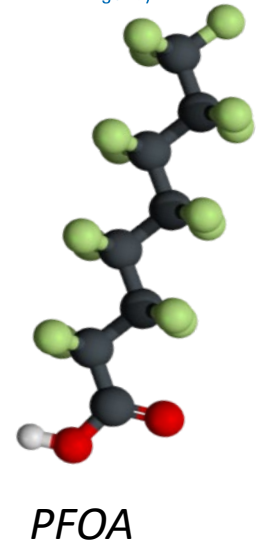
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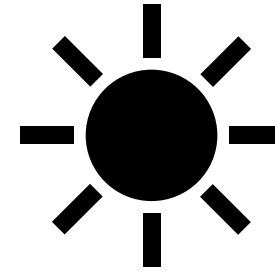
- Full-time, multi-disciplined research staff
 - 6-month timeline

- Single Focus:

How to Destroy PFAS-Contaminated Media and Waste

- Assess current and emerging destruction methods
- Explore the efficacy of methods
 - Including potentially hazardous by-products
- Evaluate feasibility, performance and costs



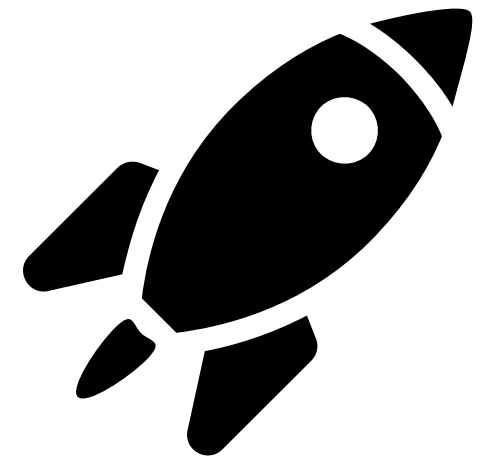


“Skunk Works”

"**skunk works**" or "**skunkworks**" describes a group within an organization given a *high degree of autonomy* and unhampered by bureaucracy, with the task of working on advanced or secret projects

PITT was provided:

- Priority access within ORD
- Direct access to ORD management
- Resources needed to perform the work



PITT Charge from ORD



- “Toolbox” of solution(s) for the destruction of PFAS in contaminated waste to meet the needs of EPA programs and regions, states and tribes, federal agencies, and industry
 - traditional destruction methods (e.g., incineration)
 - novel (high-risk) approaches
- residuals of incomplete destruction that may be released to the air, water and land
 - methods to measure these residuals

