

# Mechanochemical Destruction as a Scalable Treatment Technology for PFAS

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# Outline

- i. Technology Overview
- ii. Underlying Science
- iii. PFAS Destruction Trials
  - *Ideal Matrices*
  - *AFFF Concentrate*
  - *Impacted Soil*
- v. Scale-Up Potential
- vi. Next Steps

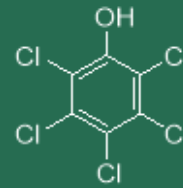


# Technology Capabilities

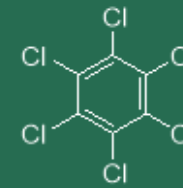
## Mechanochemical Destruction (MCD)

### Hazardous Waste Treatment

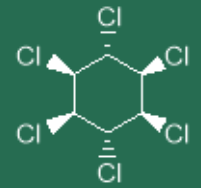
- Mechanochemistry based solution for the treatment of various toxic waste streams.
- Green approach to contaminated land and chemical stockpiles.
- Demonstrated at various scales. Scale-up required for PFAS issues.
- POPs, PFAS, PAHs, asbestos.



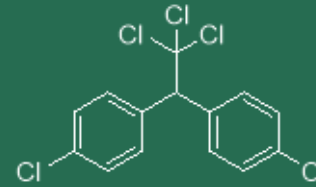
*PCP*



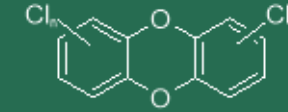
*HCB*



*Lindane*



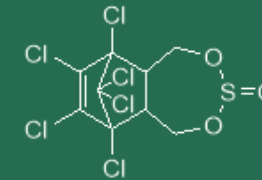
*DDT*



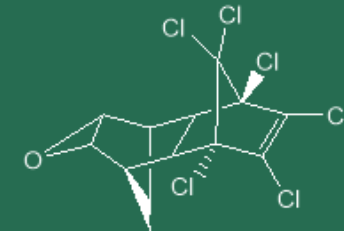
*PCDDs*



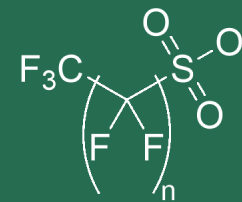
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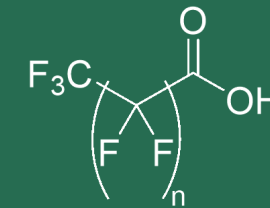
*Endosulfan*



