From Forever Chemical to Forever Treated:

Sustainably Removing PFAS via GAC Treatment & Reactivation

Angela Rodriguez, PhD

Angela.Rodriguez@Kuraray.com

Technical Director

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Agenda

1. GAC Adsorption for PFAS Removal
2. GAC Reactivation Process Fundamentals
3. Peer-Reviewed Publications on Reactivation
4. Conclusions

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GAC Adsorption for PFAS Removal

What Is Activated Carbon?



Adsorbent media manufactured from carbon rich raw materials

- Coal (lignite, bituminous, anthracite)
- Wood
- Coconut shell

Removal process - adsorption

- Electrostatic interactions cause molecules in the surrounding fluid (air or water) to stick to the surface of the carbon and be removed from the fluid

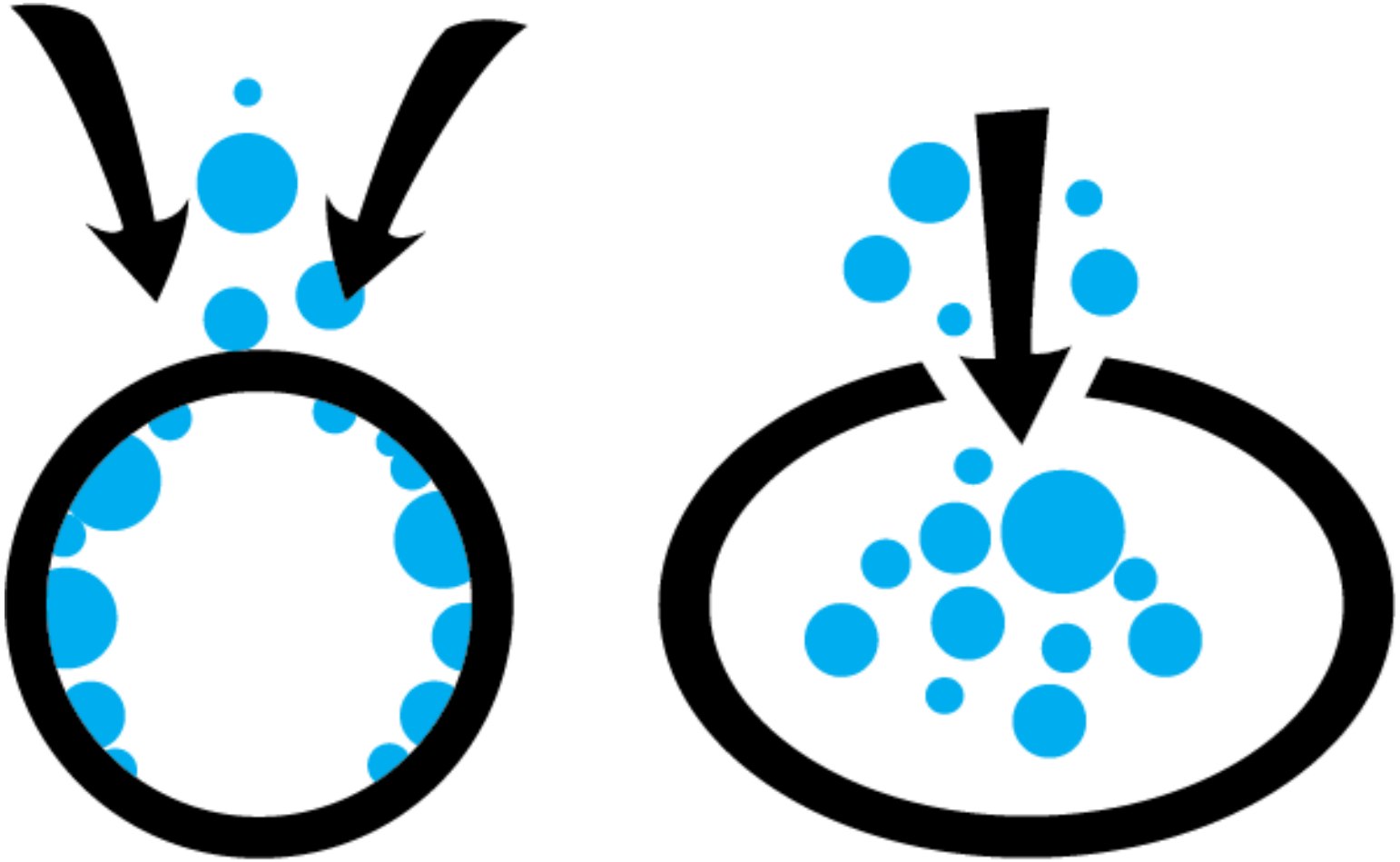
Best Available Technology (BAT) for dozens of organic contaminants regularly found in drinking water

Semi-renewable resource

- Potential for reactivation and reuse of granular media

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GAC Adsorbs Contaminants

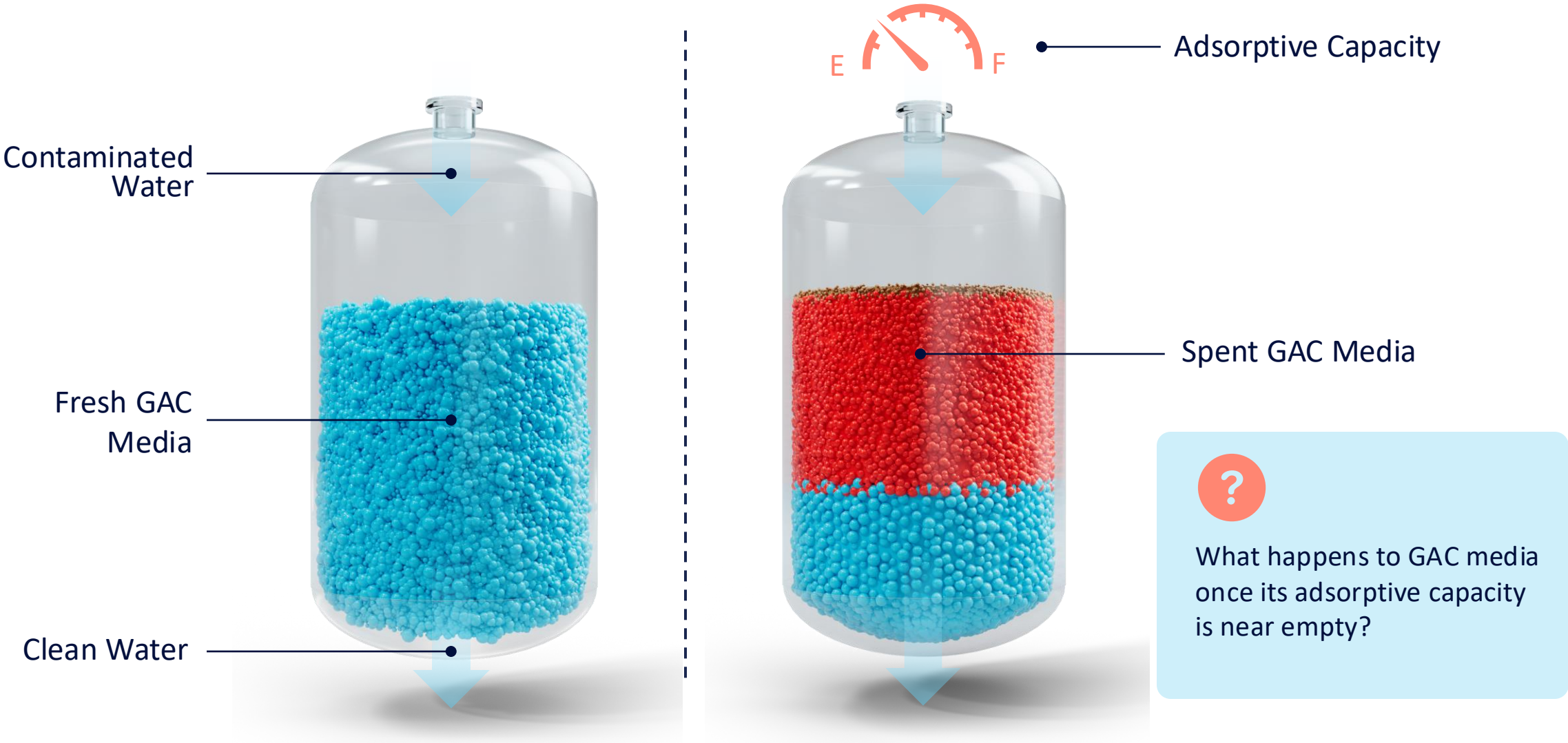


Adsorption
(Tape Sticks and **Ad**heres)