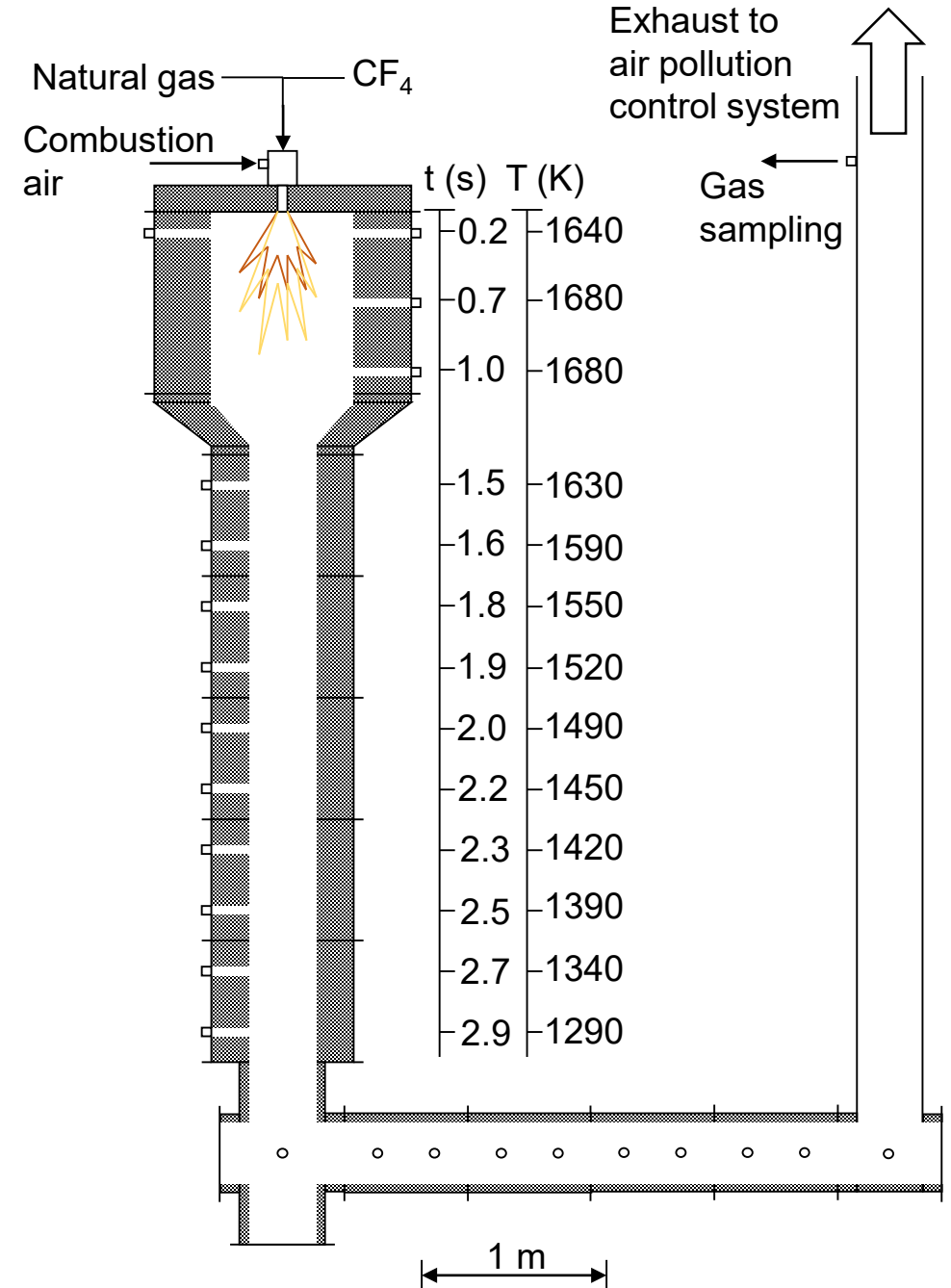
PFAS-Containing Wastes

- Aqueous film forming foam (AFFF)
 - Concentrated
 - Contaminated Soils
- Landfill Leachate, Municipal Waste Combustors (MWCs), Landfills
- Sludge and Biosolids
- Granular activated carbon (GAC) and Ion Exchange Resins



