# SMART Remediation

*Activated Carbon Solutions for PFAS Removal & Destruction*

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SMART Toronto

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www.vertexenvironmental.ca

# Activated Carbon Solution for PFAS Removal and Destruction

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# Pure innovation

Calgon Carbon remains committed to its original goal: to help customers meet their toughest purification, separation, and concentration demands. When combined, Calgon Carbon, its European business, Chemviron, and the Kuraray Carbon Materials business make up the Environmental Solutions Division (ESD) of Kuraray.


## Calgon Carbon, Chemviron, and the Kuraray Carbon Materials business at a glance

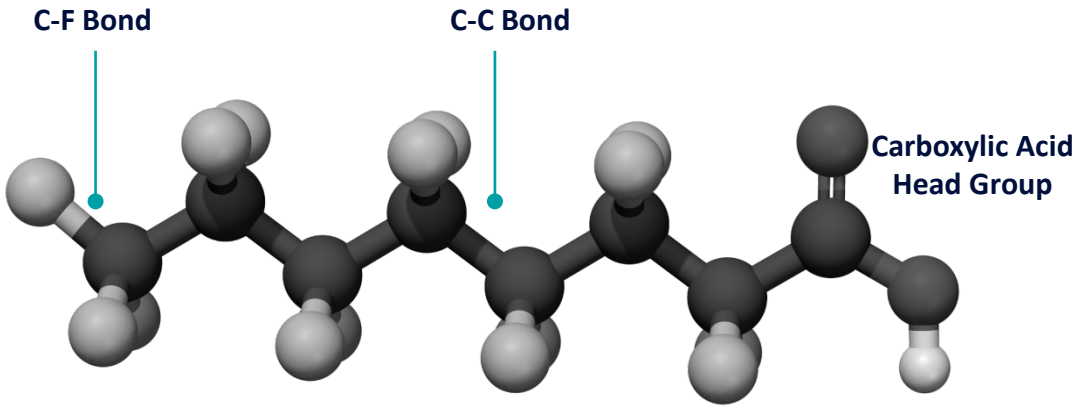
- Approximately $800 million net sales
- Almost 100 years of experience
- ~ 1,700 employees
- 27 offices
  Headquarters, R&D, Sales, and Service
- 19 manufacturing and reactivation plants
  Manufacturing, Reactivation, Equipment

## Kuraray at a glance

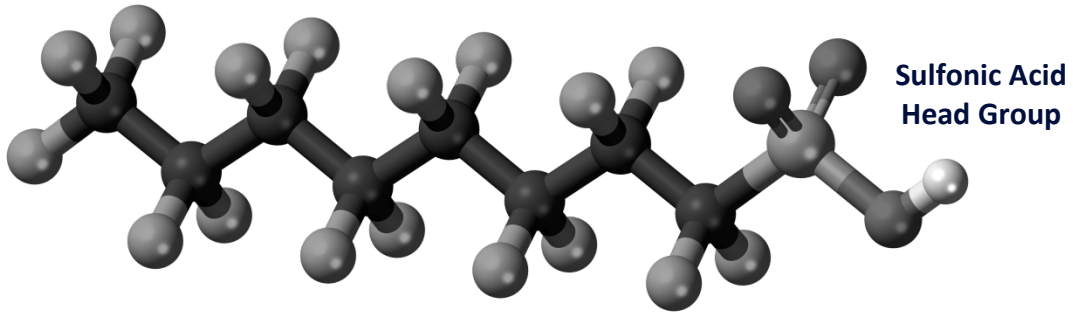
- Approximately $6 billion in annual sales
- Established June 1926
- Kuraray uses their unique technical strengths to create products that the world has never seen before.
- Business portfolio consists of five segments:
  - Vinyl Acetate
  - Isoprene
  - Functional Materials
  - Fibers and Textiles
  - Trading