Absorption
(A Sponge Uptakes and **Ab**sorbs)

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GAC Filtration Adsorbs PFAS from Water



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Agenda

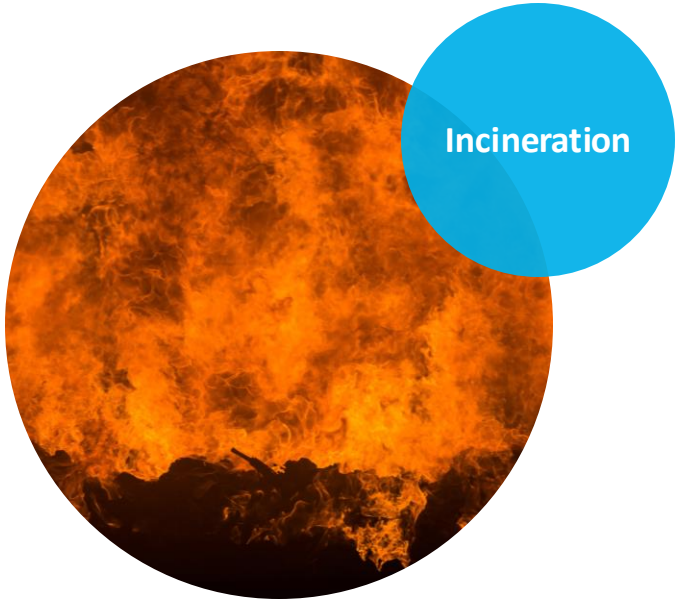
1. GAC Adsorption for PFAS Removal
2. **GAC Reactivation Process Fundamentals**
3. Peer-Reviewed Publications on Reactivation
4. Conclusions

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GAC Reactivation Process

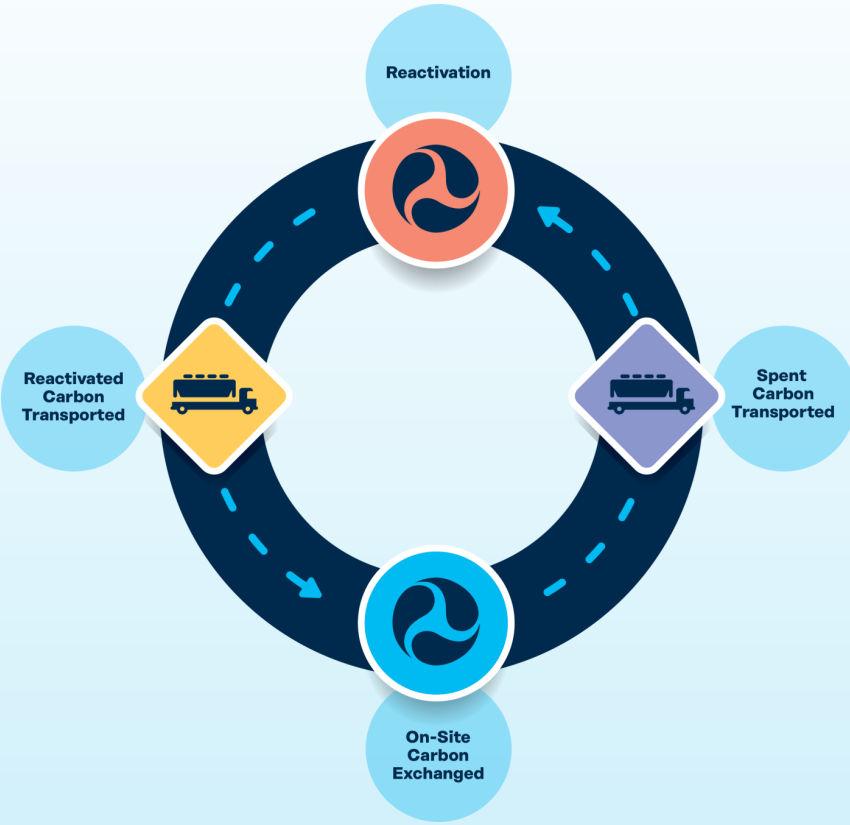
GAC Reactivation is a Unique Disposal & Reuse Option

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





Unique to activated carbon



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GAC Reactivation Fundamentals

The Reactivation Process

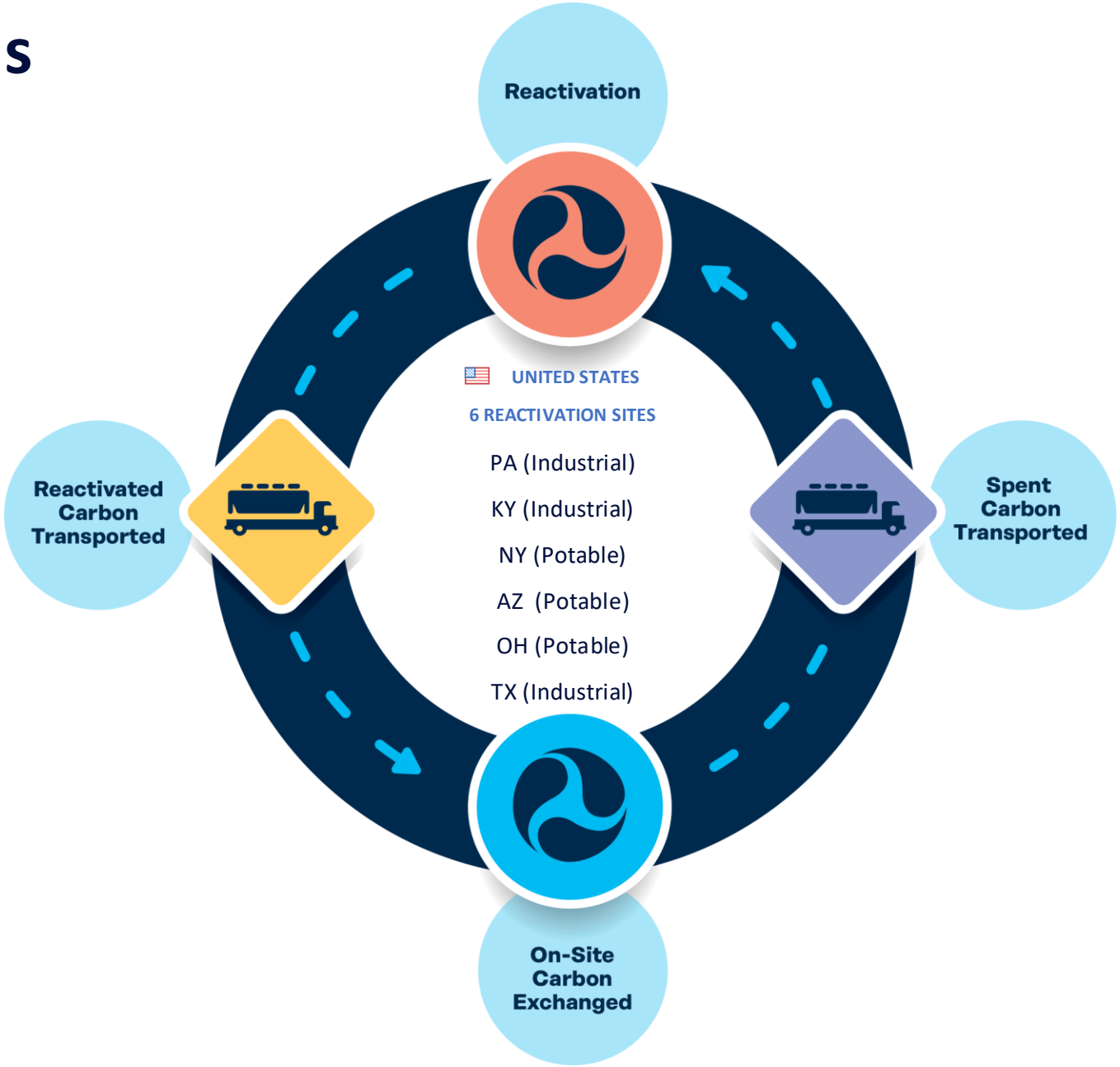
Carbon acceptance testing includes a series of evaluations to confirm a spent carbon can be effectively and safely reactivated.