Incineration Technologies

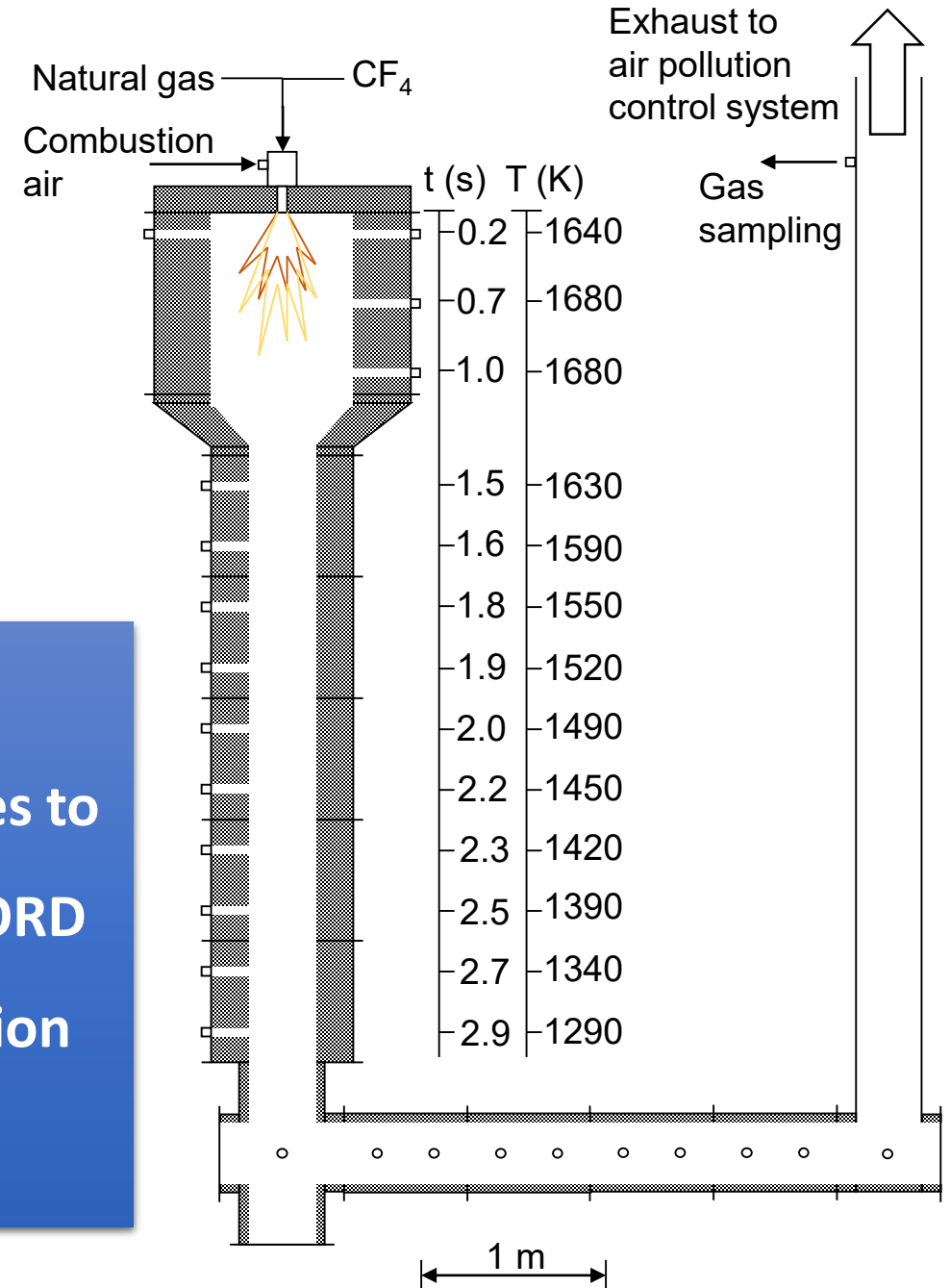
- Collaborative projects with
 - DOD
 - Universities
 - Industry Partners
- Modeling
 - Products of Incomplete Combustion (PICs)
 - Temperature/Time
 - Fuel



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**PITT provided
additional resources to
advance ongoing ORD
work on incineration
technologies**



Non-Incineration Technologies Reviewed

- Chemical
- Biological
- Plasma
- Mechanochemical
- Sonolysis
- Ebeam
- UV
- Supercritical water oxidation
- Deep well injection
- Sorption/stabilization
- Electrochemical
- Landfill
- Land application
- Pyrolysis

Assessment Factors:

- Technology readiness
- Applicability
- Cost
- Required development remaining
- Risk/reward of technology adoption