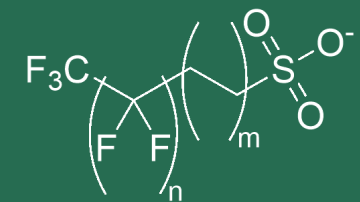
*Dieldrin*



*PFSA*s

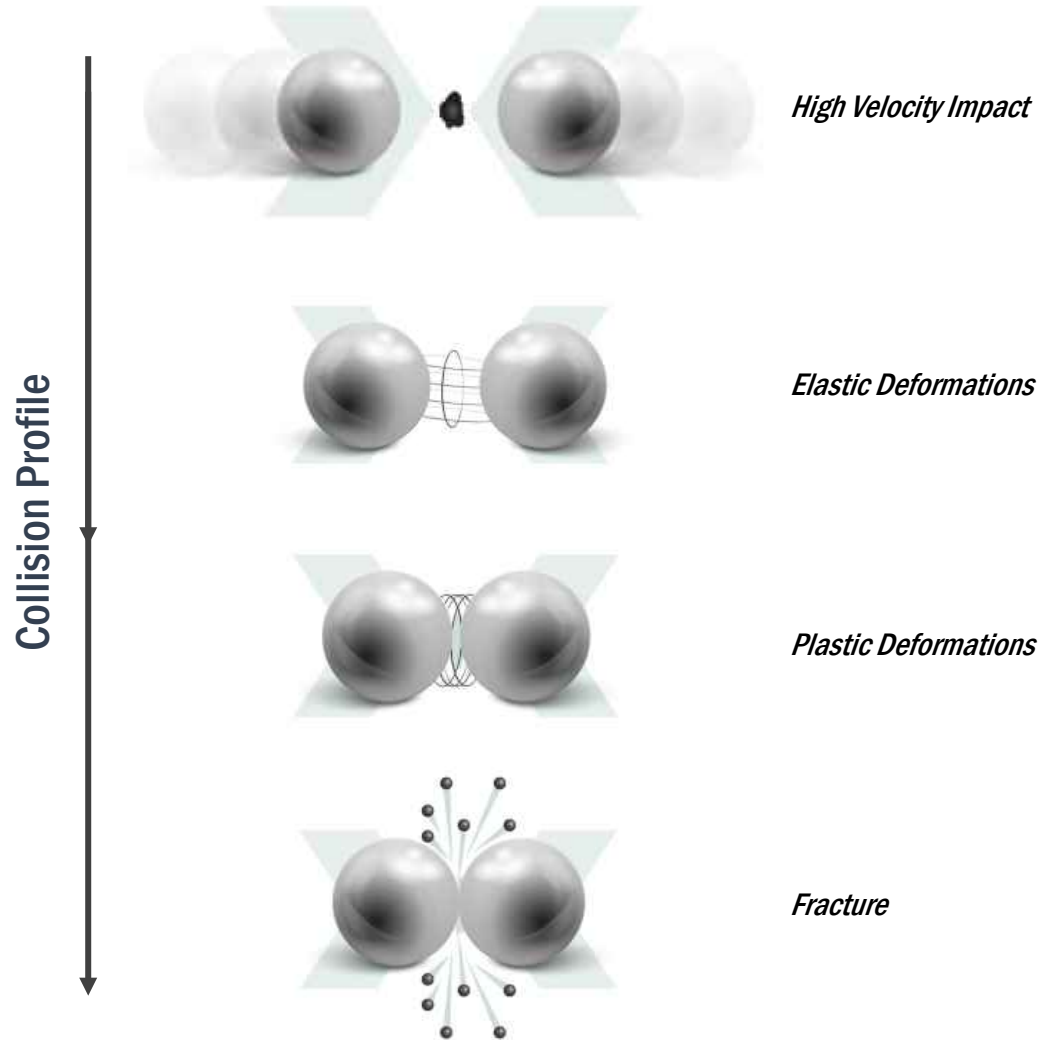


*PFCAs*



*FTSA*s

# The Science



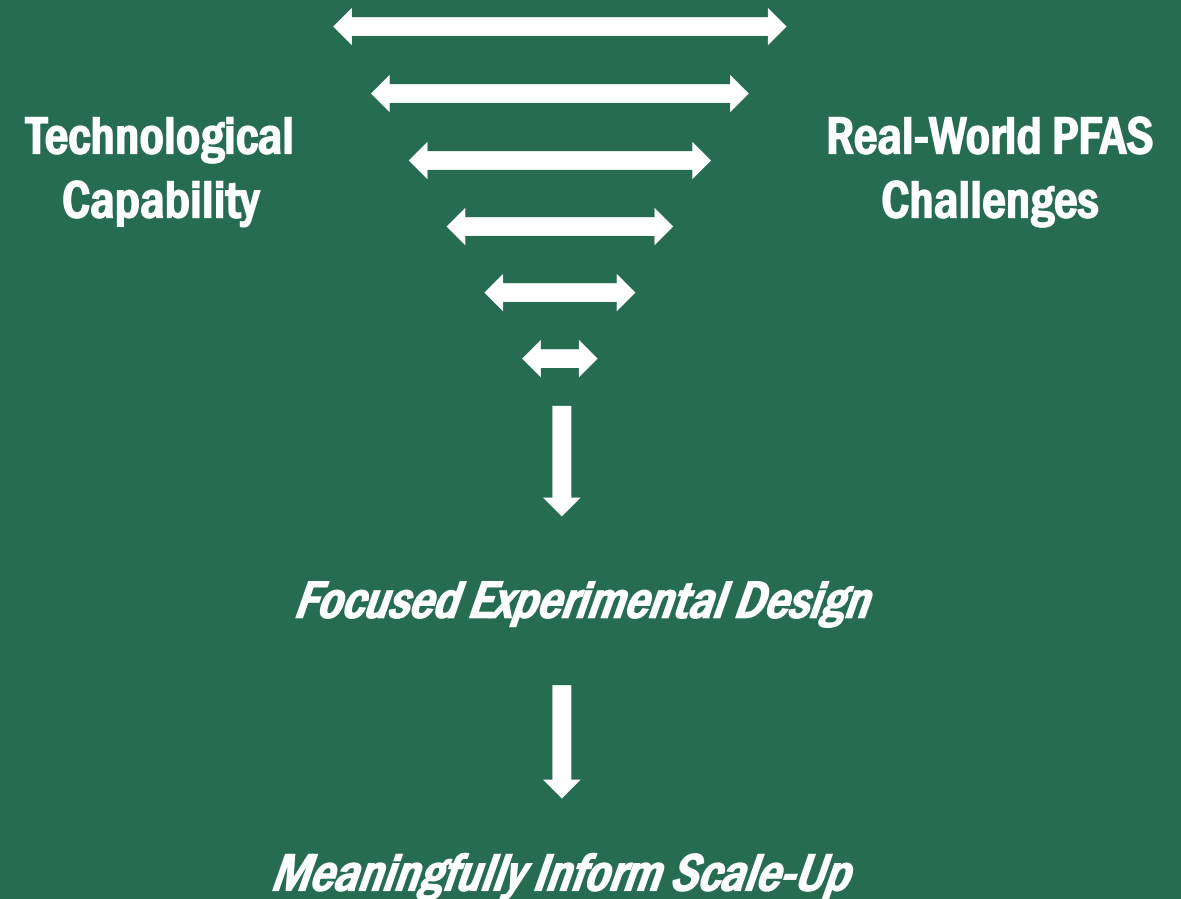
# Mechanochemistry

- Immense mechanical forces drive physical and chemical transformations.
- Ball bearings in the MCD reactors collide at incredibly fast speeds.
- Particles are subject to intense destruction conditions at the points of collision.
- Important to understand the fundamental science and technology scale-up.