Why do we test spent GAC?

- Product Quality
- Environmental Stewardship
- Equipment Integrity
- Personnel Safety

What are the advantages?

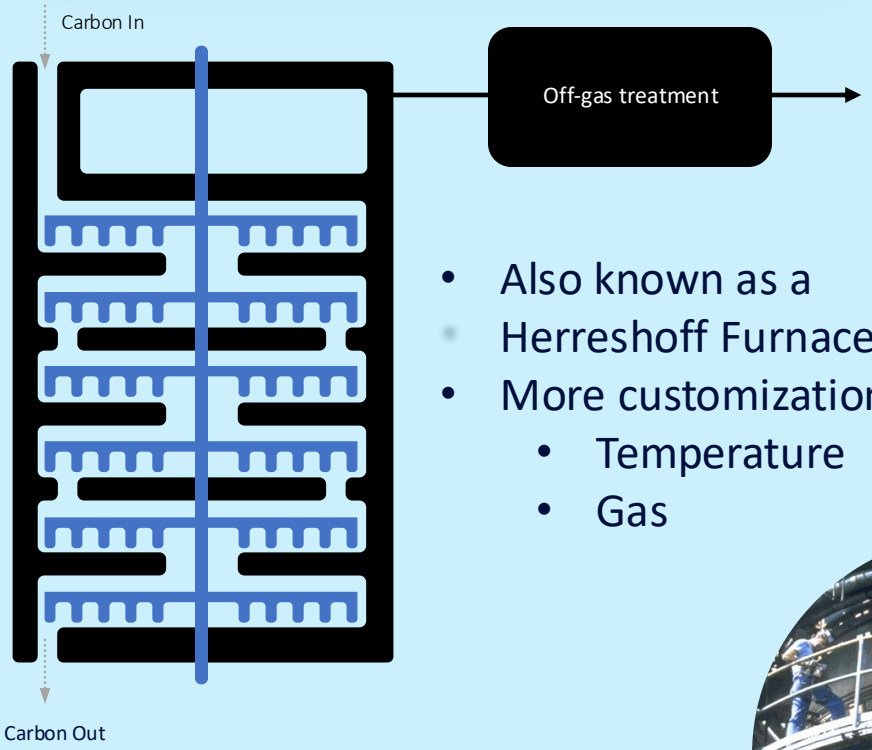
- **Certified** reactivation of spent media
- No landfill **liabilities**
- Lower **cost** than incineration
- **80%** reduction in CO_2 vs. the production of virgin carbon
- More **affordable** than virgin GAC and **comparable** performance
- **Secure** GAC supply for owner



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GAC Reactivation Process Types

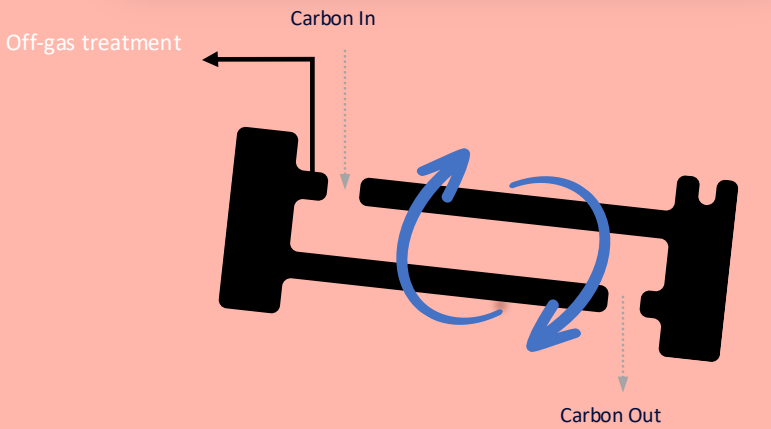
1 Multiple Hearth Furnace



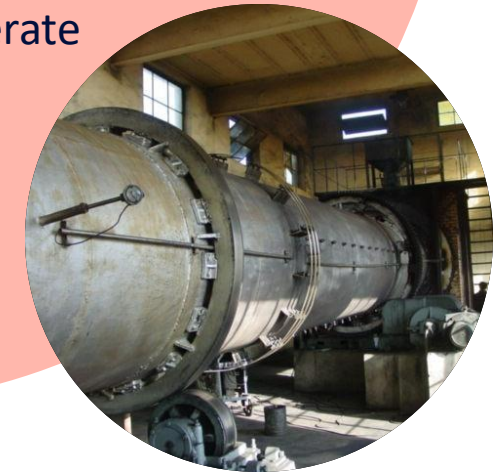
- Also known as a Herreshoff Furnace
- More customization
  - Temperature
  - Gas



2 Rotary Kiln Furnace



- Batch operation
- Simplest type of furnace to operate
- Easier product segregation



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GAC Reactivation Fundamentals

Reactivation Chemistry

Low temperature pre-treatment

- Driving off water at 100°C (evaporation)

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



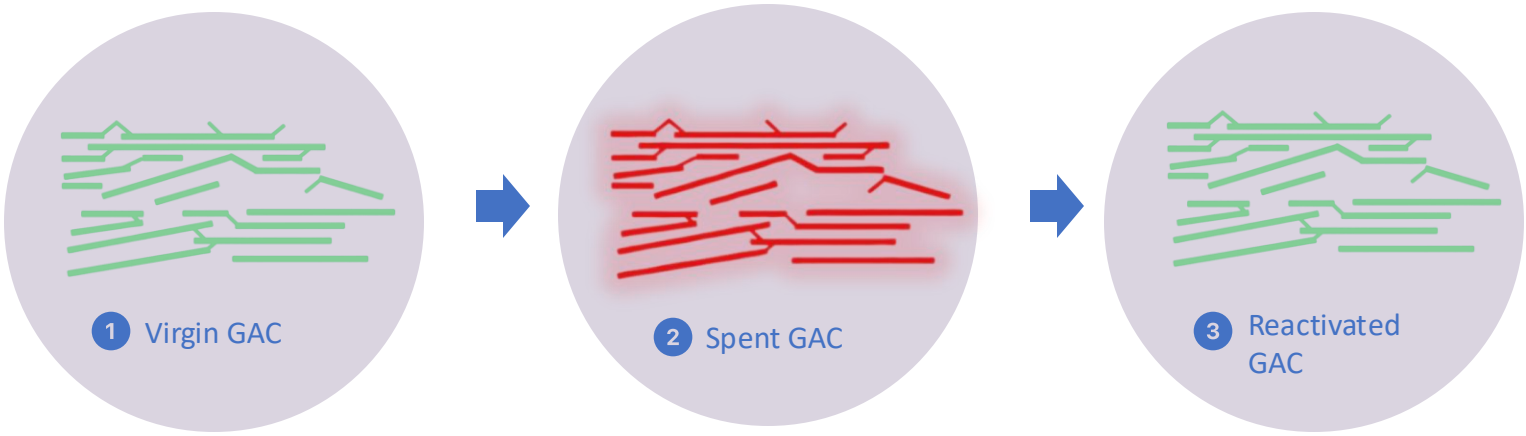
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Reactivation Process Fundamentals

Reactivation ≠ Regeneration

Reactivation

- High-temperature process
- Removes and destroys contaminants
- Restores capacity to near virgin levels



Regeneration

- Low temperature process
- Removes a portion of adsorbed species but does not destroy
- Results in a waste stream of removed contaminants



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Reactivation Process Fundamentals

