



## NEWMOA PFAS Webinar Series PFAS: Thermal Technologies

# Thermal Destruction of PFAS During Full-Scale Reactivation of PFAS- Laden Granular Activated Carbon

### Rebecca DiStefano

Senior Applications Engineer  
Industrial Solutions and  
Diversified Applications

### Author Acknowledgements:

Tony Feliciano, Richard A. Mimna,  
Adam M. Redding, John Matthis

Classification : Conference Presentation  
Creation date : October 2024  
Department responsible for handling information : Industrial Solutions  
Disclosure Scope : Meeting participants



We are better together

# Environmental Solutions Division (ESD)



- Largest activated carbon player in the world
- Greater focus on innovation and future outlook
- Diversified manufacturing base—geographically and product type
- Stronger R&D capabilities
- Higher performing specialty products
- Focused on growing our business in key markets (automotive)

# Why Do Experts Choose Experts?

## Testing



Research and Development



Technical Support and Modeling

## Implementation



Lab Testing



Pilot Testing

## Design



Sorbent Selection



System Design



### R&D, Applications Engineering, and Technical Service

- Provide recommendations on activated carbon and ion exchange products
- Determine project feasibility and scoping
- Design true cradle-to-grave water and air treatment solutions
- Establish media exchange schedule and plan for disposal of spent media



### Equipment Engineering and Fabrication

- 80,000 sq. ft. Equipment Fabrication and Assembly plant in Pittsburgh, PA
- Capabilities including fabrication, lining, and painting of both standard and customized carbon steel vessels
- Fabrication capacity of 150+ Model 10 vessels
- Over 3200 mobile service systems



### Field Services

- Field Service Team consisting of ~50 representatives across the globe
- Provided on-site services for our customers for more than 40 years
- Fully trained for equipment installation, repair, maintenance, and carbon exchanges
- International Field Service Teams based in active regions



### Logistics

- Private fleet of ~120 dedicated trailers, each with different specifications
- Ensures delivery of fresh GAC and IX resin, safe transportation and removal of spent media
- Dedicated skilled drivers work hard to meet customers' needs and requests in a timely and efficient manner

## Rapid Response



Treatment System Mobilization



Global Logistics Rapid Response

When clients need services quickly, Calgon Carbon delivers; offering a wide variety of equipment, activated carbon, specialty products, and field personnel for rapid response applications.



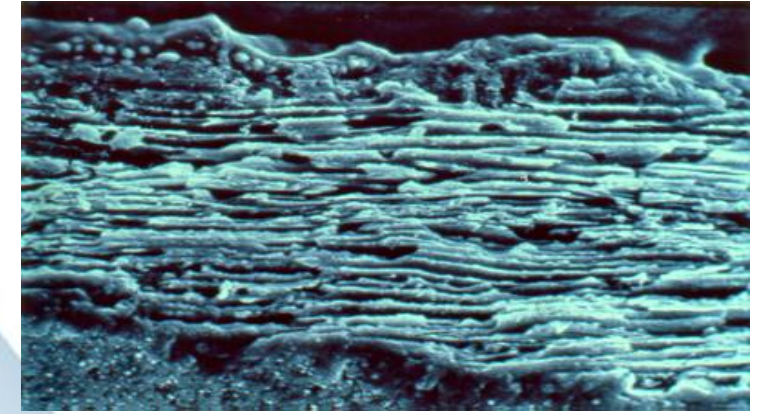
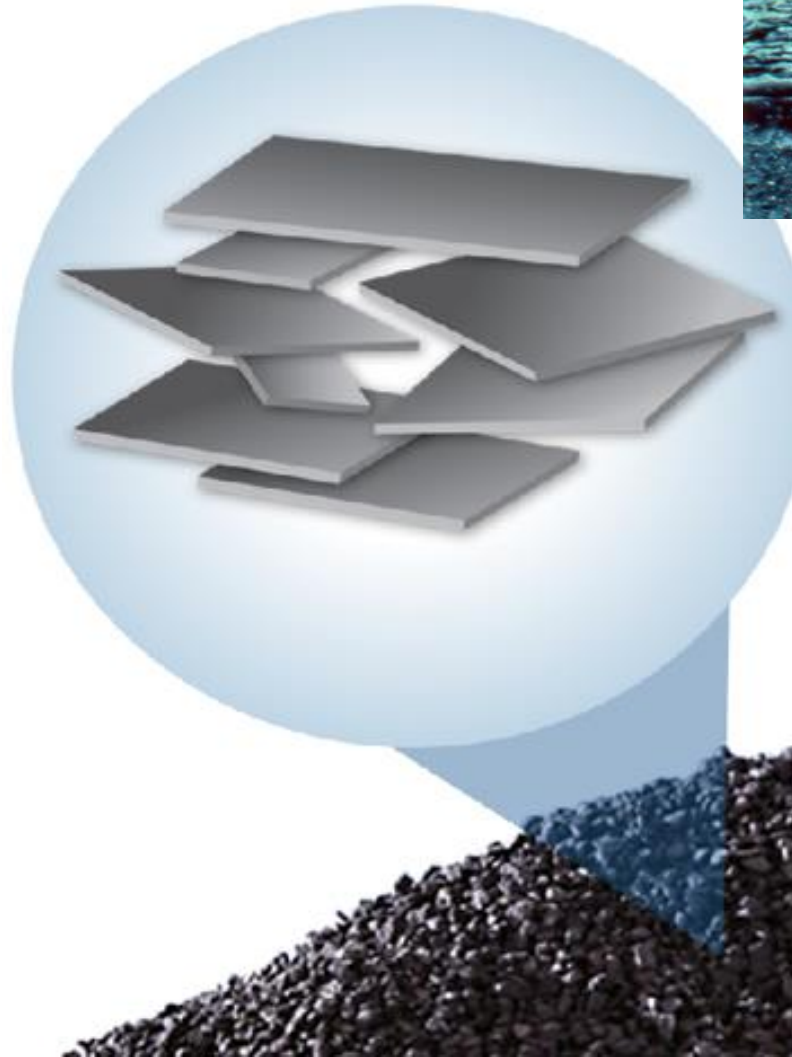
# Structure of Activated Carbon