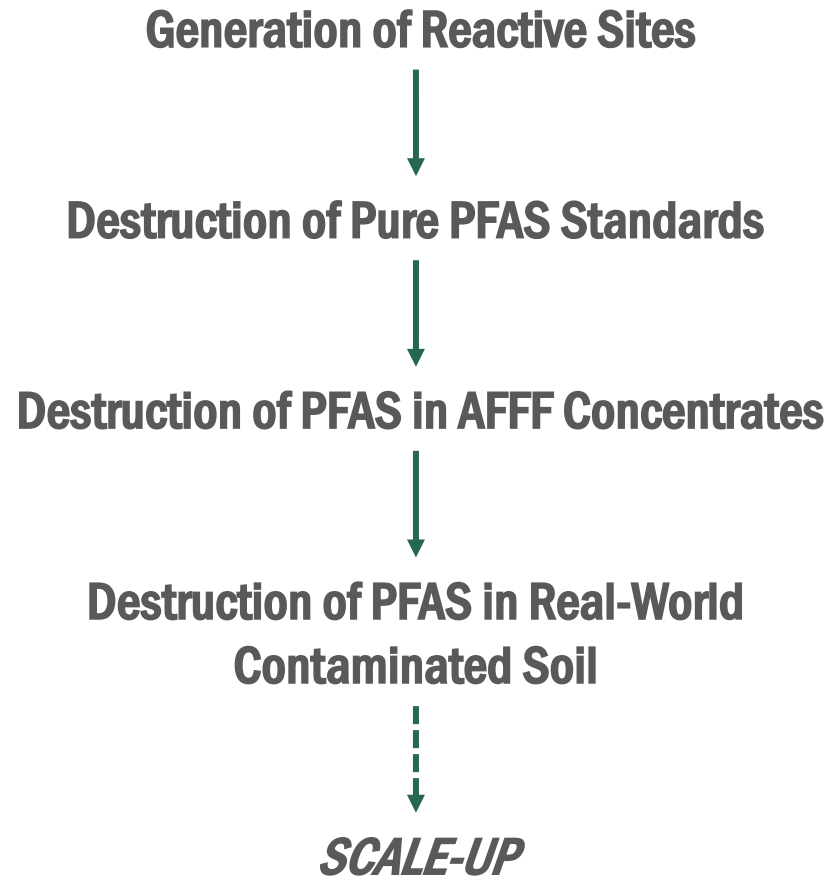
# Experimental Strategy

Explore reaction initiation and propagation induced by ball milling.

Determine destruction efficiencies, evaluate mechanisms, explore kinetics, and fluorine fate.



# Experimental Design



## Analytical Suite

*Liquid Chromatography Tandem Mass Spectrometry*

*Combustion Ion Chromatography*

*Fourier Transform Infrared*

*High Resolution Mass Spectrometry*

*Solid-State Nuclear Magnetic Resonance*

*Liquid Nuclear Magnetic Resonance*

*Electron Paramagnetic Resonance*

*Powder X-Ray Diffraction*

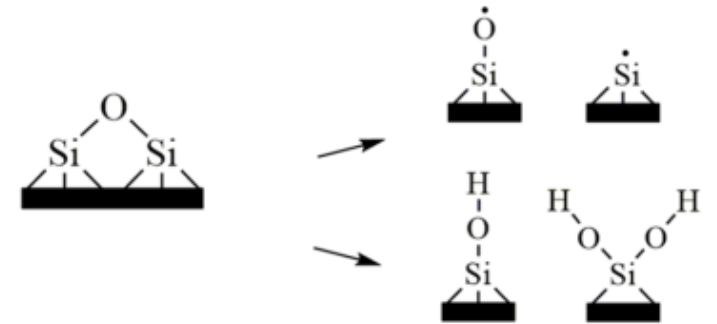
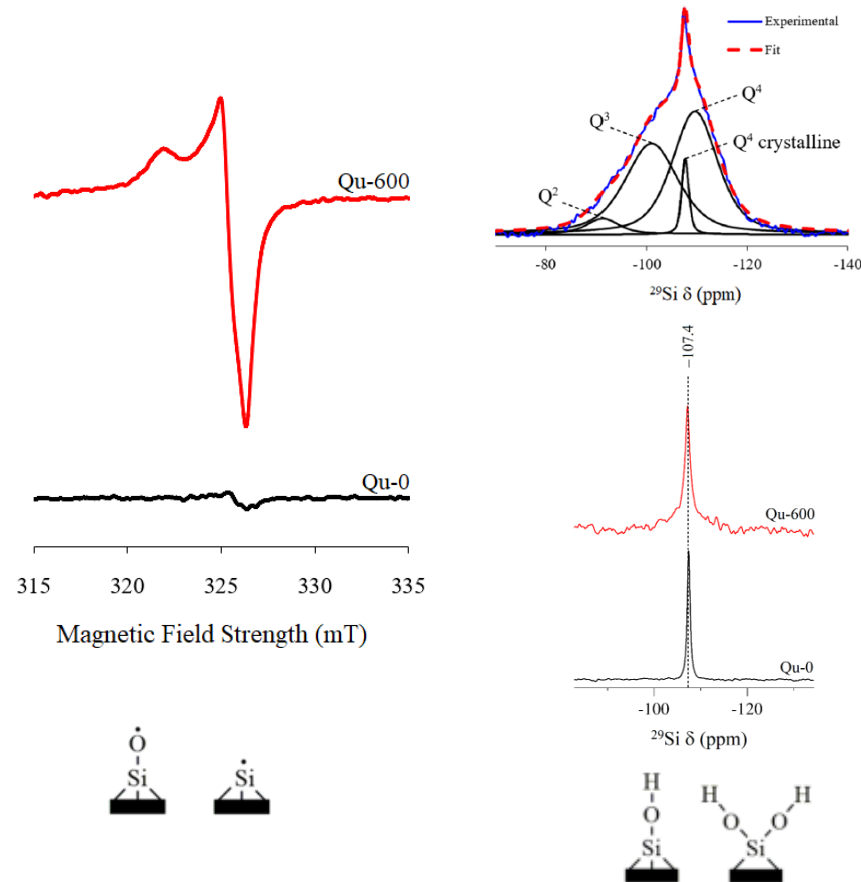
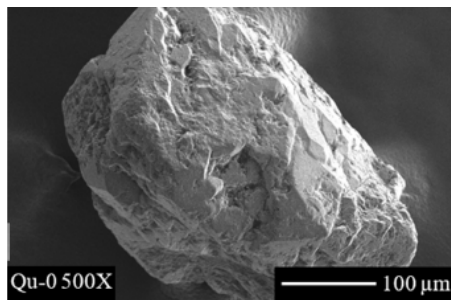
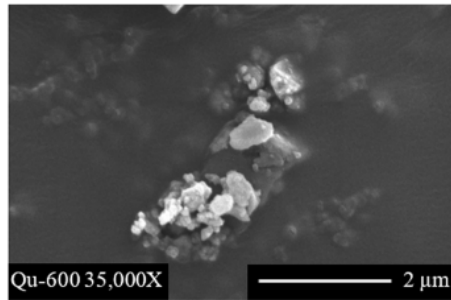
*Scanning Electron Microscopy*