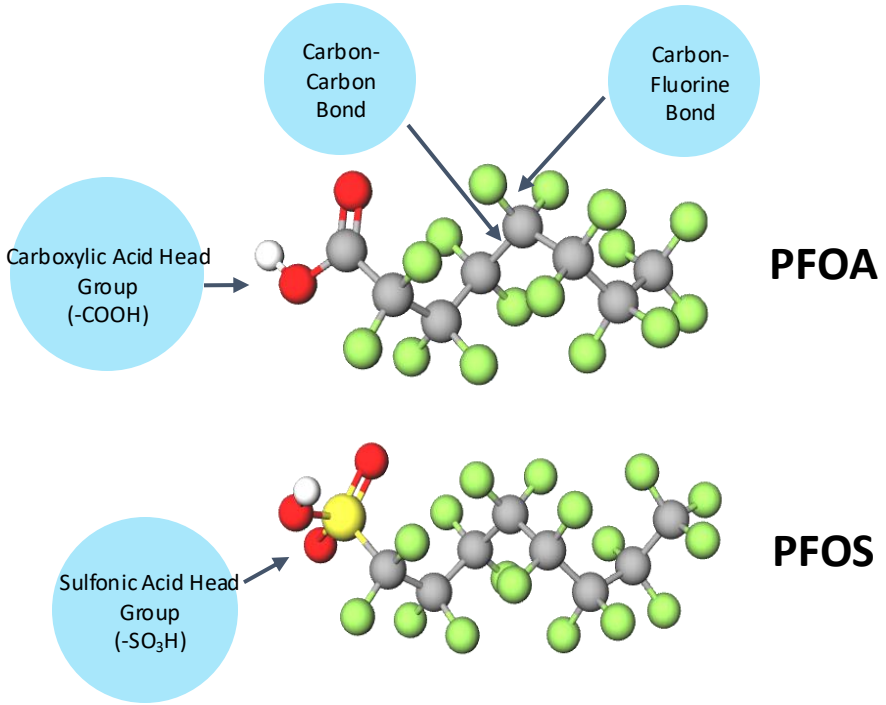
Example: High Temperatures are Needed for Spent GAC Processing

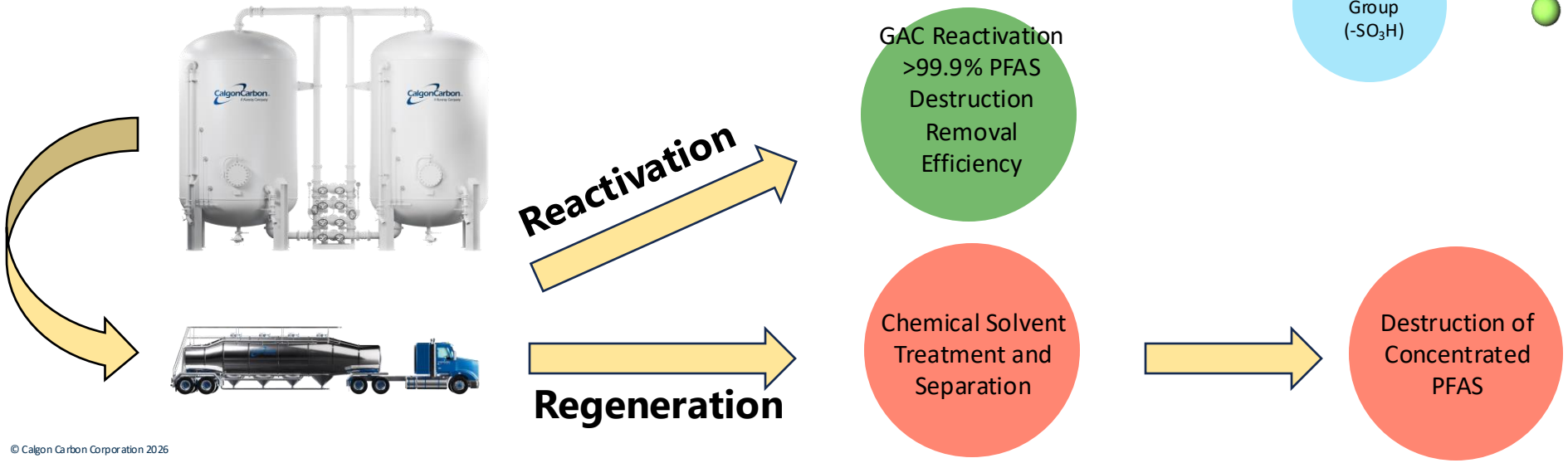
PFAS Properties

- High Stability Carbon-Fluorine Bonds
- Relatively High Molecular Weight
- Low Vapor Pressure

Reactivation vs Regeneration for PFAS Destruction

- 1-step process versus 2-step process
- Regeneration requires elution with a chemical solvent and creates a concentrated liquid waste stream





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3. **Peer-Reviewed Publications on Reactivation**
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Peer-Reviewed Publications on Reactivation

Peer-Reviewed Reactivation - Motivation

In light of PFAS being labelled a "forever-chemical", Calgon Carbon conducted a study to verify our unique reactivation process removes PFAS to below detectable levels on the reactivated carbon and are destroyed to >99.9%* in our process.

Why is it important?

- **Reactivated GAC can be reused**
  - Assists with market demand for GAC
- **Environmentally sound solution**

How is PFAS destruction verified in the reactivation process?

- **Sampling of inputs and outputs**
- **Calculating the destruction removal efficiency (DRE)**

$$\text{DRE (\%)} = \frac{\text{Input} - \text{Output}}{\text{Input}} \times 100$$

*DRE is calculated based on the EPA's defined methodology and, per this methodology, detection limits and any interference must be included in output

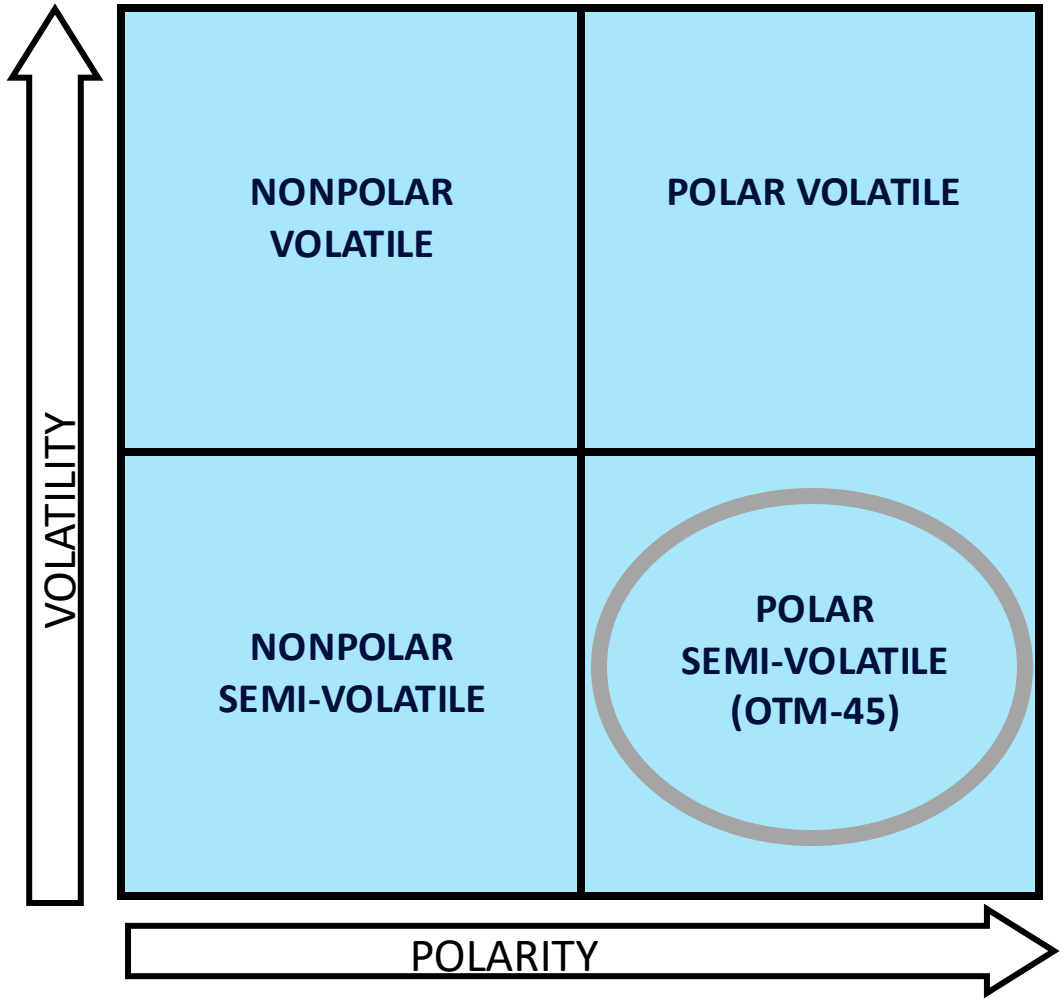
Peer-Reviewed Publications on Reactivation