# PFAS Overview

# PFAS Molecular Characteristics




PFOA MOLECULE




PFOS MOLECULE

**CHEMICALLY STABLE**

- Carbon Chain backbone
- C-F Bond

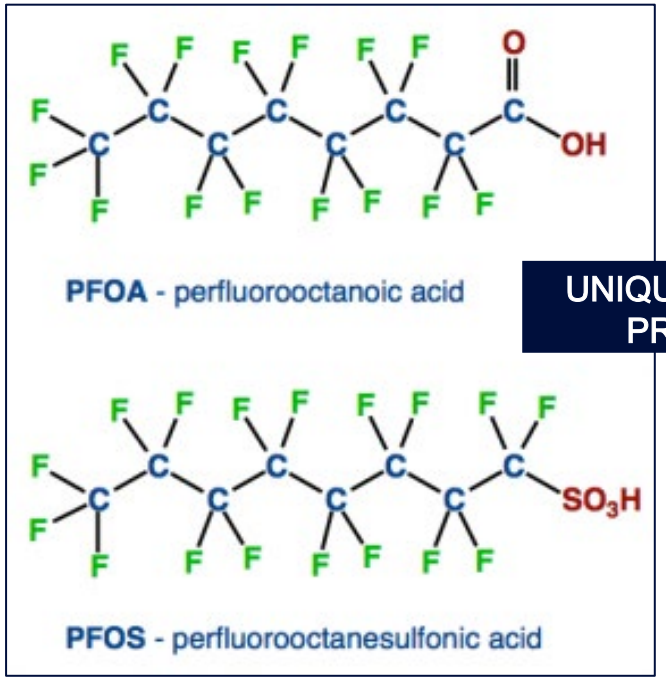
**RELATIVELY HIGH MOLECULAR WEIGHT**

**TYPICALLY LOW VAPOR PRESSURE**

**EASILY INFILTRATES INTO GROUNDWATER & SOIL**

**BIOACCUMULATES IN ORGANISMS**

# PFAS Life Cycle

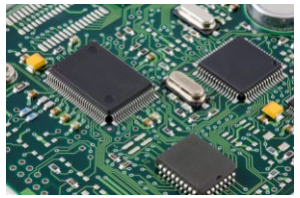



UNIQUE CHEMICAL PROPERTIES

Weather resistant

Non-stick cookware

Electronics



Food wrappers

Fire-fighting foam

Electroplated products

LONG TERM

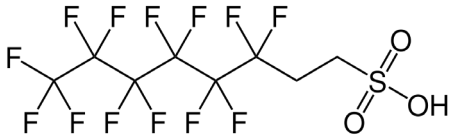
Treated Wastewater

Landfill

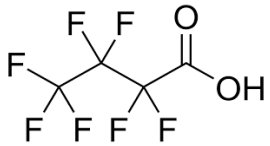
Thermal Destruction

Site Remediation

## Other PFAS



6:2-FTS



PFBA

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A Kuraray Company

# Basics of Activated Carbon
# Product Selection is Key

# Activated Carbon Comes From Different Materials

- Ash impurities inherited
- Transport pore structure and adsorption kinetics
- Hardness/Abrasion is inherited
- Raw material dictates uniqueness of product