AC is  
99%  
graphite

- Carbon is the base element of graphite

AC is a  
crude  
form of  
graphite

- Imperfections result in porosity and greater surface area

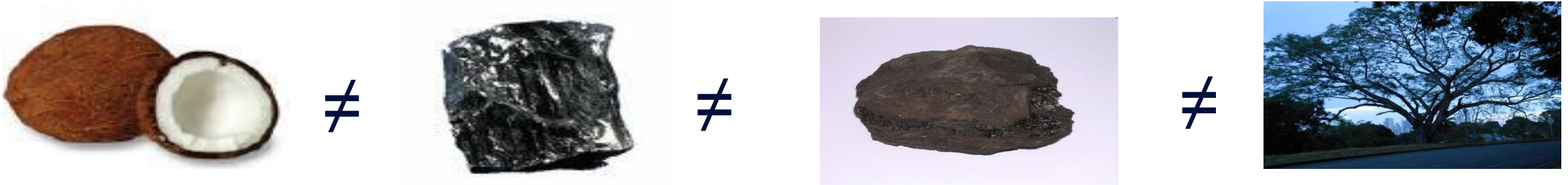


1,000,000 x micrograph

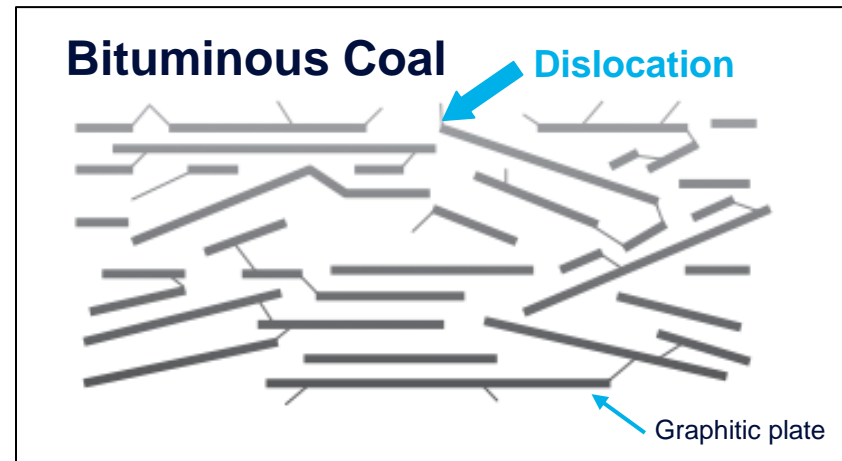
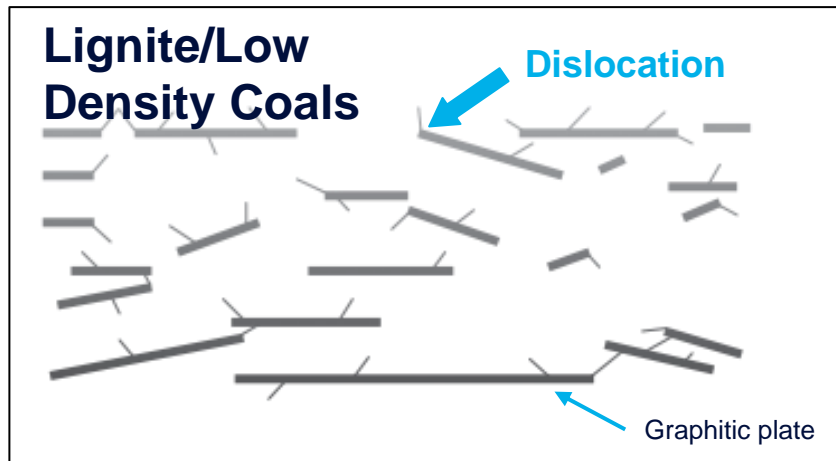
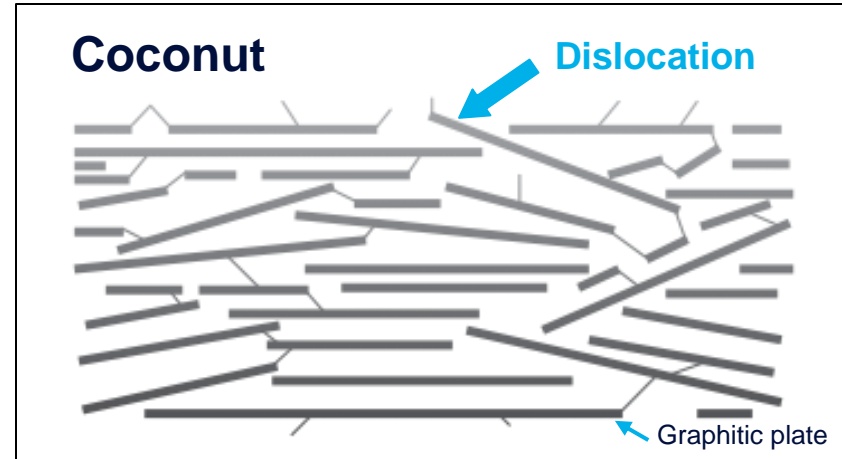
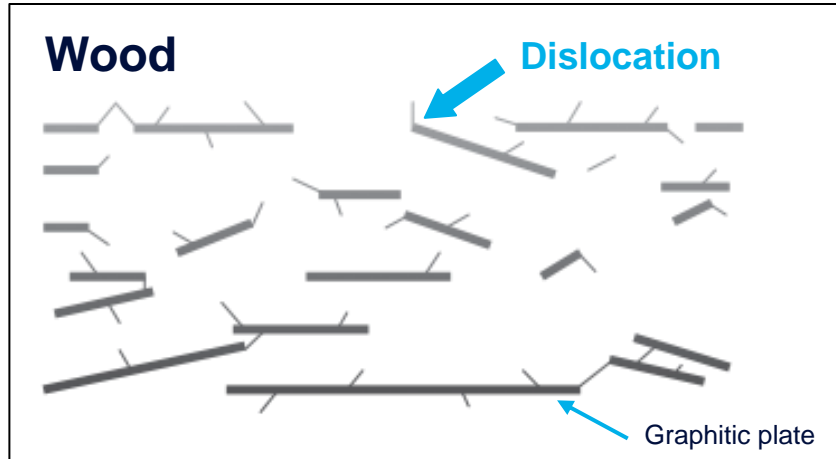
# Why are Granular Activated Carbon Products Different ?

## Raw material dictates all of the product possibilities

- Ash impurities inherited
- Density and hardness are linked
- Transport pore structure and adsorption kinetics
- Single unique family of products from a raw material source
- Coconut ≠ Bituminous Coal ≠ Lignite ≠ Wood



# Internal Fingerprint of Starting Material



# Removing PFAS for over 20 years

Effectively treating to non-detect levels mean < 1 drop in 20 Olympic size pools. This requires engineered and proven solutions, not just products... this is the Calgon Carbon Difference.