Methodology: OTM-45

OTM-45

- EPA method used for stack emissions tests
- Vapor phase analysis
- Polar semi-volatile compounds
- Currently includes 49 targeted PFAS (C4 and larger)

Ex: PFOA, PFOS - drinking water compounds



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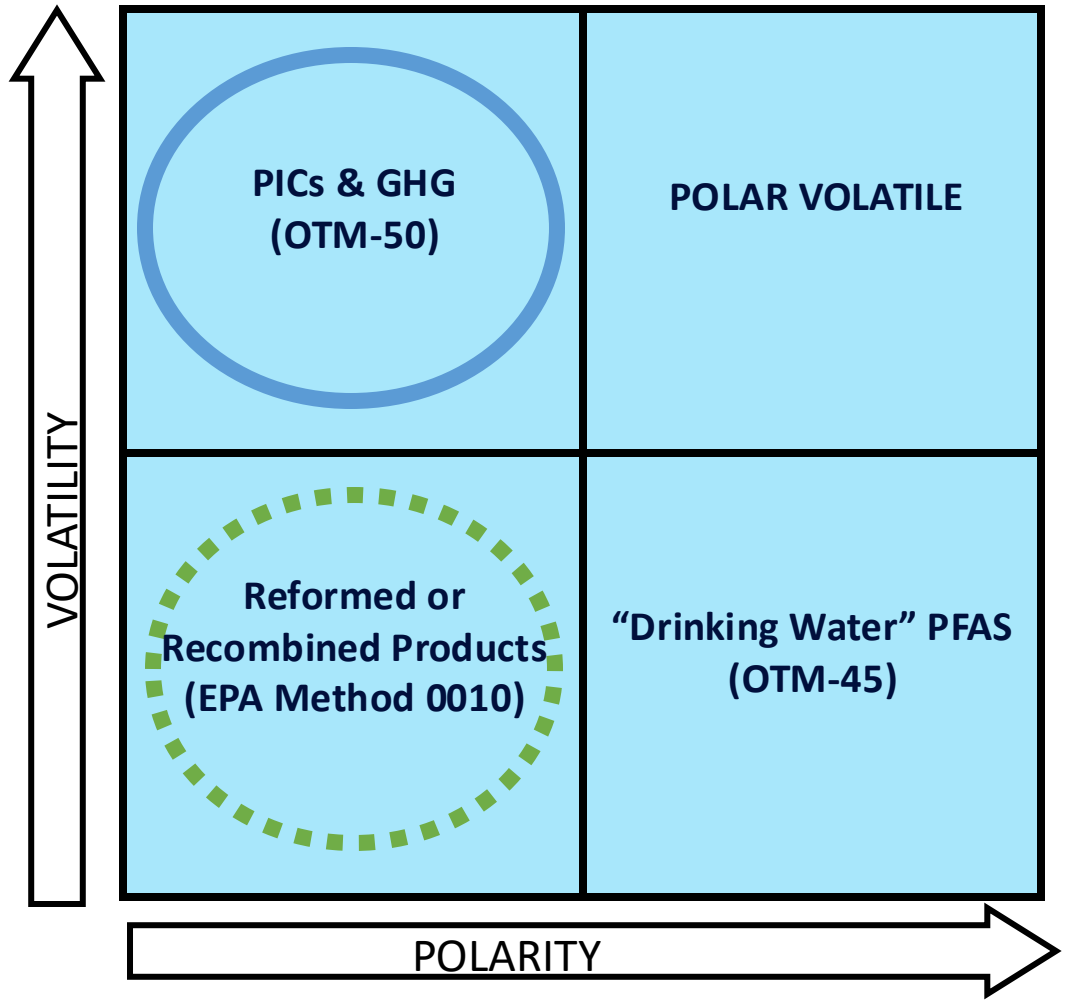
Peer-Reviewed Publications on Reactivation

Methodology: OTM 50 & EPA Method 0010

OTM-50

- Developed by the EPA to measure vapor phase PFAS
- Designed to be used as a complement to OTM-45
- Currently limited to 30 targeted C1-C8 PFAS
- Non-polar volatile compounds

Ex: carbon tetrafluoride (CF_4),C_2F_6
Volatile greenhouse gasses (GHG)
Products of incomplete destruction / combustion (PIDs & PICs)



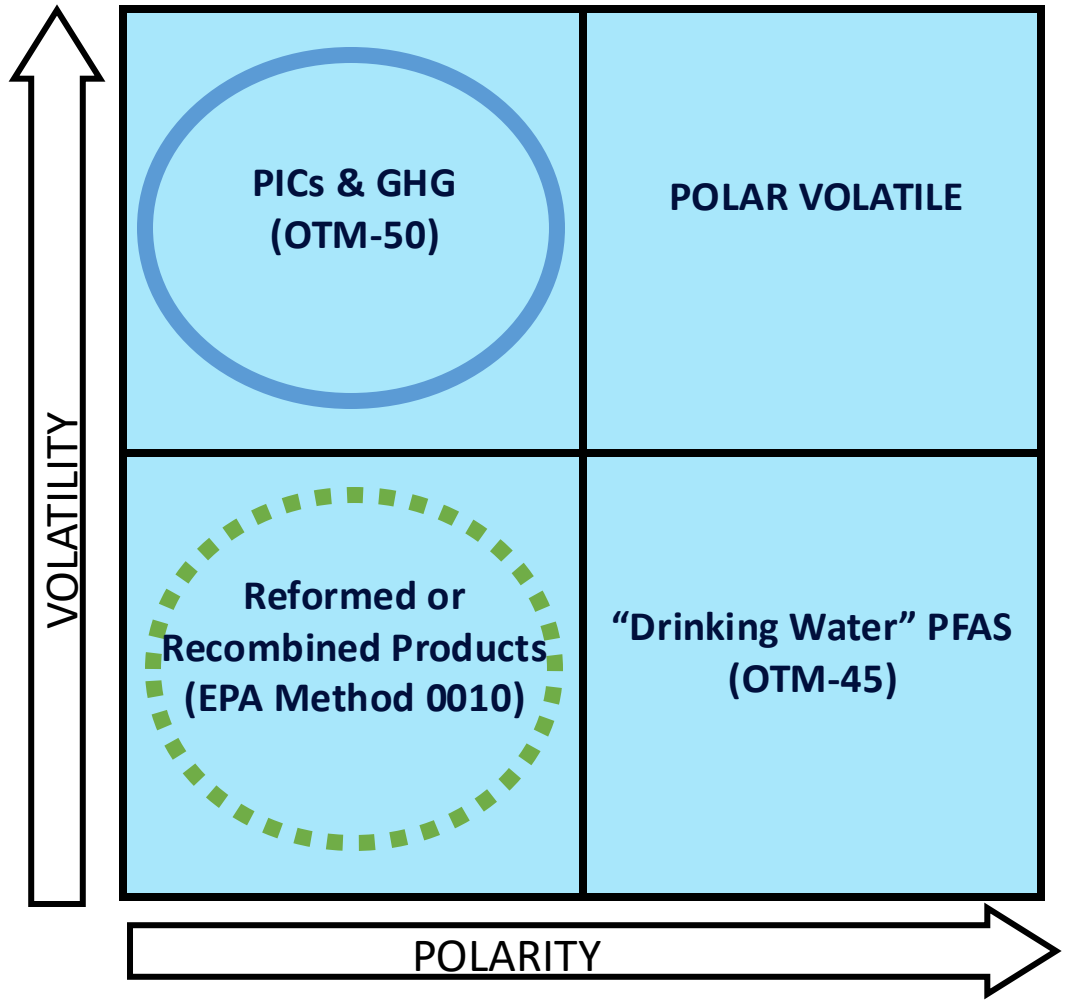
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Peer-Reviewed Publications on Reactivation

Methodology: OTM 50 & EPA Method 0010

EPA Method 0010

- Same set up as OTM-45 with a different extraction method
- Not ‘officially released’ yet, but a draft EPA method looking at reformed or recombined PFAS (~40 compounds)
- Non-polar semi-volatile compounds



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Peer-Reviewed Publications on Reactivation