**Bituminous Coal and Coconut Activated Carbons will have different performance**

COCONUT

BITUMINIOUS COAL

LIGNITE

WOOD

CalgonCarbon
A Kuraray Company

# Raw Materials for Activated Carbon





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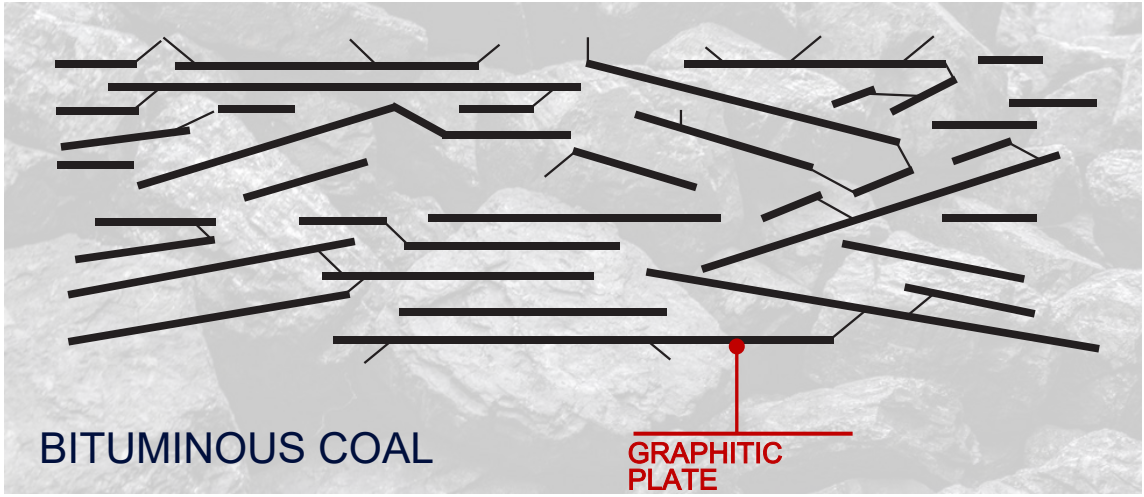
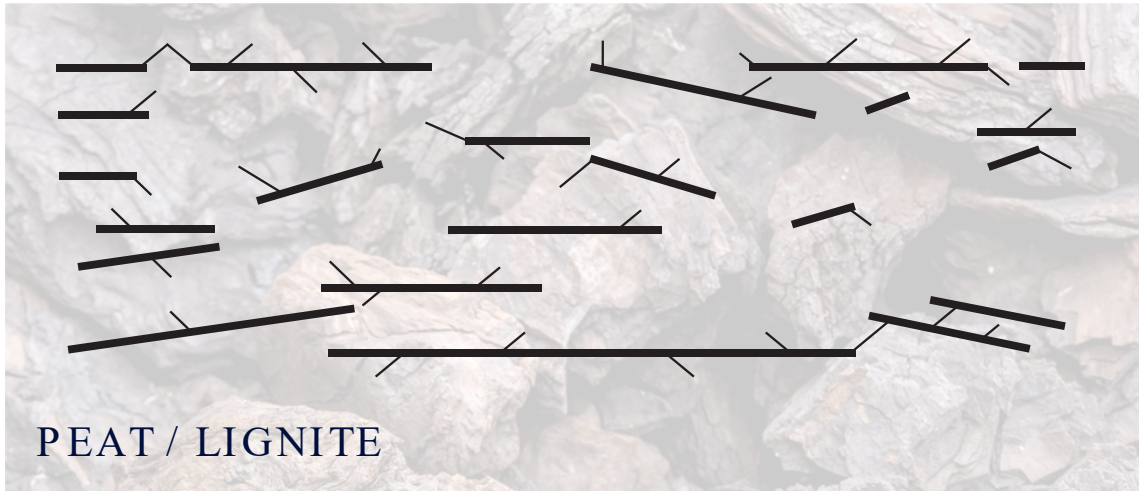
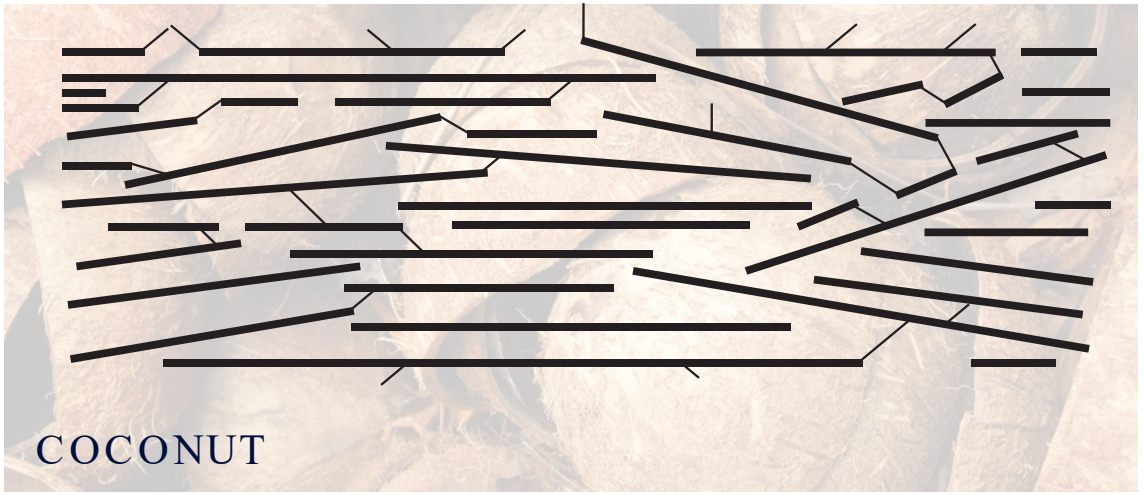
# Raw Material Selection is a Key Parameter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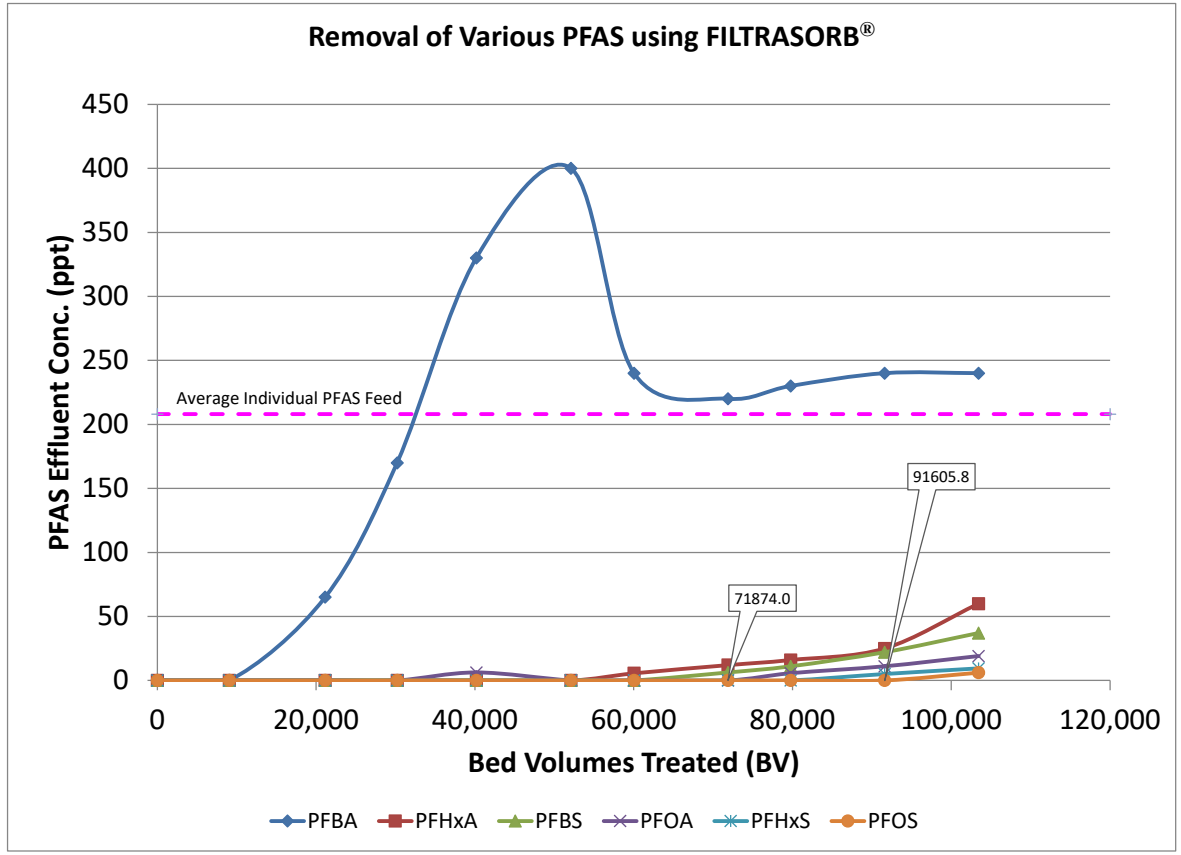
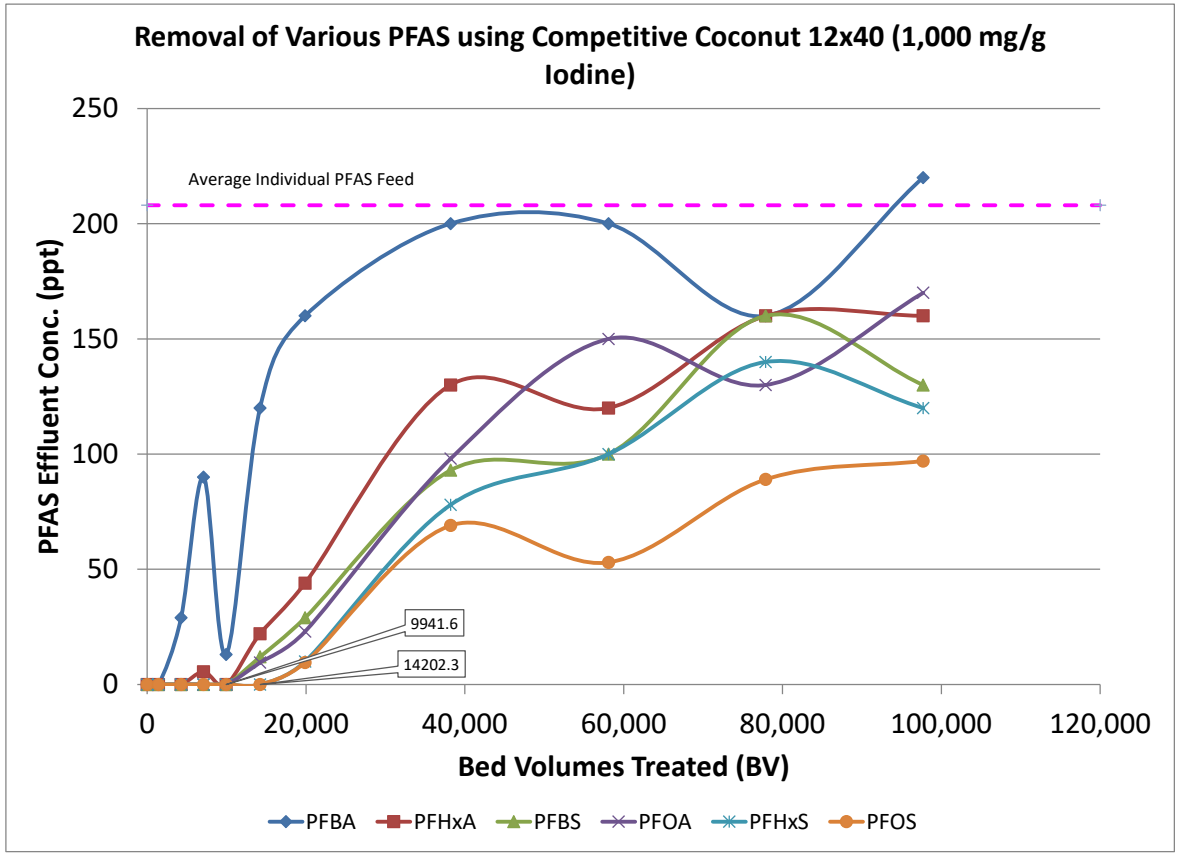
# Material Selection is Important to your Application