- Granular Activated Carbon (GAC) and CCC's Equipment Line are proven treatment solutions for PFAS removal
- Over 150 full scale installations for PFAS removal across the United States
- Offer complete solution including activated carbon, equipment, on-site installation and exchange services, reactivation and financing



Proven products and solutions for drinking water, wastewater, remediation and POET



Laboratory & field testing for tailored solutions



Carbon reactivation removes PFAS from the spent carbon and abate these compounds



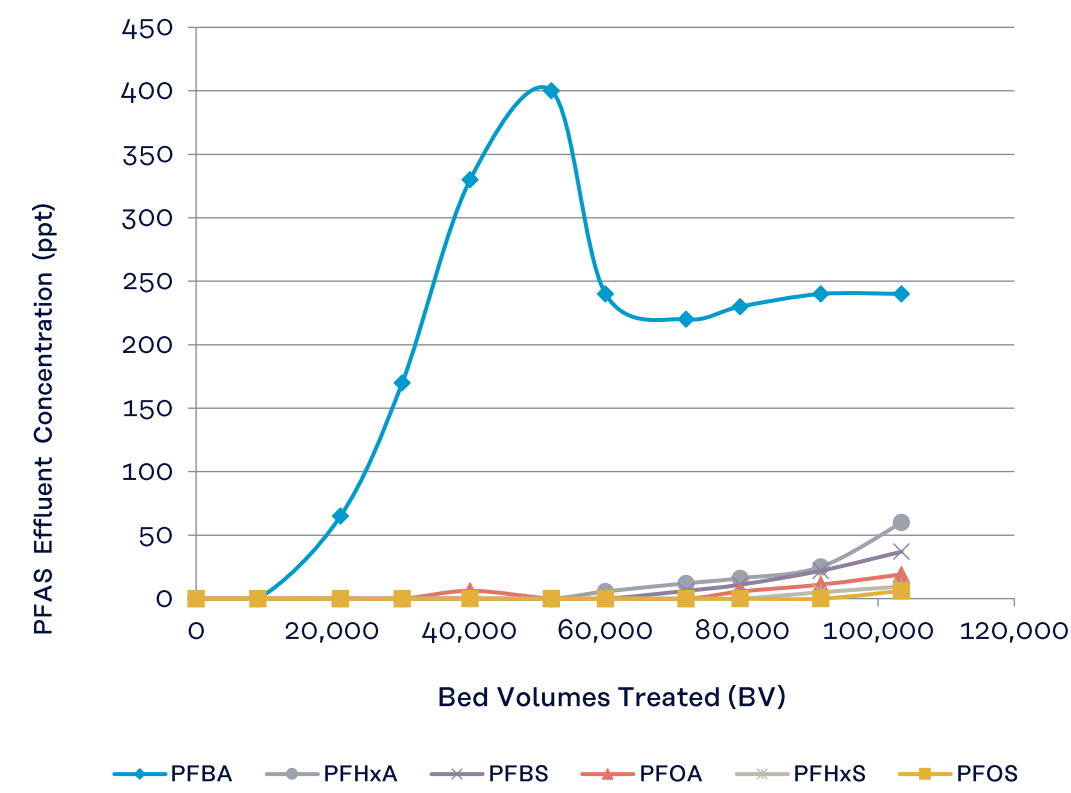
Applications Engineers and R&D team dedicated to solving customer problems



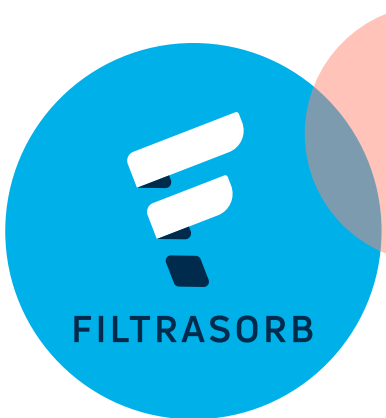
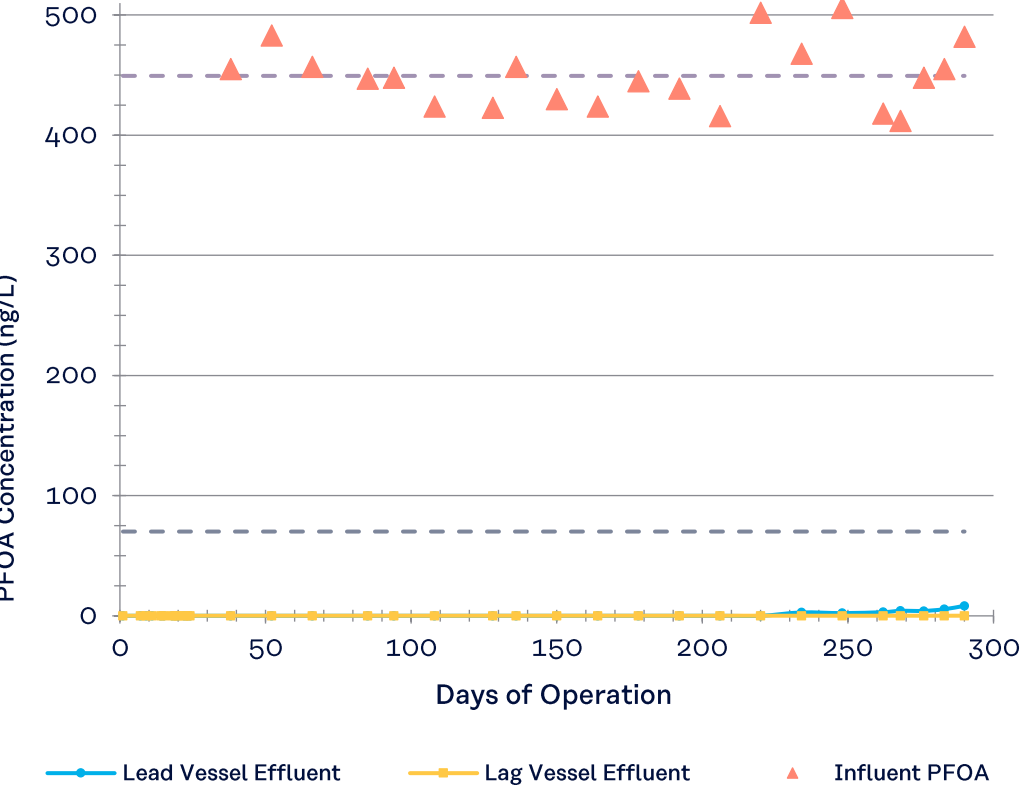
Unrivaled technical service