Municipal Reactivation

Methodology

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

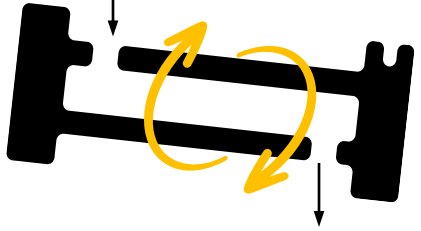
Vapor Phase Analysis
Trial 2023 (OTM-45)
Trial 2024 (OTM-45, OTM-50, EPA Method 0010)

1

High Temperature Reactivation Furnace

Remove adsorbed species & high levels of destruction

Spent Carbon



Reactivated Carbon

2

Thermal Treatment



3

Chemical Scrubber

Remove acid gases, such as HF

4

Baghouse

Remove particulate matter

5

Exhaust Stack

Vapor Phase Analysis
Trial 2023 (OTM-45)
Trial 2024 (OTM-45, OTM-50, EPA Method 0010)

Liquids Phase Analysis
(EPA 537 1.1) PFAS

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

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



- Study is comprised of **TWO** full scale studies conducted in 2023 and 2024
- Trial 2023 (OTM-45); Trial 2024 (OTM-45, OTM-50, EPA Method 0010)

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Peer-Reviewed Publications on Reactivation

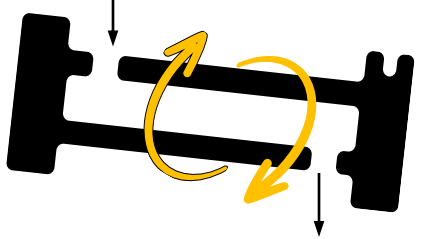
Finding: Reactivation Process Removes PFAS from the spent GAC to ND

1

High Temperature Reactivation Furnace

Remove adsorbed species & high levels of destruction

Spent Carbon



Reactivated Carbon

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



Spent Carbon



Reactivated Carbon

2023 Trial Results						
Concentration of PFAS on Spent GAC (ng/g)						
	Kiln #1			Kiln #2		
	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3
PFOA	830	540	190	790	600	220
PFOS	3100	1300	180	3000	1300	230
PFHxS	1300	480	120	1200	470	150
PFNA	85	56	13	83	60	15
PFBS	250	180	120	240	170	130
GenX	<1.2	<1.1	<1.1	<1.2	<1.2	<1.1

2023 Trial Results						
Concentration of PFAS on Reactivated GAC (ng/g)						
	Kiln #1			Kiln #2		
	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3
PFOA	<0.19	<0.19	<0.19	<0.19	<0.20	<0.20
PFOS	<0.19	<0.19	<0.19	<0.19	<0.20	<0.20
PFHxS	<0.19	<0.19	<0.19	<0.19	<0.20	<0.20
PFNA	<0.19	<0.19	<0.19	<0.19	<0.20	<0.20
PFBS	<0.39	<0.39	<0.37	<0.39	<0.40	<0.40
GenX	<0.96	<0.97	<0.93	<0.95	<0.99	<0.99

Reactivated GAC demonstrated **no PFAS remained above the detection limits** for the 2023 Trial

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Peer-Reviewed Publications on Reactivation

Finding: Reactivation Process Removes PFAS from the spent GAC to ND

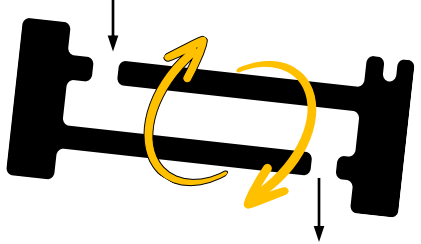
1

High Temperature Reactivation Furnace

Remove adsorbed species & high levels of destruction

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

Spent Carbon



Reactivated Carbon







Spent Carbon

2024 Trial Results						
Concentration of PFAS on Spent GAC (ng/g)						
	Kiln #1			Kiln #2		
	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3
PFOA	730	420	260	670	440	310
PFOS	2800	1400	700	2600	1600	960
PFHxS	1200	660	450	1000	760	590
PFNA	67	57	10	60	33	13
PFBS	190	170	66	180	130	77
GenX	2.7	< 1.5	< 1.4	< 1.5	< 1.5	< 1.4

Reactivated Carbon

2024 Trial Results						
Concentration of PFAS on Reactivated GAC (ng/g)						
	Kiln #1			Kiln #2		
	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3
PFOA	< 0.19	< 0.20	< 0.20	< 0.19	< 0.20	< 0.20
PFOS	< 0.19	< 0.20	< 0.20	< 0.19	< 0.20	< 0.20
PFHxS	< 0.19	< 0.20	< 0.20	< 0.19	< 0.20	< 0.20
PFNA	< 0.19	< 0.20	< 0.20	< 0.19	< 0.20	< 0.20
PFBS	< 0.38	< 0.40	< 0.40	< 0.39	< 0.40	< 0.40
GenX	< 0.94	< 1.0	< 0.99	< 0.97	< 1.0	< 0.99

Reactivated GAC demonstrated **no PFAS remained above the detection limits** for the 2024 Trial

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Peer-Reviewed Publications on Reactivation

Finding: Overall DRE > 99.9% for Total PFAS

Vapor Phase Analysis
Trial 2023 (OTM-45)
Trial 2024 (OTM-45, OTM-50, EPA Method 0010)

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

2 **Thermal Treatment**

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

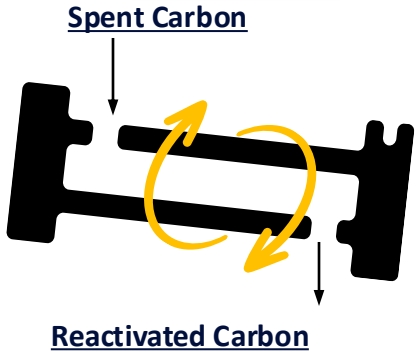
4 **Baghouse**
Remove particulate matter

5 **Exhaust Stack**

Liquids Phase Analysis
(EPA 537 1.1) PFAS

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

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





2023 Trial Results

	Total PFAS Mass Rate (lb/h)	Incremental DRE (%)	Overall DRE (%)
GAC Feed	$2.8\times10^{-3} - 14\times10^{-3}$	-	-
Kiln Outlet	3.1×10^{-5}	99.644	-
Stack Outlet			
(1) w/ GenX, w/ ND values	5.1×10^{-6}	-	99.897
(2) w/ GenX, w/o ND values	3.5×10^{-6}	-	99.936
(3) w/o GenX, w/ ND values	2.1×10^{-6}	-	99.953
(4) w/o GenX, w/o ND values	0.51×10^{-6}	-	99.993

Key Findings

- **> 99.89% PFAS DRE** was achieved using the most conservative calculation methodology (w/ GenX and w/ ND values) for the 2023 Trial
- **Overall process DRE was > 99.99%** when calculated without GenX and/or non-detect species for the 2023 Trial

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Peer-Reviewed Publications on Reactivation

Finding: Overall DRE > 99.9% for Total PFAS

Vapor Phase Analysis
Trial 2023 (OTM-45)
Trial 2024 (OTM-45, OTM-50, EPA Method 0010)

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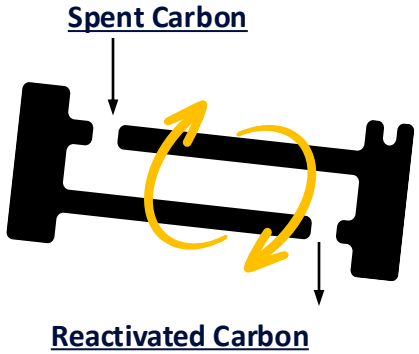
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Liquids Phase Analysis
(EPA 537 1.1) PFAS

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

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



2024 Trial Results			
	Total PFAS Mass Rate (lb/h)	Incremental DRE (%)	Overall DRE (%)
GAC Feed	$5.8\times10^{-3} - 14.7\times10^{-3}$	-	-
Kiln Outlet	2.4×10^{-7}	99.997	-
Stack Outlet			
(1) w/ GenX, w/ ND values	3.5×10^{-6}	-	99.979
(2) w/ GenX, w/o ND values	2.6×10^{-6}	-	99.984
(3) w/o GenX, w/ ND values	1.5×10^{-6}	-	99.992
(4) w/o GenX, w/o ND values	0.79×10^{-6}	-	99.995