EBCT = 10 minutes | Mesh Size = 12x40 | Operation = Continuous | TOC = 1.2 mg/L

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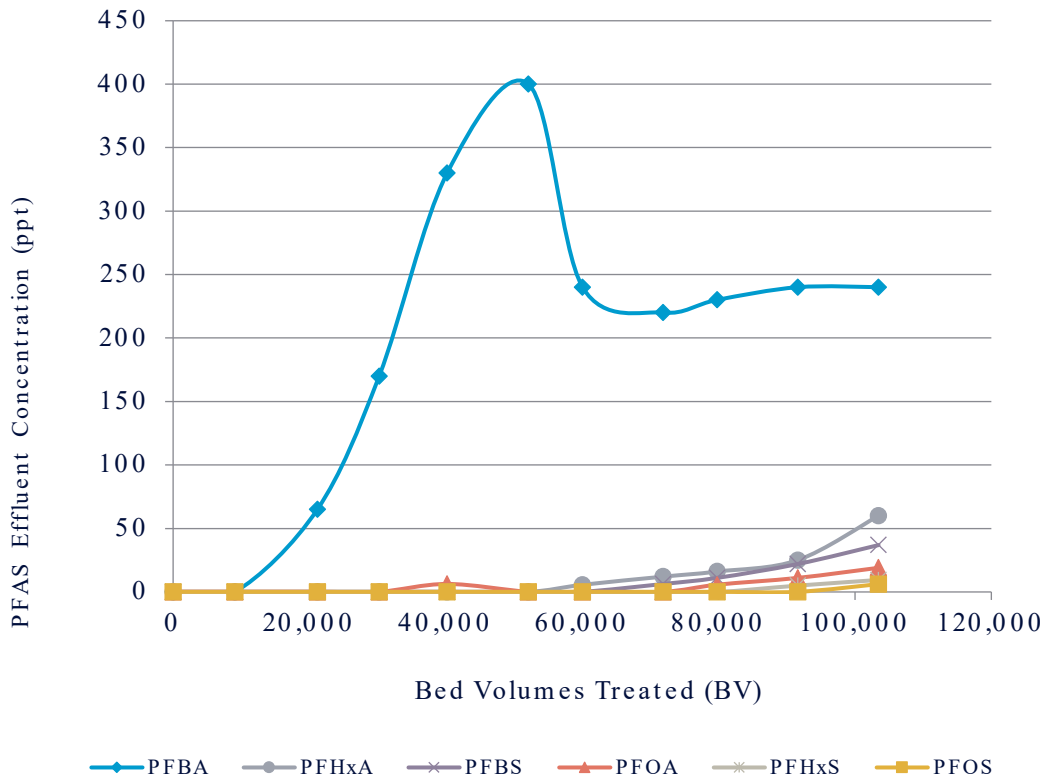
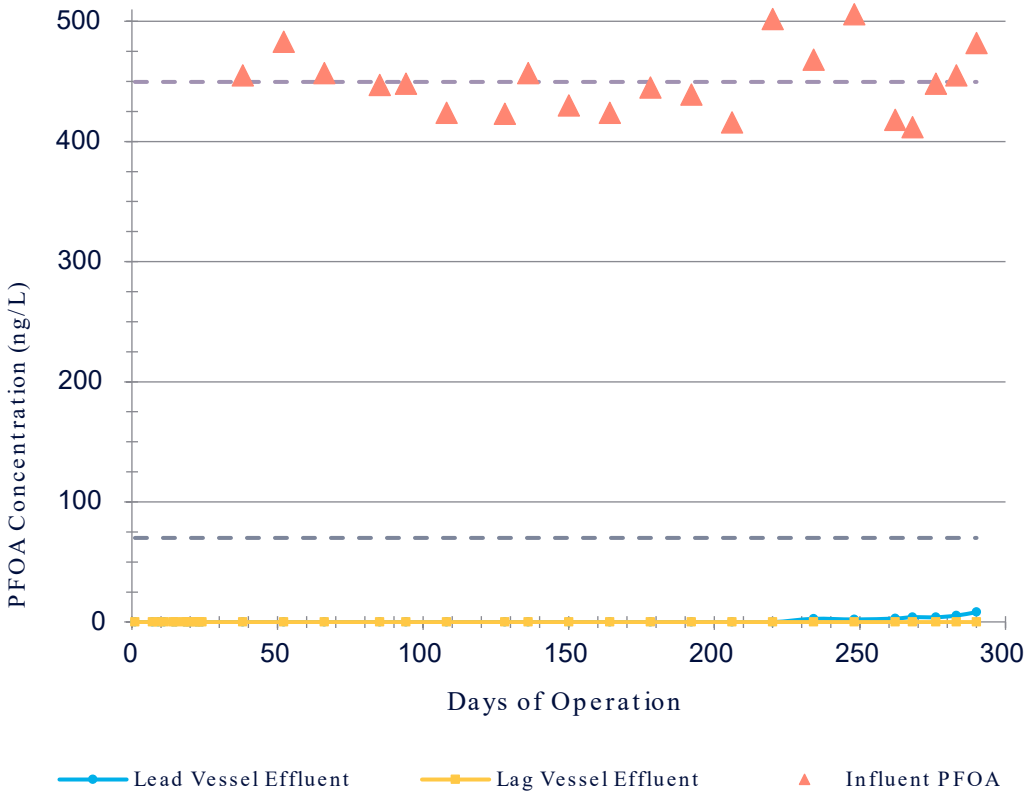
# Calgon Carbon's FILTRASORB® product is proven and capable of meeting non -detect for a range of PFAS