# Calgon Carbon's FILTRASORB® product is proven and capable of meeting non-detect for a range of PFAS

## Peer-Reviewed Lab-Scale Testing Demonstrating FILTRASORB's Effectiveness for PFAS Removal

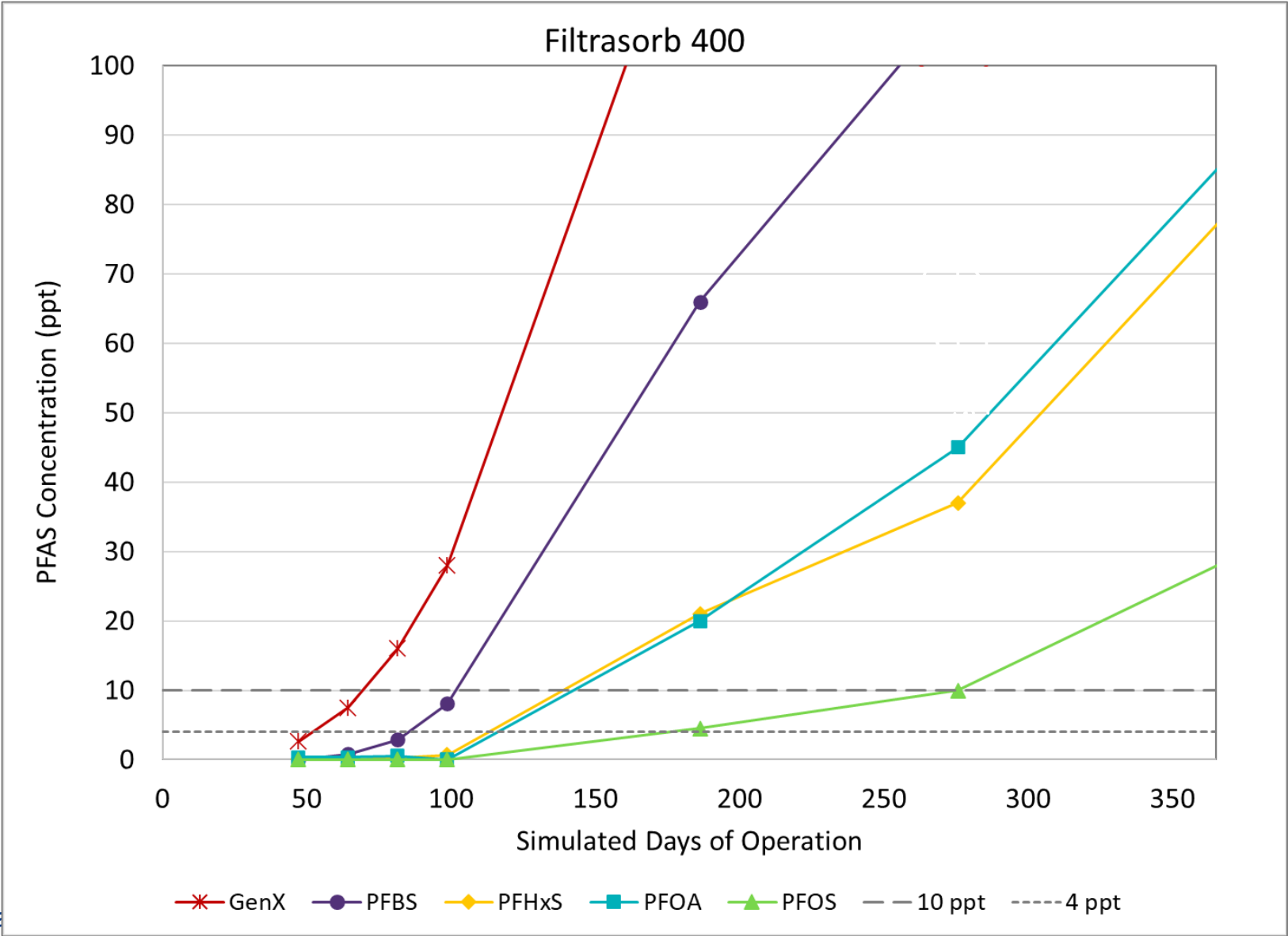


## Full-Scale Model 10 System 10 minutes EBCT





# GAC Effectively Treats to MCLs



- Rapid Small-Scale Column Test simulating CCC Model 8 Vessel with 10 minutes EBCT
- GAC service life highly dependent on
  - PFAS compounds present
  - PFAS concentrations
- Proper testing is critical

## Target Feed Concentrations

PFOA	200 ppt
PFOS	200 ppt
PFHxA	200 ppt
PFHxS	200 ppt
PFBA	200 ppt
PFBS	200 ppt
GenX	100 ppt
6:2 FTS	200 ppt
TOTAL	1500 ppt

# Water treatment removes contaminants from water

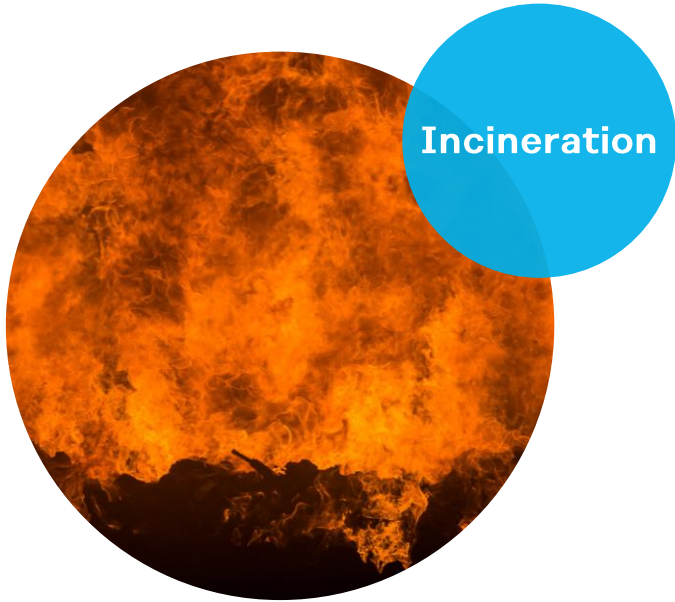


What happens  
to the media  
once its useful  
life is over?