Non-Incineration Technologies Reviewed

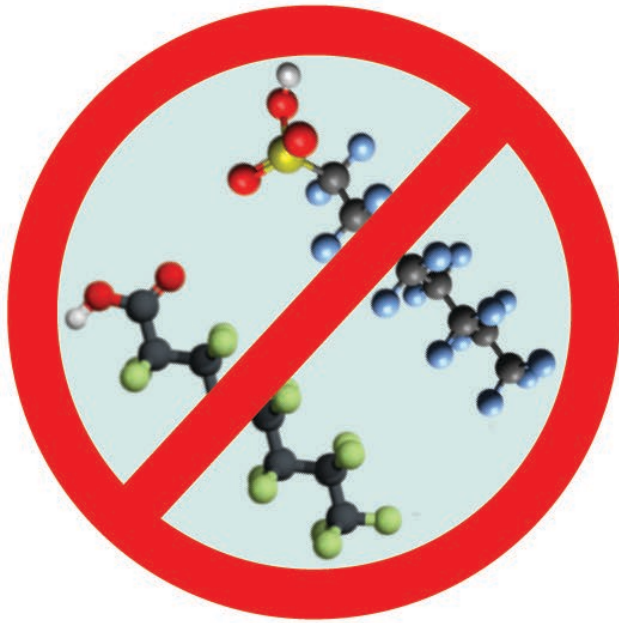
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4 technologies selected for further investigation

- What waste streams can they be used on?
- How effective are they at destroying PFAS?
- What residual PFAS molecules remain
 - Are any gaseous / volatile PFAS released?
- Can we advance these technologies?



Innovative Ways to Destroy **PFAS**

PER- AND POLYFLUOROALKYL SUBSTANCES



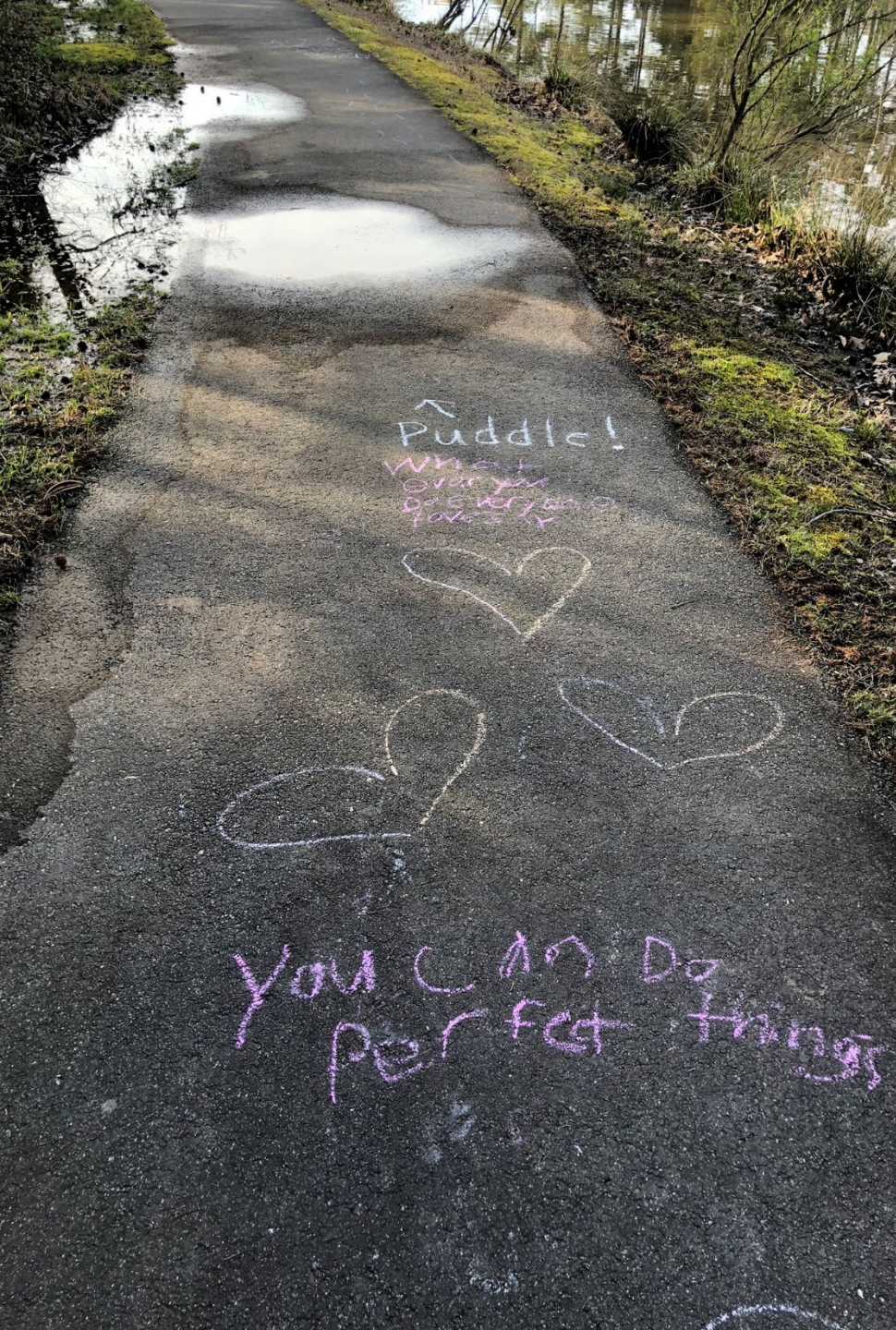
- Challenge launched by EPA Administrator Andrew Wheeler on August 25, 2020