*X-Ray Photoelectron Spectroscopy*

*BET Surface Area Analysis*

# Reactive Sites

PFAS + Reactive Surfaces → Intermediates → Mineralized By-Products



# MCD of PFAS: Ideal Matrices

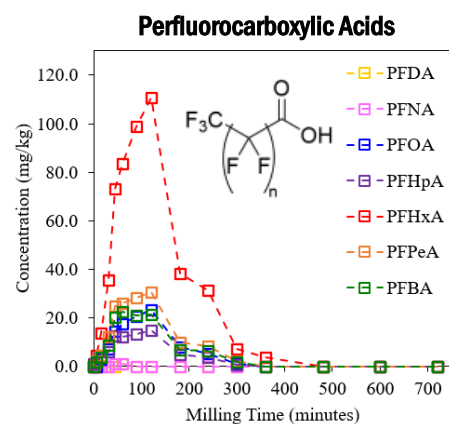
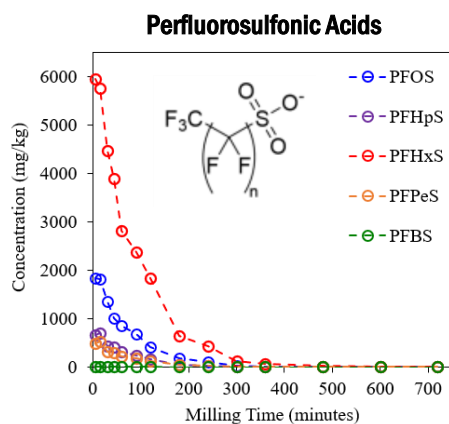
## Procedure

PFAS Standard(s)  
~0.05 g

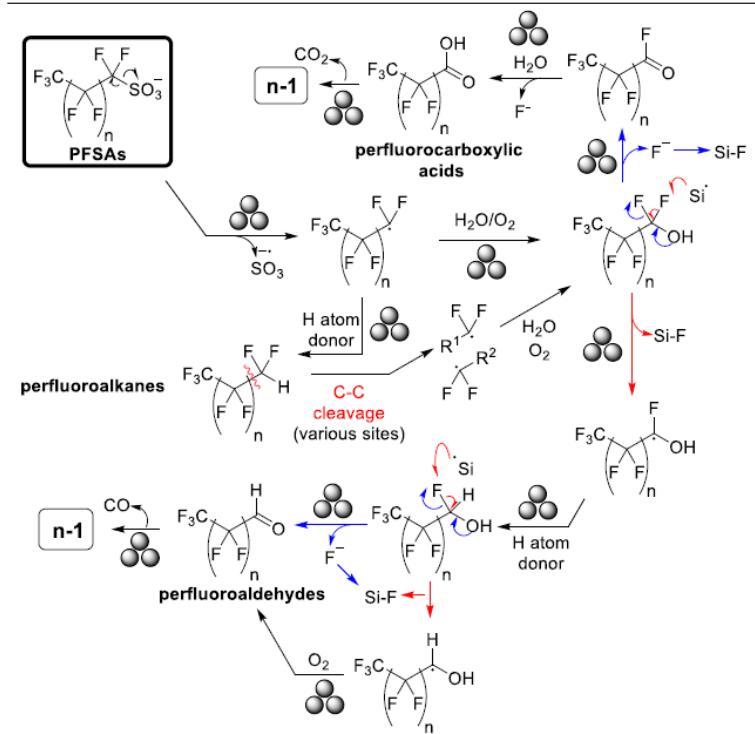
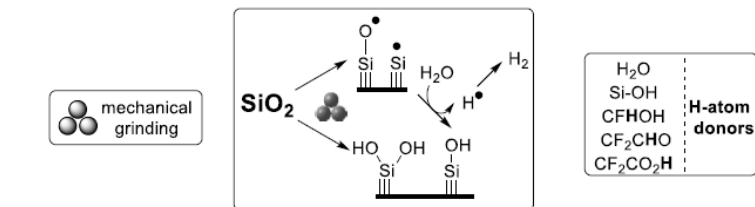
Quartz Sand  
~5.00 g