# Reactivation is a unique disposal & reuse for GAC ONLY

⊘ Common methods used by many technologies (IX resin, Clay-based or novel sorbents) :

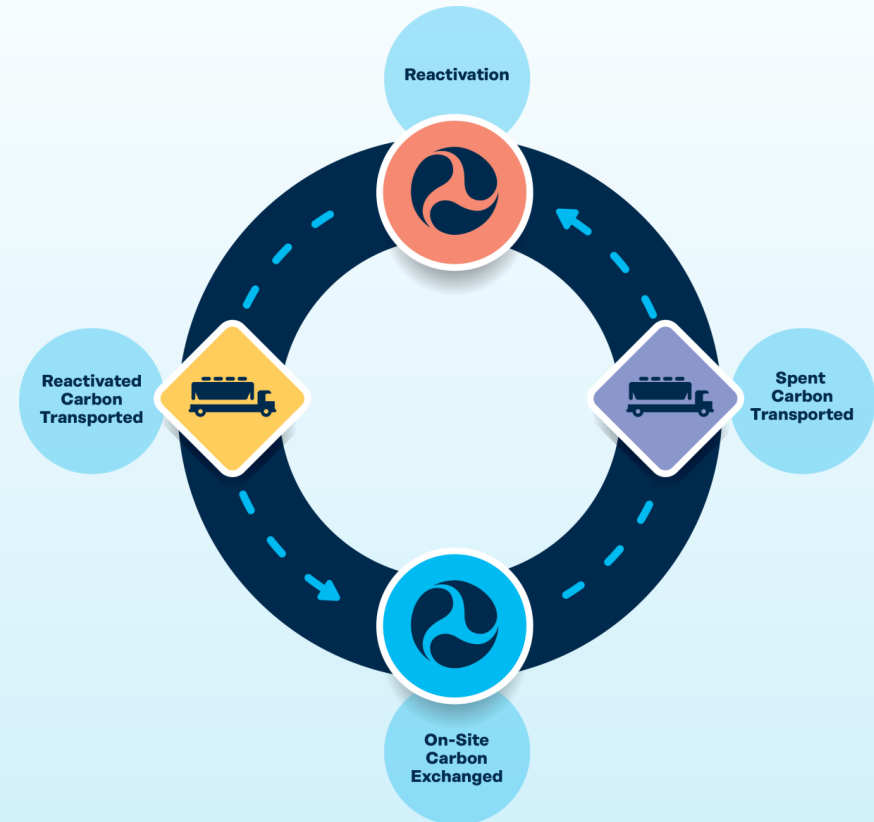
Incineration



Landfill



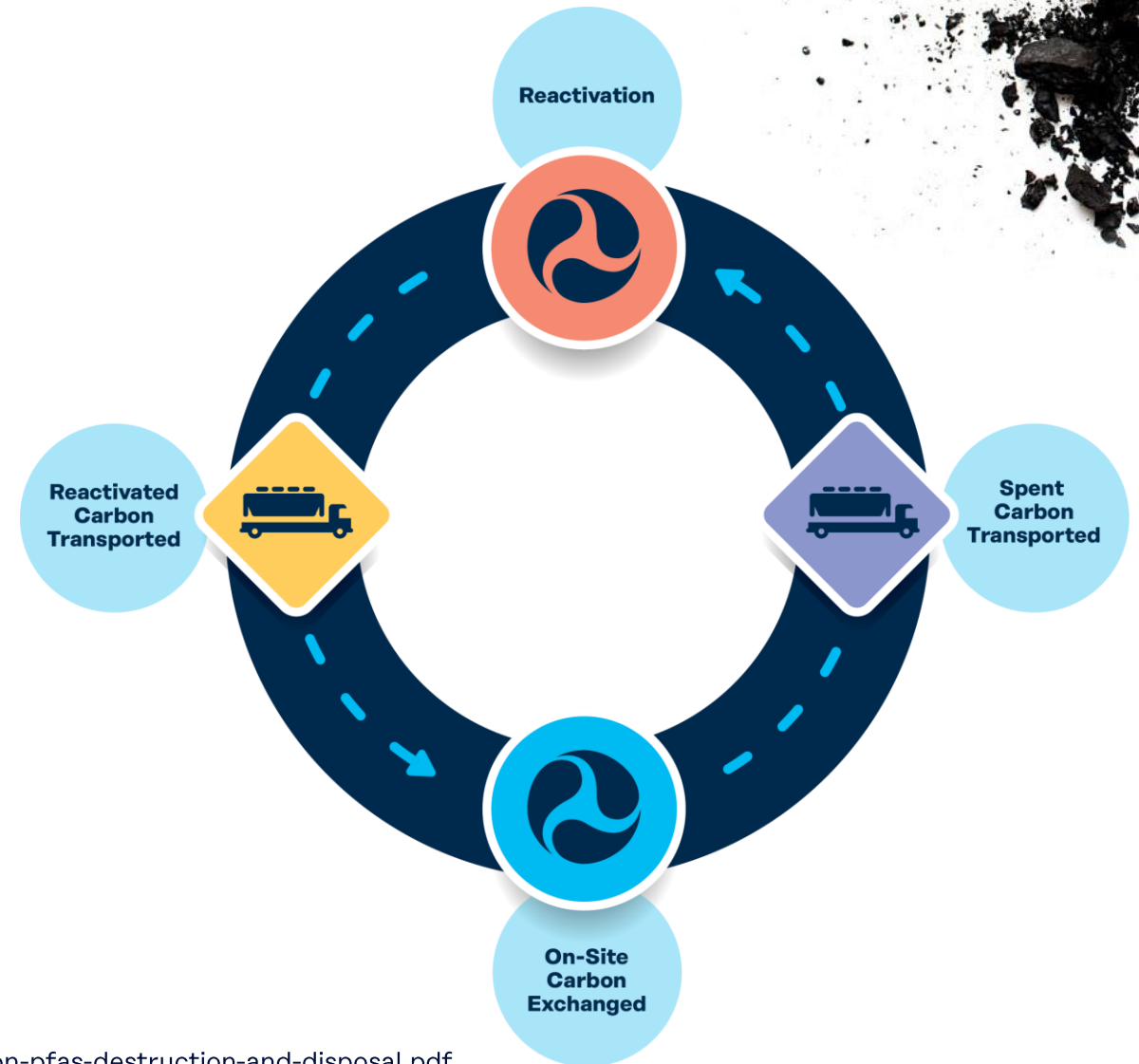
✓ Unique to Activated Carbon:



# Reactivation

## How Our Products Help Customers and Society

- Certified destruction of the adsorbed materials (which may be classified as hazardous (CERCLA or RCRA))
- No landfill liabilities and more sustainable solution
- 80% Reduction in CO<sub>2</sub> vs. the production of virgin carbon
- Lower cost than incineration and more sustainable
- ◇ Recognized by EPA as a disposal method for PFAS-laden activated carbon in their 2024 Interim Guidance<sup>1</sup>
- ◇ Recommended by DoD as the disposal method for spent PFAS-containing GAC from DoD sites in a July 2023 memo<sup>2</sup>



1. <https://www.epa.gov/system/files/documents/2024-04/2024-interim-guidance-on-pfas-destruction-and-disposal.pdf>

2. [https://www.acq.osd.mil/eie/ee/ecc/pfas/docs/news/Memorandum\\_for\\_Interim\\_Guidance\\_on\\_Destruction\\_or\\_Disposal\\_of\\_Materials\\_Containing\\_PFAS\\_in\\_the\\_U.S.pdf](https://www.acq.osd.mil/eie/ee/ecc/pfas/docs/news/Memorandum_for_Interim_Guidance_on_Destruction_or_Disposal_of_Materials_Containing_PFAS_in_the_U.S.pdf)



# Reactivation

## Global Reactivation Capacity

### UNITED STATES

- **5 Reactivation sites**
  - 2 RCRA facilities
  - 3 Potable facilities
  - 4 sites are CERCLA Approved

### UNITED KINGDOM

- **2 Reactivation sites**

### BELGIUM

- **World's largest reactivation site**

### CHINA

- **2 Reactivation sites**

Calgon Carbon reactivates millions of pounds of activated carbon every year

Over 30 years of reactivation experience globally

# Reactivation Chemistry

## Low temperature pre-treatment

- Drying of water at 100°C

## Physical processes and reactions

- Thermal Devolatilization and Desorption at 100-250°C

## High temperature carbon condensation reactions

- High temperature pyrolysis/ calcination chemistry at 200-750°C

## High temperature carbon gas/solid reactions

- Chemical reactions for Carbon Gasification with water vapor, carbon dioxide, or oxygen at 800-1000°C



Multi-hearth furnace

# Carbon Acceptance Testing Objectives

Carbon Acceptance testing includes a series of evaluations to confirm a spent carbon can be effectively and safely reactivated.

Each project is thoroughly evaluated to ensure it meets CCC's requirements for:

Safety/Toxicity  
Regulatory Compliance  
Protection of:

- The Environment
- Plant Personnel
- Process Equipment
- Quality of Reactivated Product
- Apparent Density (AD)
- pH
- Ignitability
- Nature of spent carbon:
  - % Halides (Cl, F, Br)
  - % Sulfur
- Reaction with water
- % Moisture
- Radiation Screening
- Inorganics
- Quality of Reactivated Product
- Liquid phase applications only
  - ICP Metals including lead, mercury
  - % hex chrome
- BTU content (RCRA-hazardous only)





# Reactivation is a Unique Process

Reactivation ≠ Incineration  
Reactivation ≠ Regeneration

United States Code of Federal Regulations, 40 C.R.F. 260.10 defines an incinerator as “any enclosed device that: Uses controlled flame combustion and neither meets the criteria for classification as a boiler, sludge dryer, or carbon regeneration unit, nor is listed as an industrial furnace; or meets the definition of infrared incinerator or plasma arc incinerator.”

A carbon regeneration unit is defined as “any enclosed thermal treatment device used to regenerate spent activated carbon”  
(Hazardous Waste Management, 2022)

<https://www.calgoncarbon.com/app/uploads/PFAS-Reactivation-Memo-06022020.pdf>





# Regeneration vs. Reactivation for GAC

## Reactivation

Reactivation is a high-temperature thermal process that removes and destroys contaminants from the carbon's pore structure allowing the product to be reused.