<https://www.epa.gov/innovation/innovative-ways-destroy-pfas-challenge>

- Partnership with DOD (SERDP/ESTCP), states
- Concentrated AFFF focus
- Up to \$50K for the best design concept for non-thermal technologies
- 99% destruction

Challenge Timeline

Date	Action
August 25, 2020	Challenge Launch
November 23, 2020	Challenge Closes
Early 2021	Challenge Phase 1 Awarded



Obstacles

- COVID-19
 - Building closures
 - Lab closures
 - Restricted partner access to labs
 - Closure of suppliers
 - Unavailable instrument repairs
- Thermal Treatment Testing Options
- Concurrent field sampling and sampling methodology development

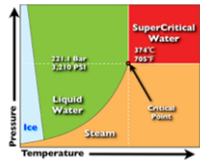
Products and Outcomes of PITT

- **Methods Development**
 - Gasification/Pyrolysis (FTIR)
 - Electrochemical
 - Supercritical water oxidation
 - Mechanochemical
- **Co-Sponsored Methods work**
 - REI Model
 - Tube Furnaces with Partners
 - EPA Incineration- Rainbow Furnace
- **Multiple Journal Articles in the works**
- **TBD Ideas from PFAS Destruction Challenge**

Technical Briefs and Fact Sheets

SUPERCRITICAL WATER OXIDATION (SCWO): POTENTIAL FOR INNOVATIVE PFAS DESTRUCTION TECHNOLOGY

Background
Supercritical water oxidation (SCWO) is a unique process to destroy hazardous waste compounds. Water above a certain temperature (375 °F) and pressure (221.1 bar) is considered supercritical, a special state of water that accelerates certain chemical oxidation processes. Since the 1980's, SCWO has been successfully used to treat halogenated waste materials (containing fluorine, chlorine, bromine, or iodine) including polychlorinated biphenyls (PCBs) (Abela et al., 2001; Kim et al., 2010). Organic compounds, especially insoluble in water, are highly soluble in supercritical water in the presence of an oxidizing agent (such as O₂ gas), supercritical water dissolves and oxidizes various hazardous organic pollutants. Implementation of SCWO 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. This document reviews SCWO as a potential method to destroy per- and polyfluoroalkyl substances (PFAS).



Potential Application to PFAS-laden Waste
Various industries have produced and used 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, and even drinking water in some locations. Certain PFAS are also bioaccumulative. The blood of most Americans contains detectable levels of several PFAS. The toxicity of PFAS is a subject of current study but enough is known to motivate efforts to limit environmental release and human exposure (EPA, 2020).