Key Findings

- **> 99.9% PFAS DRE** was achieved using the most conservative calculation methodology (w/ GenX and w/ ND values) for the 2024 Trial
- **Overall process DRE was > 99.99%** when calculated without GenX and/or non-detect species for the 2024 Trial

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Peer-Reviewed Publications on Reactivation

Finding: OTM-45 Methodology – ND and GenX Values Require a Deeper Look

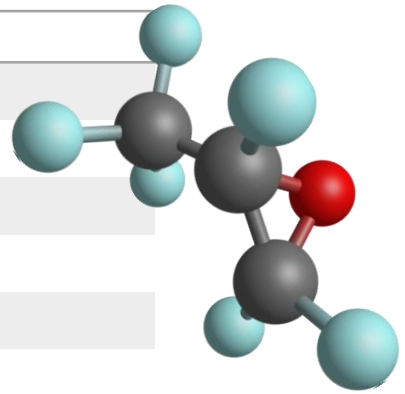
Vapor Phase Analysis (OTM-45) PFAS

5

Exhaust Stack



2024 Average Stack Outlet Emissions (lb/h) and DRE (%)		
PFOA	6.4×10^{-8}	99.997%
PFOS	1.9×10^{-8}	99.9998%
PFHxS	6.2×10^{-9}	99.9998%
PFNA	1.0×10^{-8}	99.994%
PFBS	3.7×10^{-8}	99.994%
GenX	2.0×10^{-06}	56.49%
2023 Average Stack Outlet Emissions and DRE		
PFOA	6.3×10^{-8}	99.996%
PFOS	1.2×10^{-8}	99.9993%
PFHxS	8.6×10^{-9}	99.9991%
PFNA	6.2×10^{-8}	99.954%
PFBS	2.1×10^{-8}	99.997%
GenX	3.1×10^{-6}	37.142%



Key Findings

1. GenX measurements in the laboratory blanks
2. The DREs for PFOA and PFOS were **> 99.99%** in both trials

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Peer-Reviewed Publications on Reactivation

Finding: 30 targeted C1-C8 PFAS (including PICs/PIDs) were ND

OTM-50

- Developed by the EPA to measure vapor phase PFAS
- Designed to be used as a complement to OTM-45
- Currently limited to **30 targeted C1-C8 PFAS**
- Non-polar volatile compounds

Ex: carbon tetrafluoride (CF_4),C_2F_6
Volatile greenhouse gasses (GHG)
Products of incomplete destruction/combustion (PIDs & PICs)

PIC/PID Emission Testing (µg/m³)									
	Kiln #1			Kiln #2			Stack		
	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3
Tetrafluoromethane	< 16.7	< 5.4	< 5.45	< 5.68	< 5.36	< 5.89	< 65.1	< 5.33	< 5.61
Hexafluoroethane	< 1.66	< 0.535	< 0.541	< 0.563	< 0.532	< 0.584	< 6.46	< 0.528	< 0.556
Tetrafluoroethene	< 1.43	< 0.463	< 0.468	<0.487	< 0.46	< 0.505	< 5.59	< 0.457	< 0.481
Trifluoromethane	< 4.07	< 1.31	< 1.33	< 1.38			< 15.9	< 1.3	< 1.37
Octafluoropropane	< 3.5	< 1.13	< 1.14	< 1.			.6	< 1.11	< 1.17
Difluoromethane	< 4.23	< 1.37	< 1.38					< 1.35	< 1.42
Fluoromethane	< 26.4	< 8.52	< 8.6					< 8.41	< 8.85
1,1,1,2,2-Pentafluoroethane	< 3.11	< 1.01	< 1.02					.993	< 1.05
Hexafluoropropene	< 1.63	< 0.526	< 0.					19	< 0.546
Hexafluoropropylene oxide	< 129	< 41.6							< 43.2
Decafluorobutane	< 2.77	< 0.894							< 0.929
Dodecafluoropentane	< 6.25	< 2.02							< 2.1
Tetradecafluorohexane	< 6.55	< 2.12							< 2.2
1H-Perfluoropentane	< 4.6	< 1.49							< 1.55
Hexadecafluoroheptane	< 3.01	< 0.971							< 1.01
Heptafluoropropyl 1,2,2,2-tetrafluoroethyl ether	< 3.21	< 1.04							< 1.08
1H-Perfluorohexane	< 2.6	< 0.841							< 0.874
1H-Perfluoroheptane	< 4.87	< 1.57							< 1.64
2H-Perfluoro-5-methyl-3,6-dioxanonane	< 3.85	< 1.24							< 1.29
1H-Perfluorooctane	< 3.42	< 1.1							< 1.15
Octadecafluorooctane	< 3.9	< 1.26							< 1.31
1H-Nonafluorobutane	< 3.15	< 1.02	<						< 1.06
1H-Heptafluoropropane	< 1.51	< 0.489	< 0.					83	< 0.509
Ethane, 1,1,1,2-tetrafluoro-	< 3.56	< 1.15	< 1.16					1.13	< 1.19
1,1,1-Trifluoroethane	< 7.16	< 2.31	< 2.34					< 2.28	< 2.4
Chlorodifluoromethane	< 4.69	< 1.52	< 1.53					< 1.5	< 1.57
Chlorotrifluoromethane	< 3.36	< 1.09	< 1.1	< 1.			.1	< 1.07	< 1.13
Octafluorocyclobutane	< 1.55	< 0.501	< 0.506	< 0.527			< 6.04	< 0.494	< 0.52
Octafluorocyclopentene	< 3.61	< 1.17	< 1.18	< 1.23	< 1.16	< 1.27	< 14.1	< 1.15	< 1.21
Trichlorofluoromethane	< 4.89	< 1.58	< 1.6	< 1.66	< 1.57	< 1.73	< 19.1	< 1.56	< 1.64
1,1,2-Trichloro-1,2,2-trifluoroethane	< 1.81	< 0.586	< 0.592	< 0.617	< 0.582	< 0.64	< 7.07	< 0.579	< 0.609
Chlorotrifluoroethene	< 1.4	< 0.452	< 0.456	< 0.476	< 0.449	< 0.493	< 5.45	< 0.446	< 0.47
Vinyl Fluoride	< 2.32	< 0.749	< 0.756	< 0.788	< 0.744	< 0.818	< 9.04	< 0.739	< 0.778

Key Findings

- Emission samples from the **stack and kiln outlets** were ND for all compounds tested via OTM-50

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Peer-Reviewed Publications on Reactivation

Finding: ~40 targeted reformed or recombined PFAS were ND

EPA Method 0010

- Same set up as OTM-45 with a different extraction method
- Not ‘officially released’ yet, but a draft EPA method looking at reformed or recombined PFAS (~40 compounds)
- Non-polar semi-volatile compounds