## Degradation Kinetics



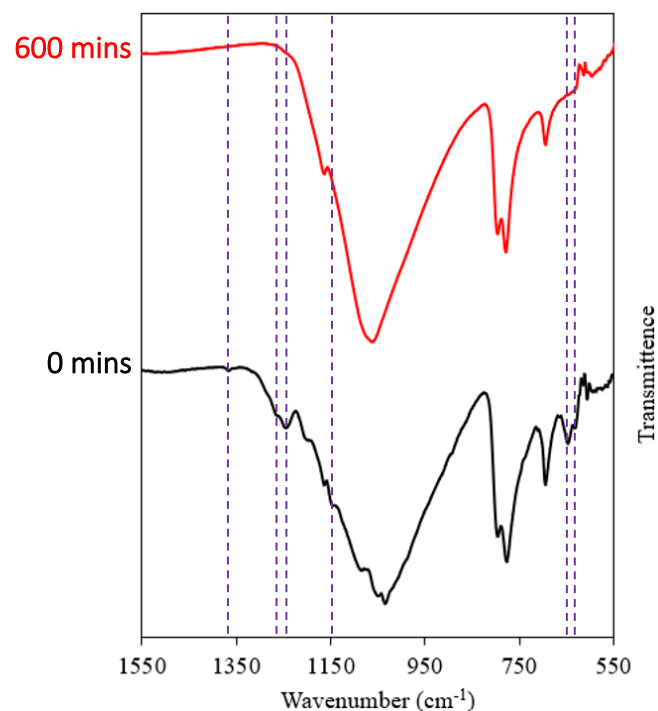
## Degradation Mechanism





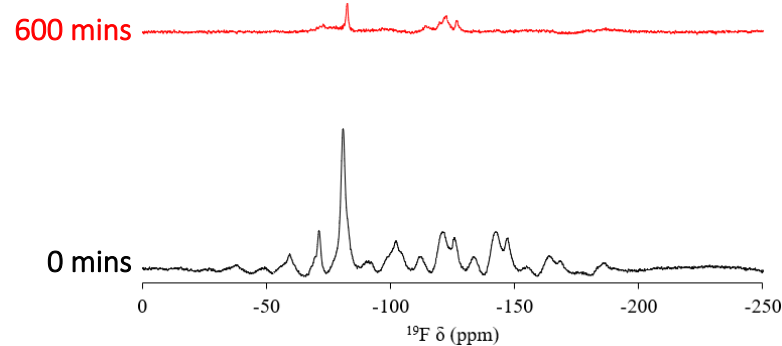
# Fluorine Fate

## Infrared

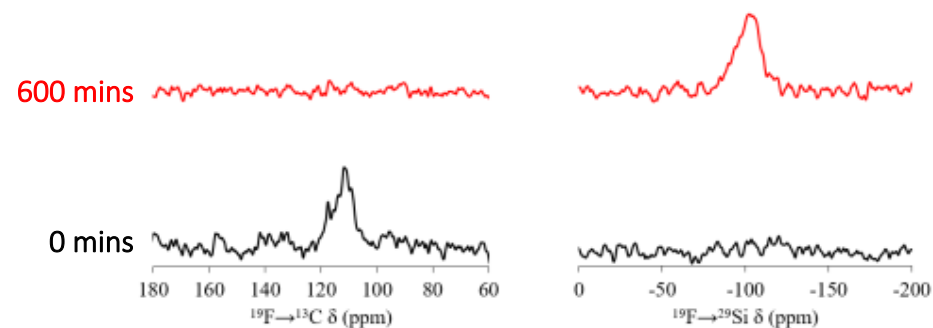


## Solid-State Nuclear Magnetic Resonance

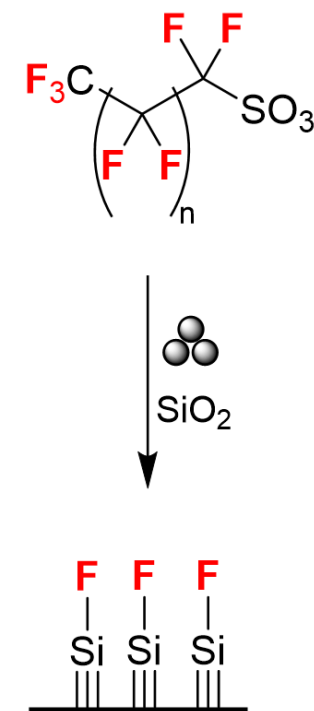