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




## Full-Scale Model 10 System 10 minutes EBCT



# Removing PFAS for over 20 years

- Granular Activated Carbon (GAC) and CCC's Equipment Line are proven treatment solutions for PFAS removal
- Over 100 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 abatements these compounds

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

Unrivaled technical service

# PFAS End of Life Considerations

## Carbon Reactivation and PFAS Destruction

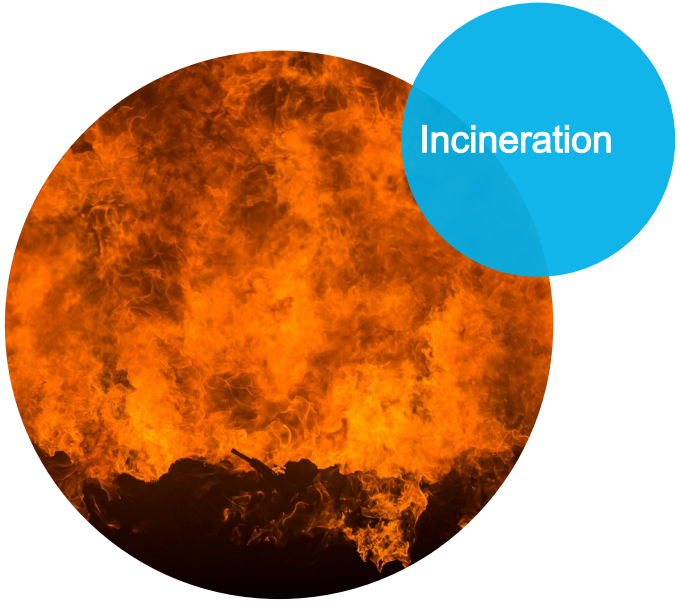
# Water treatment removes contaminants from water



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

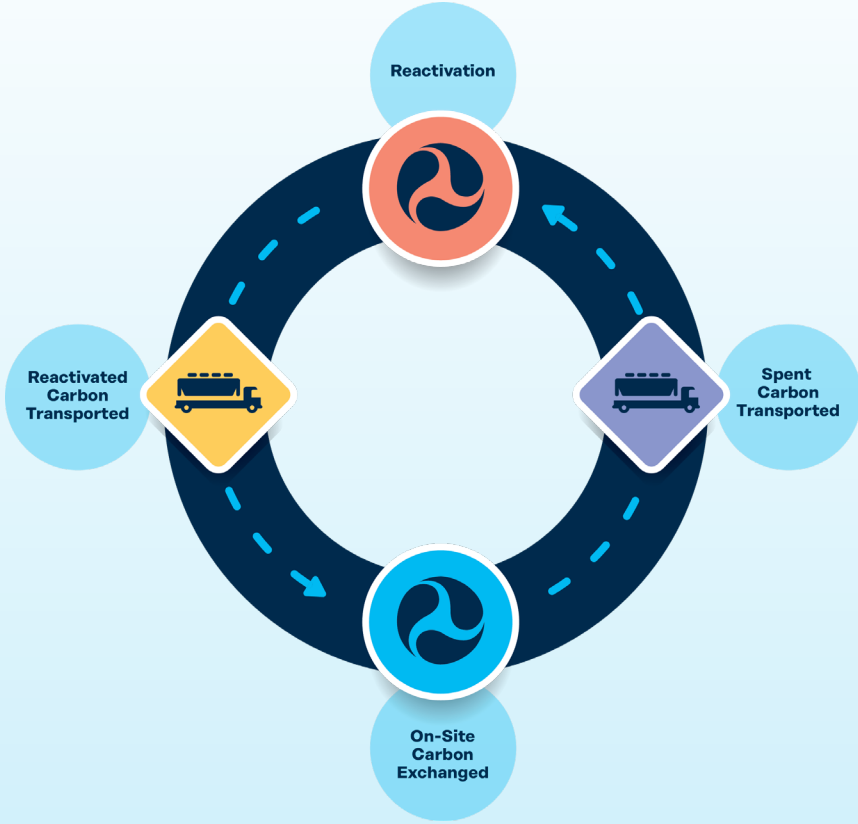
# Reactivation is a unique disposal & reuse for GAC ONLY