PFAS-containing material such as aqueous film-forming foam (AFFF) have been used by nearly every fire-fighting department for the previous 50 years. Inventory estimates that there are millions of gallons of material in private, public, and military custody. Other waste streams that contain PFAS, such as municipal sewage, landfill leachate, or industrial process waters, also have other co-contaminants that make targeting treatment of PFAS very difficult. The capability to decompose

Per- and Polyfluoroalkyl Substances (PFAS): Mechanochemical Destruction to Manage Waste Streams

Background
Fluorinated organic compounds and fluoropolymers have undergone extensive use in a wide variety of consumer products and industrial processes due to their chemical stability and function as oil and water repellants. Per- and polyfluoroalkyl substances (PFAS), of which there are thousands of chemical derivatives, are found in non-stick coatings, waterproofing and stain-resistance agents, fire suppression systems, lubricants, artificial blood, insulating fluids, and many other products. The same properties that make PFAS useful in many products and applications also cause PFAS to persist in the environment and bioaccumulate in living species. The sources of human exposure to PFAS are believed to be industrial emissions, wastewater, and drinking water. Several PFAS compounds have been found to have negative health effects and more research is underway (Lewis, KC et al. 2015; Sunderland, EM et al. 2019). Limiting human and environmental exposure to PFAS compounds requires adequate means of disposal and treatment.

MC degradation has shown promise at the benchtop and pilot scale and has the potential to be an alternative to incinerating solids. One commercial company can typically destroy ~99% POP in about six tons of soil an hour with a transportable MC destruction setup (Bolun et al., 2020).

Research Gaps
Further research into the destruction of PFAS by mechanochemical means is needed to understand the effects of various matrices, the function of different co-milling agents, the potential for loss of volatile PFAS, and performance at field application scales. MC methods for POP destruction perform best with sandy soil and the efficiency decreases as the soil becomes more claylike. Co-milling reagents and conditions can be modified to provide high efficiency but the destruction of PFAS in variety of soils has not been fully studied yet. A large scale PFAS remediation project has not yet undertaken, so design projections from laboratory pilot-scale testing have not been verified. The emissions from large-scale milling devices have not been studied. Preliminary benchtop studies show promising results, but a large-scale test is needed to ensure are not emitted in the gas stream from the system.

Mechanochemical Destruction of PFAS
One potential method to remediate PFAS-contaminated solid or semi-solid matrices is mechanochemical (MC) degradation. MC describes the mechanism of destruction that persistent organic pollutants (POPs) undertake in a high energy ball-milling device (Caporaso, Huang et al., 2016). Co-milling reagents like silica, potassium fluoride, or calcium oxide, are added to help react with the PFAS and to produce highly reactive conditions. The crystalline structures of the co-milling reagents are crushed and sheared by the high energy impacts from the stainless steel milling balls in the rotating vessel (Figure 1). These collisions produce radicals, electrons, heat, and even plasma in localized areas (Nakayama 2010) that react with PFAS producing mainly inorganic fluoride compounds and graphite (Wang et al., 2019).

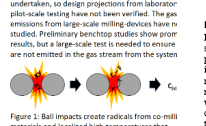


Figure 1. Mechanism of mechanochemical destruction of PFAS. A ball mill impacts create radicals from co-milled materials and localized high temperatures that mineralize PFAS.

Destruction Efficiency
The proposed mechanism of perfluoroalkyl acid destruction by EC begins with the rate limiting step of direct electron transfer from PFAS compound to the anode. This is followed by

References
Bolun, N., Sarkar, B., et al. (2020) Remediation of and perfluoroalkyl substances (PFAS) contamination – to mobilize or to immobilize or to destroy? *J. Hazard Mater.* in print.

To protect human health and the environment, research is being conducted to identify technologies that destroy PFAS in concentrated and spent (used) AFFF, landfill leachate, and other PFAS-containing liquid streams. These technologies must be readily available, cost effective, and produce little to no residuals or byproducts. EC has been identified as a promising technology that may be able to meet these requirements with further testing, development, and demonstrations.