### Direct Polarisation



### Cross Polarisation



## Overall Reaction

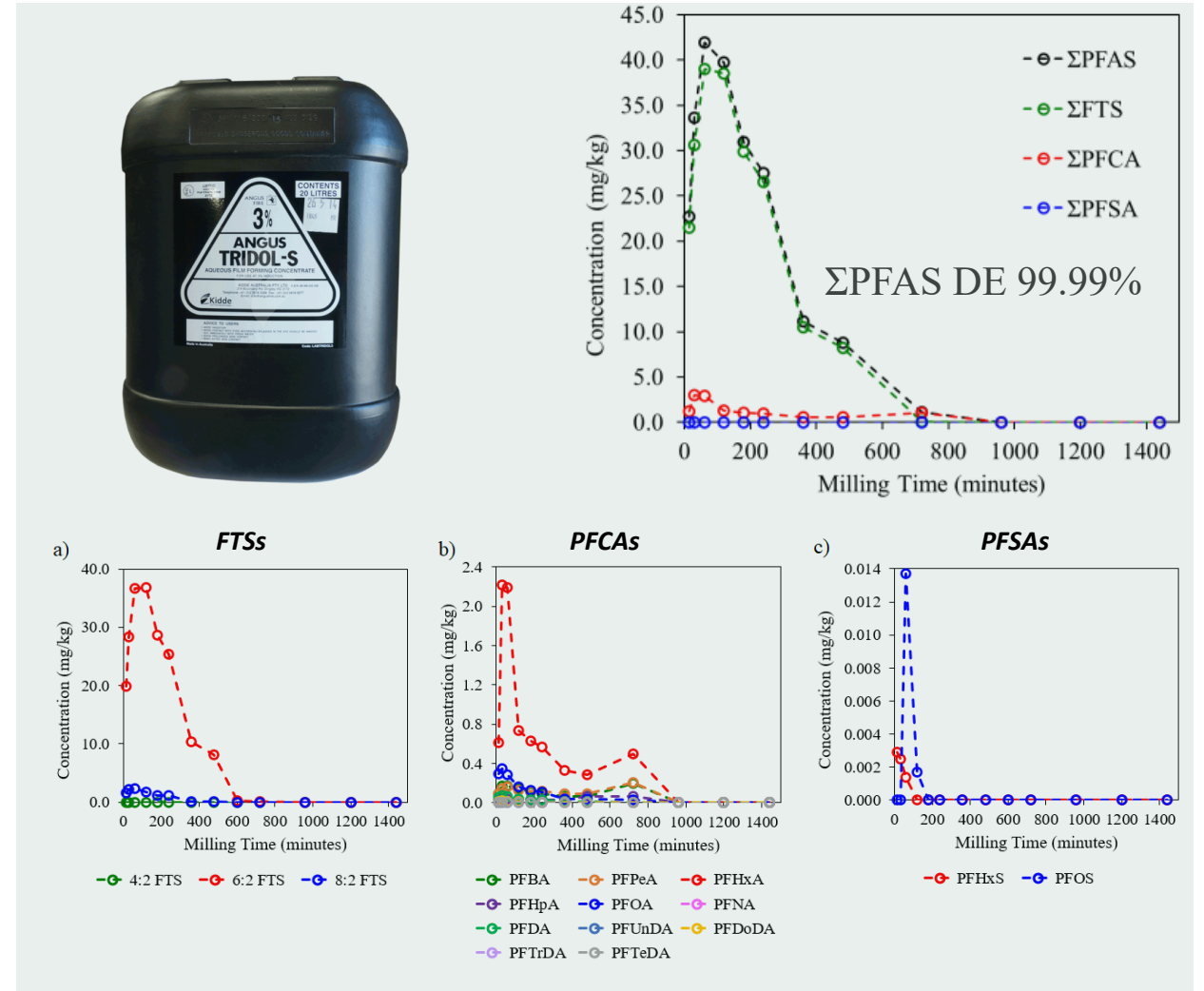
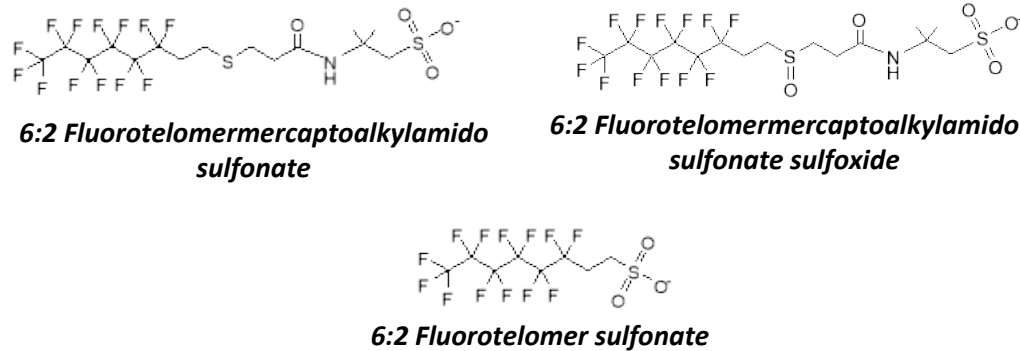


# Real-World Challenges: AFFF Concentrates

Obsolete foam concentrates are a major liability issue.