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





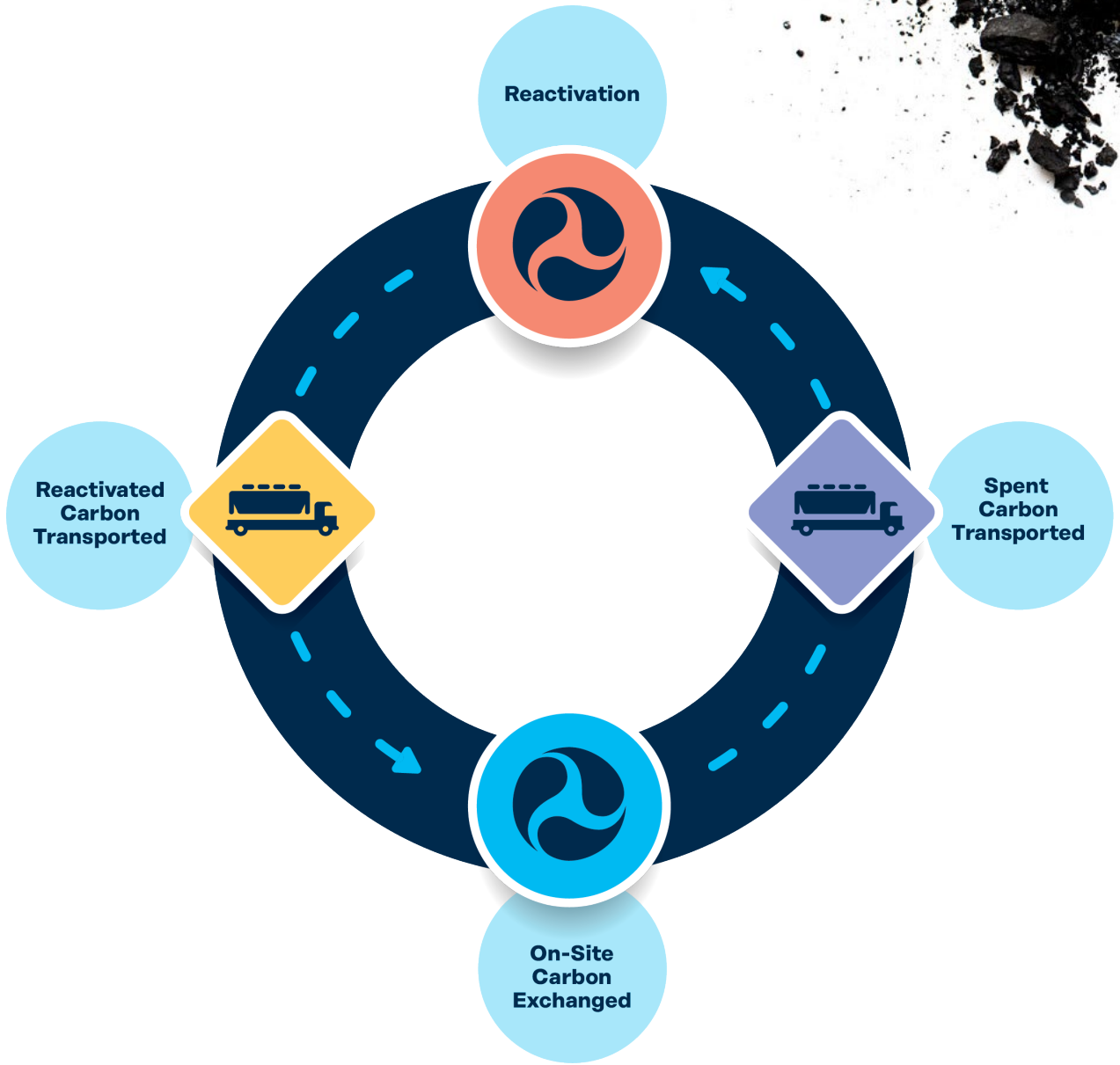
**Unique to Activated Carbon:**



# 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 $CO_2$ vs. the production of virgin carbon
- Lower cost than incineration and more sustainable



# Reactivation Chemistry

## Low temperature pre -treatment

- Drying of water at 100°C

## Physical processes and reactions

- Thermal Devolatilization and Desorption at 100-250°C

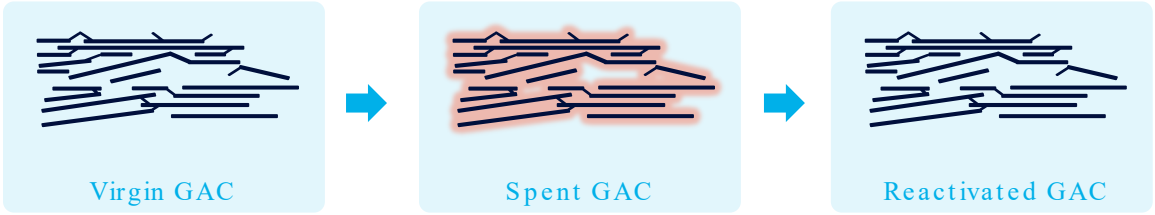
## High temperature carbon condensation reactions