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Configured Fireside Simulator (CFS)

Background
Thermal incineration in high temperature combustors is one approach that has been used for managing toxic organo-chlorides in various waste streams. However, it is very expensive and logistically difficult to scale from full-scale treatment of streams, and it may require large quantities of toxic compounds to understand the conditions to achieve optimal CFS and Reactor.

Combustor Design Variants Contained in CFS
CFS includes models for five different combustor design variants, based on real-world facilities and EPA laboratory combustors. These are:

- EPA Laboratory pilot-scale rotary kiln located in Research Triangle Park, NC
- EPA "Rainbow" rotary barrel combustor located in Research Triangle Park, NC
- a commercial medical/geriatric "baked air" incinerator
- a commercial-scale bio-refuse waste rotary kiln incinerator
- a waste-to-energy "boiler" incinerator

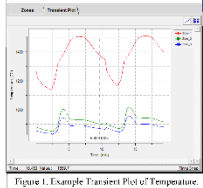


Figure 1. Example Transient Plot of Temperature.

PFAS IN WASTEWATER SOLIDS – THE POTENTIAL FOR TREATMENT BY PYROLYSIS AND GASIFICATION

Background
Per- and poly-fluoroalkyl substances (PFAS) are synthetic fluorinated compounds that have been produced for decades for a range of purposes including non-stick coatings, waterproofing, and manufacturing additives. The use of PFAS in numerous products and industrial processes, coupled with their chemical persistence, has led to their discovery within environmental systems. The toxicity of PFAS is a subject of current study, but enough is known to motivate efforts to limit environmental release and human exposure.



Figure 1. Biosolid, from wastewater, is beneficial use.

New options for the treatment of PFAS-impacted WWTW solids may be found in a range of 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 SSI for reduction of WWTW solids to inert ash, with potential uses as input material in Portland cement production and fine aggregate applications.

What is Pyrolysis and Gasification?
Pyrolysis is a process that decomposes materials at moderately elevated temperatures in an oxygen-free environment. Gasification is similar to pyrolysis but uses stoichiometric quantities of oxygen, taking advantage of the partial combustion process to provide the heat to operate the process. Pyrolysis, and certain forms of

some US sites are beginning to test biosolids for PFAS contamination and prevent land application if concentrations exceed state-specific screening levels. An increase in rejected biosolids may lead to an increased use of incineration of wastewater solid residuals. Currently, approximately 16% of wastewater solids are incinerated. This increased amount of incineration could introduce additional costs and other environmental considerations.

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Find more information on EPA PFAS Data and Tools

EPA PFAS Research

<https://www.epa.gov/chemical-research/research-and-polyfluoroalkyl-substances-pfas>

EPA PFAS Action Plan:

<https://www.epa.gov/pfas/pfas-action-plan-program-update-february-2020>

Research on Per- and Polyfluoroalkyl Substances (PFAS)



to PFAS. There is evidence that continued exposure above specific levels to certain PFAS may lead to adverse health effects.

Per- and polyfluoroalkyl substances (PFAS) are a group of synthetic chemicals that have been in use since the 1940s. PFAS are found in a wide array of consumer and industrial products. PFAS manufacturing and processing facilities, facilities using PFAS in production of other products, airports, and military installations are some of the potential contributors of PFAS releases into the air, soil, and water. Due to their widespread use and persistence in the environment, most people in the United States have been exposed

Related Topics

- [Learn more about Per- and polyfluoroalkyl substances \(PFAS\)](#)
- [List of PFAS EPA is currently researching](#)
- [Reducing PFAS in Drinking Water with Treatment Technologies Science Matters Article](#)
- [EPA Toxicologists Focus Innovative Research on PFAS Compounds Science](#)

<https://www.epa.gov/pfas>



Questions?

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