5%-10% fluorosurfactants in foams.

Ball milling of AFFFs on quartz sand bed proved highly effective.



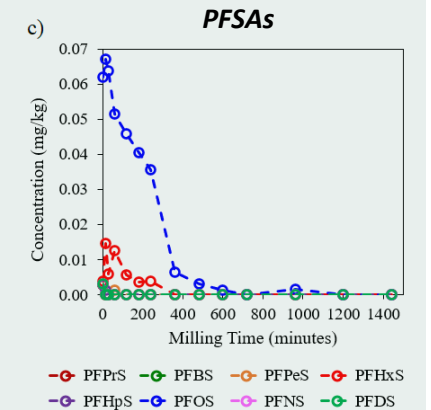
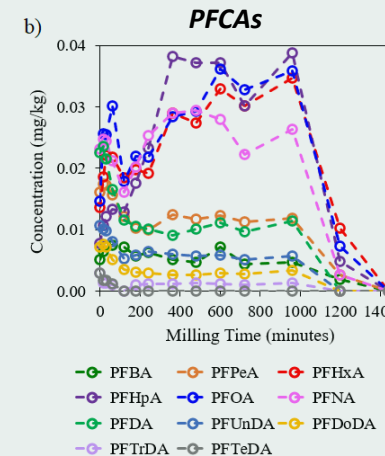
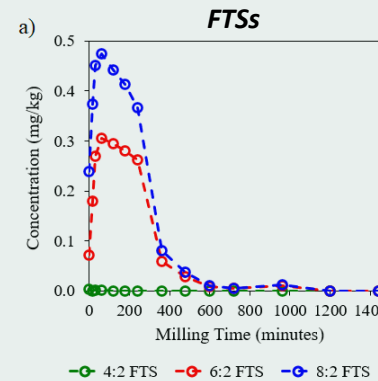
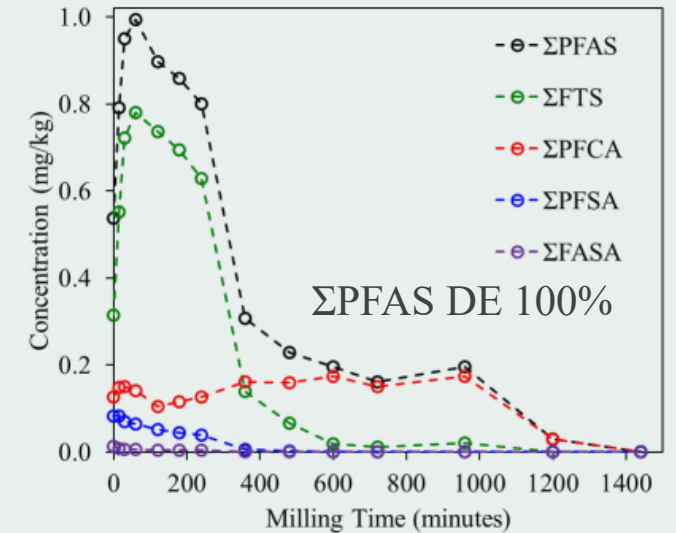
# Real-World Challenges: Contaminated Soil

Authentic sample derived from a Defence Force site.

Incredibly complex PFAS profile due to decades of foam use.

Ball milling of PFAS-impacted soil leads to an inert end-product.

Theoretical EE/O of 45-180 kWh/m<sup>3</sup> (destruction).



# Technology Scale-Up

The primary objective of scale-up strategy is to de-risk the implementation of the MCD technology at full-scale.

## *Lab*

5 g batch.

Efficacy.

Fundamental science.



## *Pilot*

100s kgs semi-continuous.

Scalability.

Operational conditions.