- 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

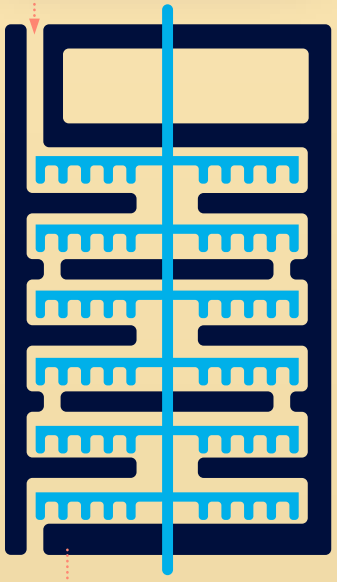


# Calgon's Reactivation is a unique process with multiple destructive technologies

1

## High Temperature Reactivation Furnace

Remove adsorbed species & high levels of destruction



Carbon Out

2

## Thermal Oxidizer/ Post -treatment

Further reduce species present from furnace offgas

3

## Chemical Scrubber

Remove acid gases, such as HF

4

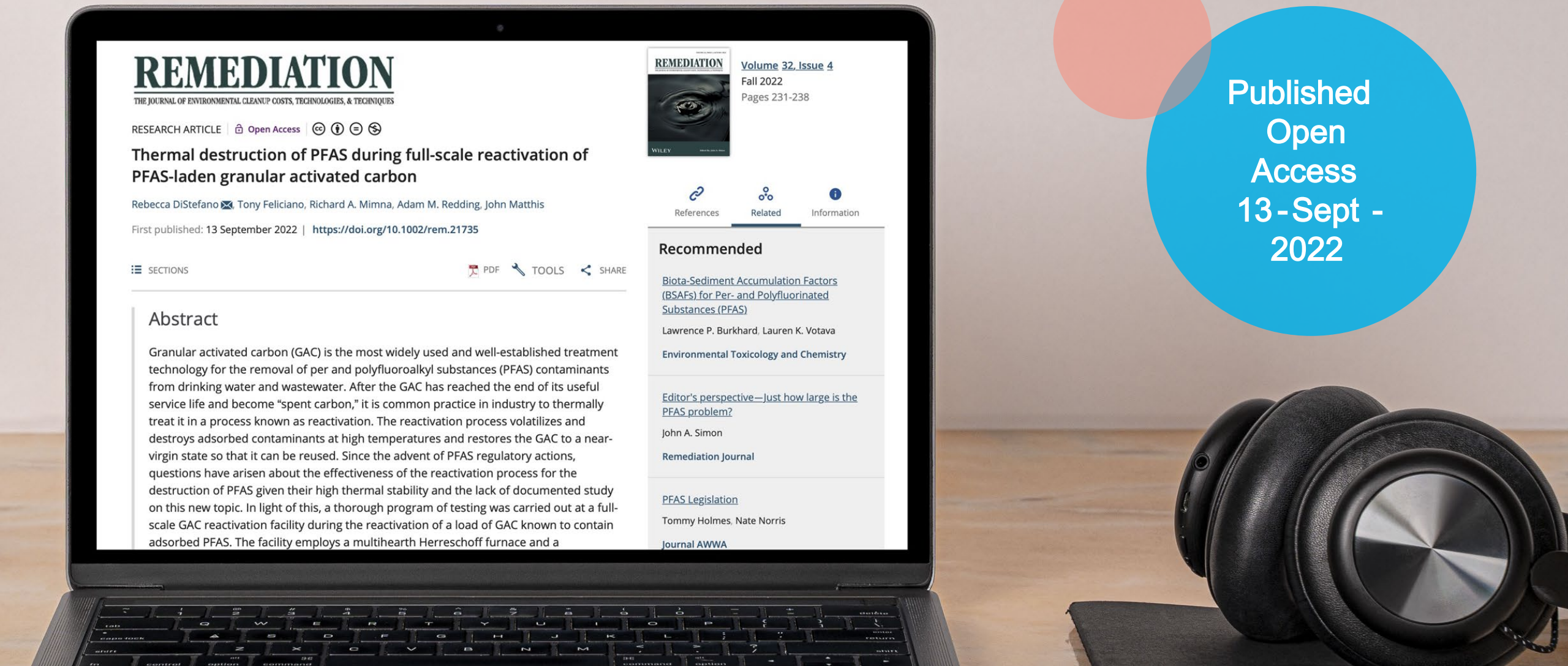
## Baghouse

Remove particulate matter

5

## Exhaust Stack

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

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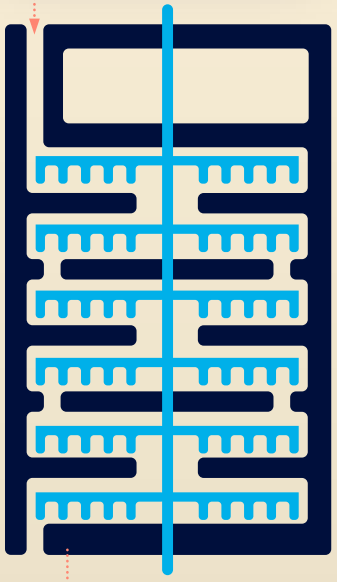
# Calgon's Reactivation is a Unique Process with Multiple Destructive Technologies