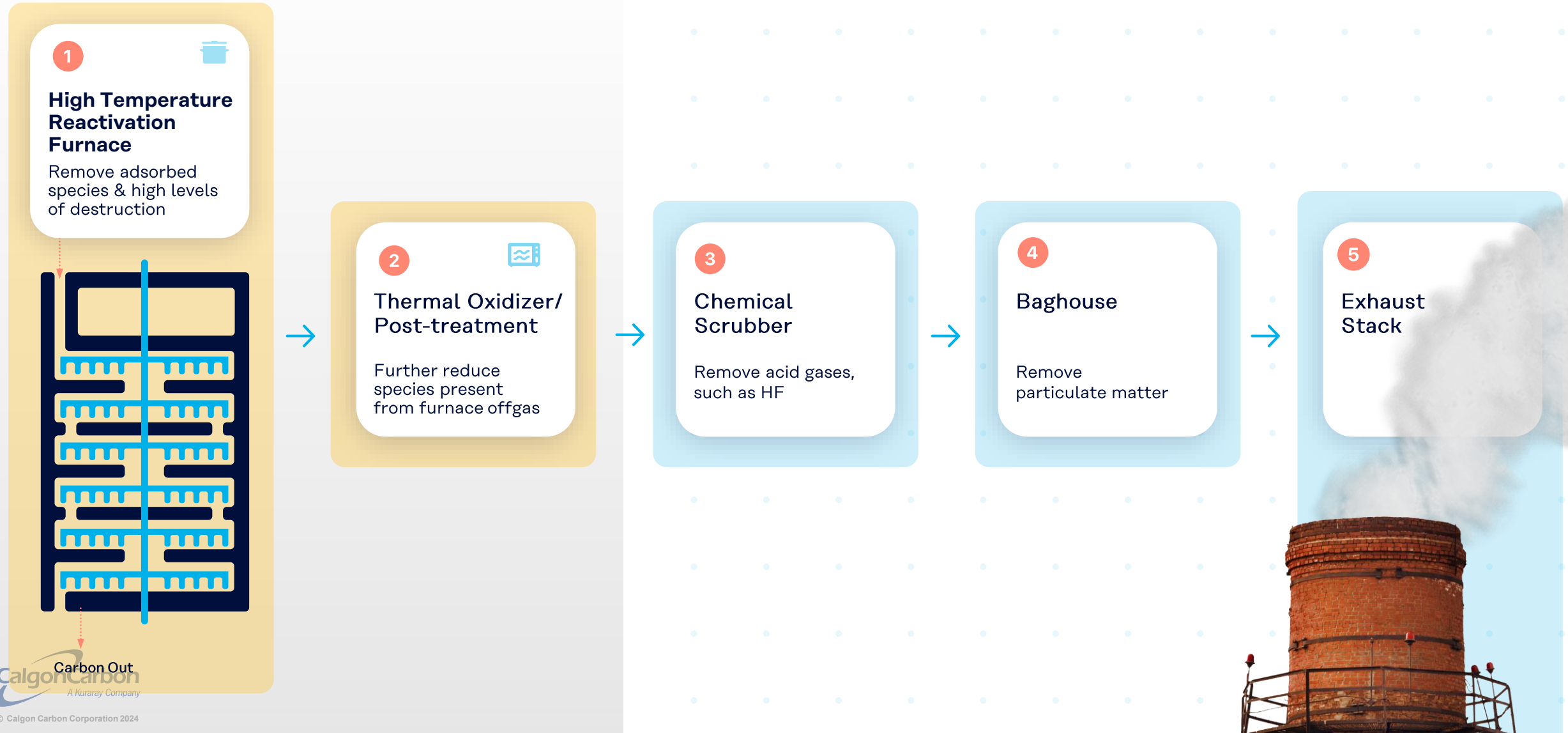
## Regeneration

Regeneration utilizes steam, solvents, or a low temperature process to remove a portion of the adsorbed species, allowing the product to be re-used. Typically results in a waste stream as this is not a destructive process.

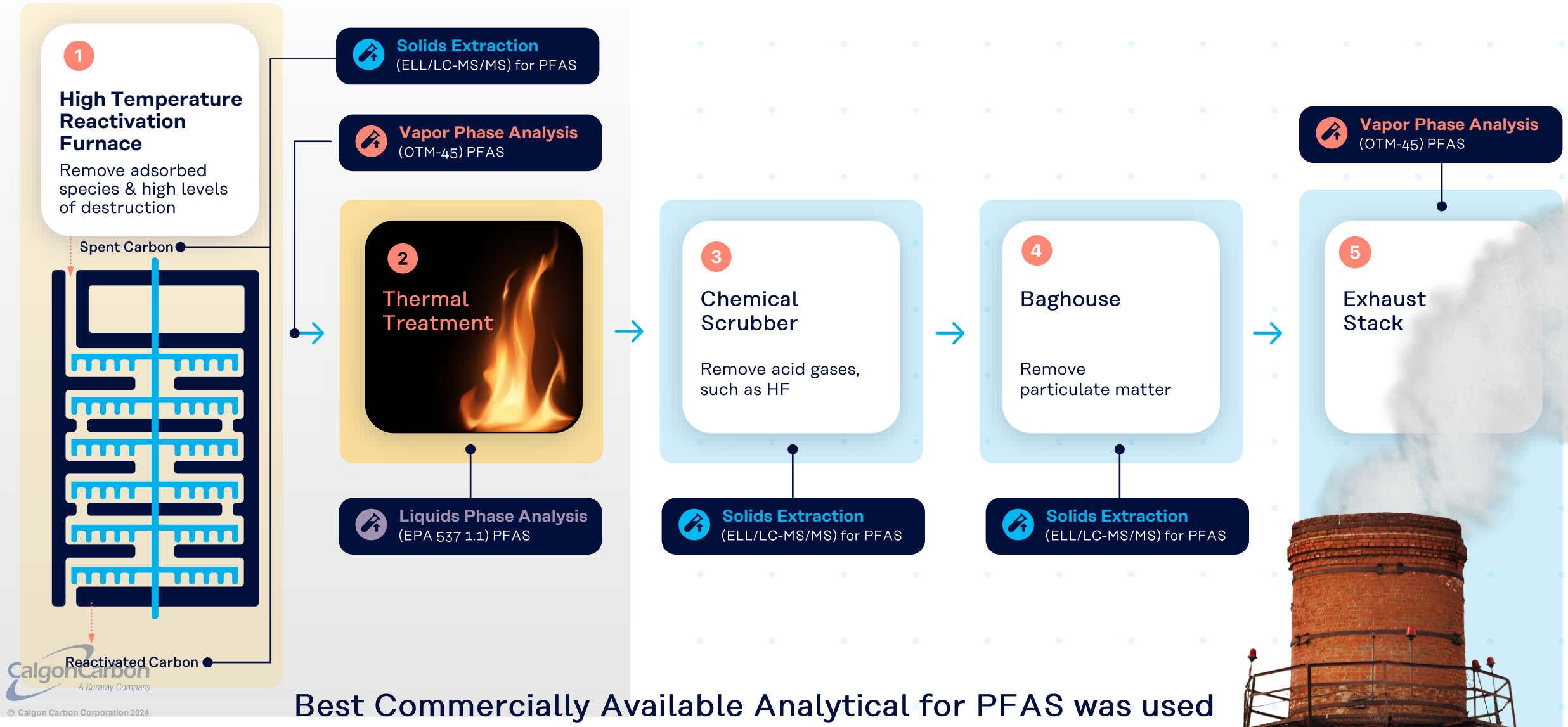


# NEWMOA Poll Question

# Calgon's Reactivation is a unique process with multiple destructive technologies



# Calgon's Reactivation is a Unique Process with Multiple Destructive Technologies







# Recent Peer Reviewed Journal Article Demonstrating Calgon Carbon's Reactivation Effectiveness

Published  
Open  
Access  
13-Sept-  
2022

## REMEDATION

THE JOURNAL OF ENVIRONMENTAL CLEANUP COSTS, TECHNOLOGIES, & TECHNIQUES

RESEARCH ARTICLE | [Open Access](#) |    

### Thermal destruction of PFAS during full-scale reactivation of PFAS-laden granular activated carbon

Rebecca DiStefano , Tony Feliciano, Richard A. Mimna, Adam M. Redding, John Matthis