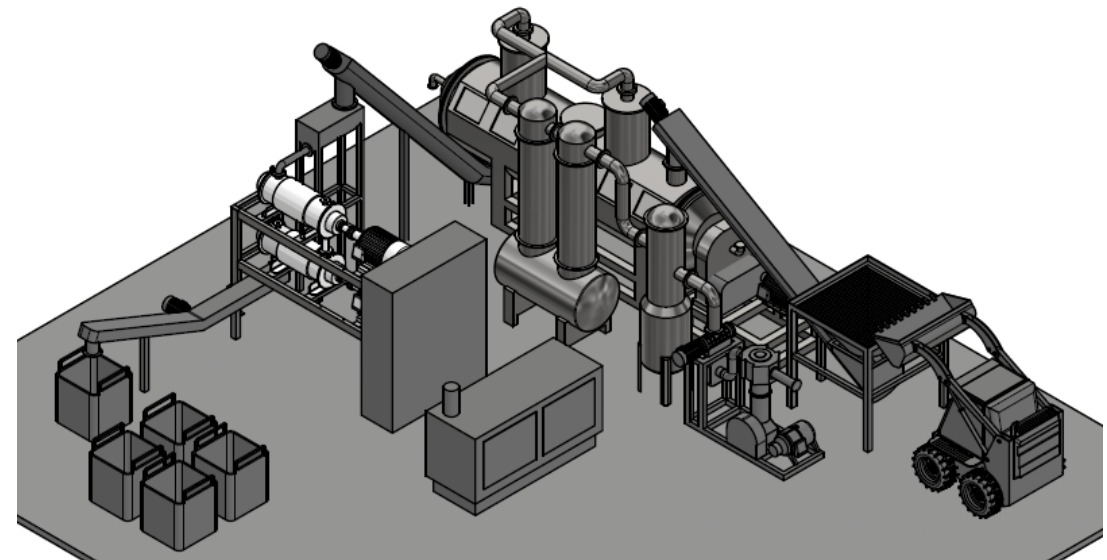


## *Full-Scale*

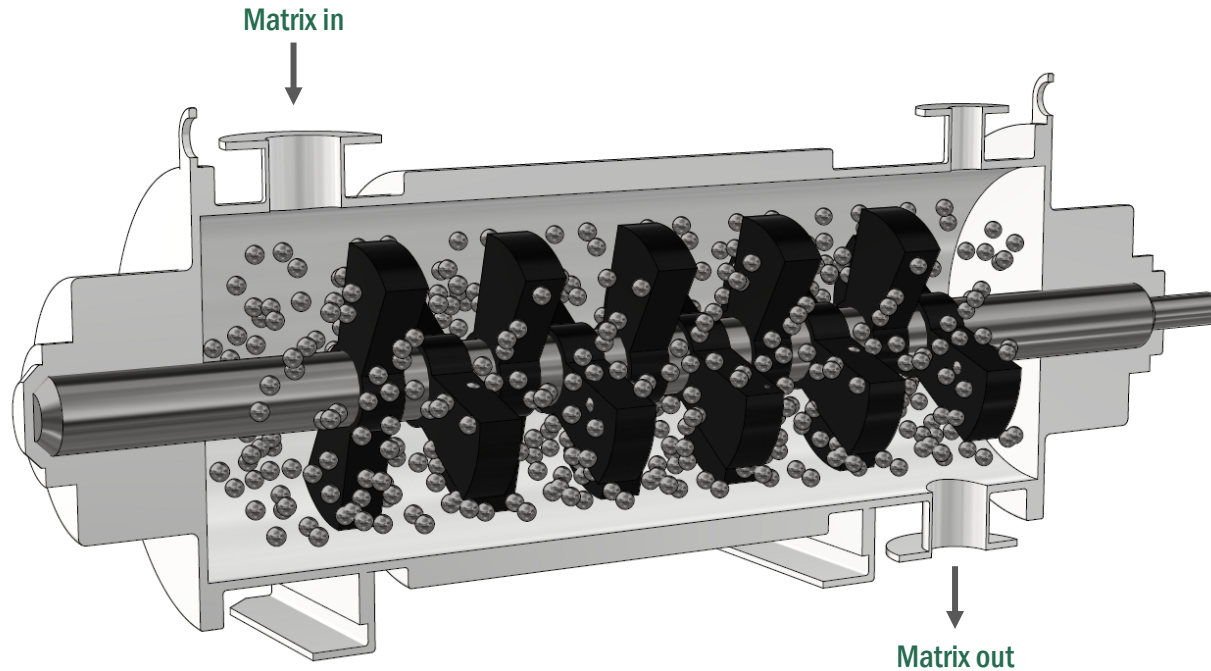
Tonnes per hour continuous.

QA/QC.

Plant maintenance.



# MCD Reactor Design



Full-scale = tonnes per hour

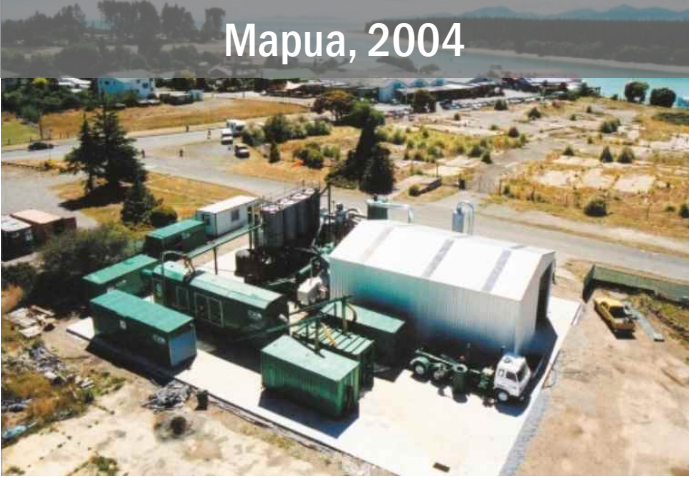
## Technology Fundamentals

Horizontal stirred ball mill design is a proven high efficiency mechanochemical system.

Engineered to destroy organic pollutants (e.g., PFAS, POPs) in solid matrices.

Focused on sustainability and providing the environmental sector with a greener solution for destruction.

# Technology Adaptability



# Next Steps





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