1

**High Temperature Reactivation Furnace**

Remove adsorbed species & high levels of destruction

Spent Carbon



Reactivated Carbon

**Solids Extraction** (ELL/LC-MS/MS) for PFAS

**Vapor Phase Analysis** (OTM-45) PFAS

2

**Thermal Treatment**

**Liquids Phase Analysis** (EPA 537 1.1) PFAS

3

**Chemical Scrubber**

Remove acid gases, such as HF

**Solids Extraction** (ELL/LC-MS/MS) for PFAS

4

**Baghouse**

Remove particulate matter

**Solids Extraction** (ELL/LC-MS/MS) for PFAS

**Vapor Phase Analysis** (OTM-45) PFAS

5

**Exhaust Stack**

**Best Commercially Available Analytical for PFAS was used**

# Calgon's Reactivation effectively removes PFAS below detection limits

| ng/g (ppb) | | Spent Carbon Composite Sample for Each Emissions Test | | | Reactivated Carbon Composite Sample for Each Emissions Test | | |
|---|---|---|---|---|---|---|---|
| | | TEST 1 | TEST 2 | TEST 3 | TEST 1 | TEST 2 | TEST 3 |
| PERFLUOROBUTANOIC ACID | PFBA | 6300 | 6700 | 4700 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| PERFLUOROPENTANOIC ACID | PFPEA | 2600 | 2500 | 1500 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROHEXANOIC ACID | PFHXA | 3700 | 2900 | 1600 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROHEPTANOIC ACID | PFHPA | 1600 | 1300 | 620 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROOCTANOIC ACID | PFOA | 18000 | 14000 | 5800 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUORONONANOIC ACID | PFNA | 88 | 72 | 53 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUORODECANOIC ACID | PFDA | 71 | 51 | 21 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROUNDECANOIC ACID | PFUNDA | 45 | 24 | 24 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUORODODECANOIC ACID | PFDODA | <9.7 | <9.1 | <9.6 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROTRIDECANOIC ACID | PFTRIDA | 59 | 30 | 28 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROTETRADECANOIC ACID | PFTETDA | <9.7 | <9.1 | <9.6 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROBUTANESULFONIC ACID | PFBS | 11000 | 8200 | 6300 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| PERFLUOROPENTANESULFONIC ACID | PFPES | 6700 | 4700 | 1200 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROHEXANESULFONIC ACID | PFHXS | 33000 | 22000 | 5900 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROHEPTANESULFONIC ACID | PFHPS | 5100 | 3100 | 810 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROOCTANESULFONIC ACID | PFOS | 16000 | 12000 | 6700 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUORONONANESULFONIC ACID | PFNS | 40 | 27 | 9.9 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUORODECANESULFONIC ACID | PFDS | 180 | 110 | 37 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUORODODECANESULFONIC ACID | PFDOS | <32 | <30 | <32 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| PERFLUOROOCTANESULFONAMIDE | PFOSA | 340 | 340 | 380 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| NMEFOSAA | NMEFOSA | 720 | 550 | 560 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| NETFOSAA | NETFOSAA | 610 | 520 | 440 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| HFPODA | GENX | 6500 | 40000 | 55000 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| 4:2 FLUOROTELOMER SULFONIC ACID | 4:2 FTS | <32 | <30 | <32 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| 6:2 FLUOROTELOMER SULFONIC ACID | 6:2 FTS | 290 | 110 | 800 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| 8:2 FLUOROTELOMER SULFONIC ACID | 8:2 FTS | <48 | <46 | <48 | <2.9 (ND) | <2.9 (ND) | <2.9 (ND) |
| 10:2 FTS | 10:2 FTS | <32 | <30 | <32 | <1.9 (ND) | <1.9 (ND) | <1.9 (ND) |
| PERFLUOROHEXADECANOIC ACID | | <9.7 | <9.1 | <9.6 | <0.58 (ND) | <0.58 (ND) | <0.58 (ND) |
| PERFLUOROOCTADECANOIC ACID | | <9.7 | <9.1 | <9.6 | 2.2 / <0.57 (ND) | <0.58 (ND) | <0.58 (ND) |
| SUM 29 PFAS COMPOUNDS: | | 112943 | 119234 | 92483 | 2.2 | 0 | 0 |

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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) [1] | 0.748 | | |
| Furnace off -gas (36 compound list) [2] | $8.41 \times 10^{-5}$ | 99.989% | |
| Stack emissions (36 compound list)[2] | $4.88 \times 10^{-5}$ | 42.024% | 99.993% |

- Reactivation Demonstrated >99.99% Destruction for Total PFAS

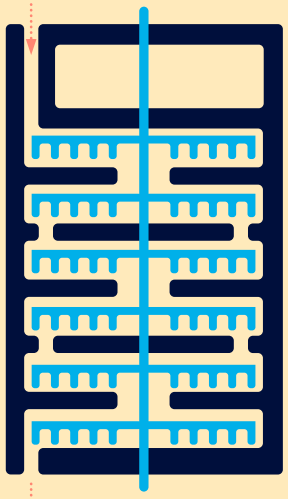
# Calgon's Furnace & Abatement System PFAS DREs

## DRE PFAS: >99.9%

## Total DRE PFAS: > 99.99 %

1
**High Temperature Reactivation Furnace**
Remove adsorbed species & high levels of destruction

Spent Carbon



Reactivated Carbon

2
**Thermal Treatment**
Further reduce species present from furnace offgas

3
**Chemical Scrubber**
Remove acid gases, such as HF

4
**Baghouse**
Remove particulate matter

5
**Exhaust Stack**

Robust, Additional Abatement Systems

# 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

- Activated carbon products such as FILTRASORB®400 are effective at removing PFAS from water and air
- Calgon Carbon's Reactivation is a unique process that thermally removes and destroys PFAS to a high degree
- Reactivation is different from 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 $CO_2$

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