First published: 13 September 2022 | <https://doi.org/10.1002/rem.21735>

 SECTIONS

 PDF  TOOLS  SHARE

#### Abstract

Granular activated carbon (GAC) is the most widely used and well-established treatment technology for the removal of per and polyfluoroalkyl substances (PFAS) contaminants from drinking water and wastewater. After the GAC has reached the end of its useful service life and become "spent carbon," it is common practice in industry to thermally treat it in a process known as reactivation. The reactivation process volatilizes and destroys adsorbed contaminants at high temperatures and restores the GAC to a near-virgin state so that it can be reused. Since the advent of PFAS regulatory actions, questions have arisen about the effectiveness of the reactivation process for the destruction of PFAS given their high thermal stability and the lack of documented study on this new topic. In light of this, a thorough program of testing was carried out at a full-scale GAC reactivation facility during the reactivation of a load of GAC known to contain adsorbed PFAS. The facility employs a multihearth Herreschoff furnace and a



Volume 32, Issue 4

Fall 2022

Pages 231-238

 References

 Related

 Information

#### Recommended

[Biota-Sediment Accumulation Factors \(BSAFs\) for Per- and Polyfluorinated Substances \(PFAS\)](#)

Lawrence P. Burkhard, Lauren K. Votava

Environmental Toxicology and Chemistry

[Editor's perspective—just how large is the PFAS problem?](#)

John A. Simon

Remediation Journal

[PFAS Legislation](#)

Tommy Holmes, Nate Norris

Journal AWWA



# Calgon's Reactivation effectively removes PFAS below detection limits

	ng/g (ppb)
PERFLUOROBUTANOIC ACID	PFBA
PERFLUOROPENTANOIC ACID	PFPEA
PERFLUOROHXANOIC ACID	PFHXA
PERFLUOROHEPTANOIC ACID	PFHPA
PERFLUOROOCTANOIC ACID	PFOA
PERFLUORONONANOIC ACID	PFNA
PERFLUORODECANOIC ACID	PFDA
PERFLUOROUNDECANOIC ACID	PFUNDA
PERFLUORODODECANOIC ACID	PFDODA
PERFLUOROTRIDECANOIC ACID	PFTRIDA
PERFLUOROTETRADECANOIC ACID	PFTETDA
PERFLUOROBUTANESULFONIC ACID	PFBS
PERFLUOROPENTANESULFONIC ACID	PFPEs
PERFLUOROHXANESULFONIC ACID	PFHXS
PERFLUOROHEPTANESULFONIC ACID	PFHPS
PERFLUOROOCTANESULFONIC ACID	PFOS
PERFLUORONONANESULFONIC ACID	PFNS
PERFLUORODECANESULFONIC ACID	PFDS
PERFLUORODODECANESULFONIC ACID	PFDOS
PERFLUOROOCTANESULFONAMIDE	PFOSA
NMEFOSAA	NMEFOSA
NETFOSAA	NETFOSAA
HFPODA	GENX
4:2 FLUOROTELOMER SULFONIC ACID	4:2 FTS
6:2 FLUOROTELOMER SULFONIC ACID	6:2 FTS
8:2 FLUOROTELOMER SULFONIC ACID	8:2 FTS
10:2 FTS	10:2 FTS
PERFLUOROHXADECANOIC ACID	
PERFLUOROOCTADECANOIC ACID	
SUM 29 PFAS COMPOUNDS:	



## Spent Carbon

Composite Sample for Each Emissions Test

TEST 1	TEST 2	TEST 3
6300	6700	4700
2600	2500	1500
3700	2900	1600
1600	1300	620
18000	14000	5800
88	72	53
71	51	21
45	24	24
<9.7	<9.1	<9.6
59	30	28
<9.7	<9.1	<9.6
11000	8200	6300
6700	4700	1200
33000	22000	5900
5100	3100	810
16000	12000	6700
40	27	9.9
180	110	37
<32	<30	<32
340	340	380
720	550	560
610	520	440
6500	40000	55000
<32	<30	<32
290	110	800
<48	<46	<48
<32	<30	<32
<9.7	<9.1	<9.6
<9.7	<9.1	<9.6
112943	119234	92483

## Reactivated Carbon

Composite Sample for Each Emissions Test

TEST 1	TEST 2	TEST 3
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<2.9 (ND)	<2.9 (ND)	<2.9 (ND)
<1.9 (ND)	<1.9 (ND)	<1.9 (ND)
<0.58 (ND)	<0.58 (ND)	<0.58 (ND)
2.2 / <0.57 (ND)	<0.58 (ND)	<0.58 (ND)
2.2	0	0

High Loadings of PFAS on spent carbon!

PFAS below detection on reactivated carbon extraction

# Destruction Efficiency Calculations from Spent Carbon to Furnace ; Furnace to Stack ; and overall Spent Carbon to Stack

	Total PFAS (lb/hr)	Incremental Destruction Removal Efficiency (DRE)	Overall DRE
Spent Carbon (29 compound list) <sup>1</sup>	0.748		
Furnace off-gas (36 compound list) <sup>2</sup>	$8.41 \times 10^{-5}$	99.989%	
Stack emissions (36 compound list) <sup>2</sup>	$4.88 \times 10^{-5}$	42.024%	99.993%

- **Reactivation Demonstrated >99.99% Destruction for Total PFAS**

# Calgon's Furnace & Abatement System PFAS DREs

DRE PFAS: >99.9%

Total DRE PFAS: >99.99%





# Fluoride Measurements

	Total PFAS (lb/hr)	Calculated Total Fluoride from PFAS (lb/hr)	Measured Total Fluoride (lb/hr)
Spent Carbon	0.748	0.396	9.05
Reactivated Carbon	0.000	0.000	2.61
Furnace off-gas	8.41E-05	5.47E-05	2.95
Abatement Dust	0.000	0.000	1.26

- **Mass balance at 61.4% on total fluoride**
- **Fluoride is very reactive with furnace linings, process equipment, EVERYTHING!**

Fluoride Mass  
Balances are very  
difficult in the field

# Conclusions & Key Findings



**Calgon's Reactivation is a unique process that thermally removes PFAS and achieves high destruction in the reactivation furnace and our robust abatement systems**



**Reactivation is very different than Regeneration**



**Reactivation is very different than Incineration**



**Calgon Carbon's proprietary reactivation process and conditions achieved > 99.99% PFAS destruction for total PFAS**



**High levels of hydrogen fluoride generated support mineralization of these compounds**



**Reactivation is a safe, proven, simple, cost-effective and fully commercial offering**



**Reactivation is sustainable process that has 80% reduction in CO<sub>2</sub>**

Contact:  
Jennifer Shultz  
Senior Technical Sales Representative  
Jennifer.Shultz@Kuraray.com

<https://www.nomorepfas.com/>

<https://www.calgoncarbon.com/>

# Thank You!