PIC/PID Emission Testing (µg/m³)									
	Kiln #1			Kiln #2			Stack		
	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3	Test #1	Test #2	Test #3
1,1'-Biphenyl, 4-bromo-4'-fluoro-	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
1,2-Dibromo-4,5-difluorobenzene	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
1,2-Dibromotetrafluorobenzene	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
1,3-Dibromo-5-fluorobenzene	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
1,3-Dibromotetrafluorobenzene	< 80.7	< 74.3	< 14	< 13			< 12	< 12	< 13
1-Bromo-2,3,4,5-tetrafluorobenzene	< 80.7	< 74.3	< 14	< 13			< 12	< 12	< 13
1-Bromo-2-fluorobenzene	< 80.7	< 74.3	< 14					< 12	< 13
1-Bromo-3,5-difluorobenzene	< 80.7	< 74.3	< 14					< 12	< 13
1-Bromo-4-fluoronaphthalene	< 80.7	< 74.3	< 14					12	< 13
1-Bromo-5-fluoronaphthalene	< 80.7	< 74.3	<						< 13
1-Chloro-3-fluorobenzene	< 80.7	< 74.3							< 13
1-Chloro-4-fluorobenzene	< 80.7	< 74.3							< 13
1-Fluoronaphthalene	< 80.7	< 74.3							< 13
2,2'-Dibromooctafluorobiphenyl	< 80.7	< 74.3							< 13
2,2'-Difluorobiphenyl	< 80.7	< 74.3							< 13
2,3,4,5,6-Pentafluorobiphenyl	< 80.7	< 74.3							< 13
2,4-Difluorobiphenyl	< 80.7	< 74.							13
2-Bromo-4-chloro-1-fluorobenzene	< 80.7	< 74.							13
2-Bromo-4-chloro-6-fluorobiphenyl	< 80.7	< 74							13
2-Bromo-6-fluoronaphthalene	< 80.7	< 74.							13
2-Bromoheptafluoronaphthalene	< 80.7	< 74.							13
2-Chloro-4-fluorophenol	< 80.7	< 74.							13
2-Fluorofluorene	< 80.7	< 74.3							< 13
2-Fluoronaphthalene	< 80.7	< 74.3							< 13
3,3'-Difluorobiphenyl	< 80.7	< 74.3							< 13
3-Chloro-4-fluoro-1,1'-biphenyl	< 80.7	< 74.3							< 13
3-Chloro-4-fluorophenol	< 80.7	< 74.3							< 13
4,4'-Difluorobiphenyl	< 80.7	< 74.3							< 13
4,4'-Dihydrooctafluorobiphenyl	< 80.7	< 74.3	<						< 13
4-Bromo-3-chloro-2-fluoro-1,1'-biphenyl	< 80.7	< 74.3	< 14					< 12	< 13
4-Bromofluorobenzene	< 80.7	< 74.3	< 14					< 12	< 13
4-Chloro-2-fluoro-1,1'-biphenyl	< 80.7	< 74.3	< 14	< 13			12	< 12	< 13
4-Fluorobiphenyl	< 80.7	< 74.3	< 14	< 13			< 12	< 12	< 13
4-Fluorophenol	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
Bromopentafluorobenzene	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
Decafluorobiphenyl	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
o-Chlorofluorobenzene	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13
Octafluoronaphthalene	< 80.7	< 74.3	< 14	< 13	< 12	< 15	< 12	< 12	< 13

Key Findings

- Emission samples from the **stack and kiln outlets** were ND for all compounds tested via EPA Method 0010

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Second Peer-Reviewed Study, Same Verified Result:

No more PFAS.



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RESEARCH ARTICLE

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

Calgon Carbon Corporation, Moon Township, Pennsylvania, USA

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 downstream abatement train that includes a thermal oxidizer, spray quench cooler, dry injection scrubber, and baghouse. All inputs and outputs of the system were tested for targeted PFAS compounds and fluoride (total and as hydrogen fluoride). Under typical operating conditions, the system demonstrated both full removal of PFAS compounds from GAC and >99.99% destruction of PFAS compounds through the furnace and abatement system. Additional key findings include: (1) a large portion of the PFAS destruction occurs in the furnace, before the thermal oxidizer; (2) the fluoride mass balance was close to <1.4%; and (3) emission levels were significantly lower than available public data for

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RESEARCH ARTICLE OPEN ACCESS

Destruction of PFAS During Thermal Reactivation of Granular Activated Carbon Used in Potable Water Treatment

Elisa Mayerberger | Angela Rodriguez | Eli Townsend | Rebecca DiStefano | Rebecca Alward | John Matthis

Calgon Carbon Corporation, Moon Township, Pennsylvania, USA

Correspondence: Elisa Mayerberger (Elisa.Mayerberger@Kuraray.com)

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ABSTRACT

Granular activated carbon (GAC) is one of the best available technologies for the removal of the recently regulated poly- and perfluoroalkyl substances (PFAS) identified by the Environmental Protection Agency. This is prompting an increasing number of municipalities to implement GAC treatment. As such, the drinking water community is seeking to better understand the fate of PFAS-laden spent GAC. Several studies have demonstrated that thermal reactivation of GAC can accomplish destruction of PFAS. However, the work presented herein addresses the knowledge gaps for full-scale potable reactivation facilities. Two separate reactivation trials of PFAS-laden spent GAC were performed at a full-scale potable-classed reactivation facility employing two rotary kiln furnaces and an off-gas abatement system. Three main objectives were pursued: (1) determination of the PFAS destruction removal efficiency, (2) demonstration that the current production rates and kiln operating conditions remove [illegible] limits on reactivated GAC, and (3) incorporation of state-of-the-art capture and analytical methods from [illegible] and products of incomplete combustion or destruction (PICs/PIDs) analysis (OTM-45, OTM-50, [illegible] for fluorinated PICs/PIDs). Each of the reactivation trials consisted of three independent reactivation tests, [illegible] six data sets. The 2024 Trial utilized the revised OTM-45 method (revised in July 2024), and the [illegible] Trial utilized the original OTM-45 method. At the temperatures and operating conditions tested, no targeted PFAS were [illegible] GAC and > 99.99% destruction removal efficiency of PFAS was achieved through the reactivation [illegible]pound emissions were found to exist at levels significantly below the current and proposed state [illegible] and EPA Method 0010/8270, test methods that measure reformed PFAS and PICs/PIDs, yielded non-[illegible]le collection points for each temperature and operating condition evaluated. The results herein [illegible] GAC reactivation as a viable method for the destruction of PFAS, thus breaking the cycle of these [illegible] the environment.

1.1 | [illegible]nt State of Affairs

Poly- and perfluoroalkyl substances (PFAS) are a class of anthropogenic chemicals whose ubiquitous presence in natural and engineered aqueous environments is well documented (Hu et al. 2016; Wang et al. 2017). PFAS have been produced for decades for use in industrial and consumer products (e.g., firefighting foams (Høisæter et al. 2019), nonstick coating (Ramírez Carnero et al. 2021; Sajid and Ilyas 2017), waterproof fabrics (Whittaker and Heine 2018; X. Zhao et al. 2025),

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2nd Study Published
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Agenda

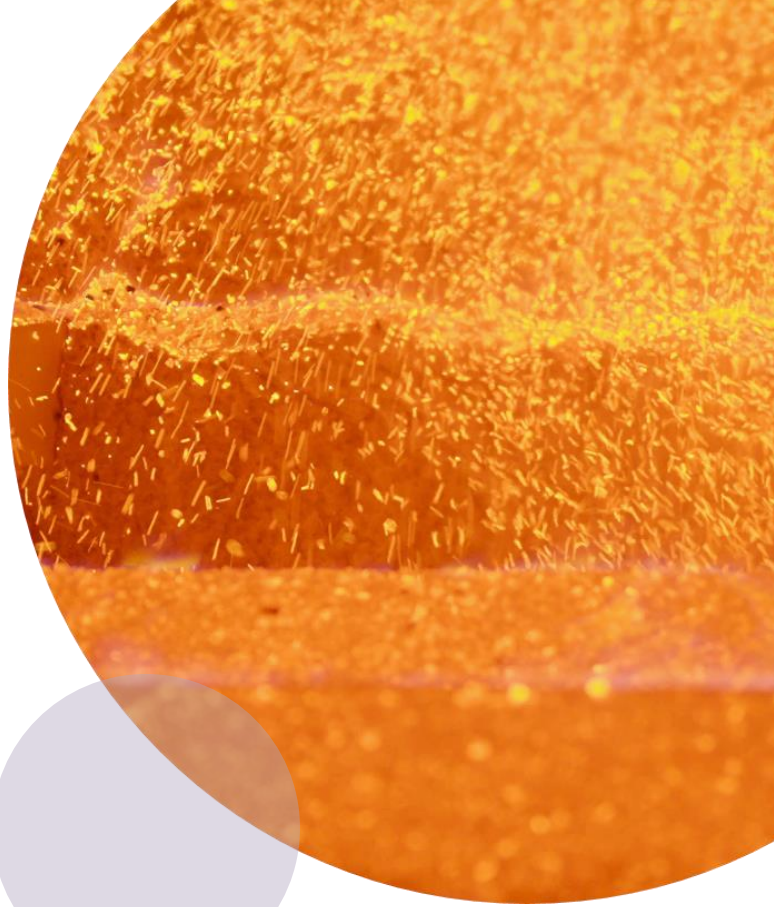
1. GAC Adsorption for PFAS Removal
2. GAC Reactivation Process Fundamentals
3. Peer-Reviewed Publications on Reactivation
4. **Conclusions**

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Conclusions

CCC's unique potable reactivation process is capable of high levels of PFAS destruction:

- Reactivated GAC demonstrated **no PFAS remained above the detection limits**
- **> 99.9% PFAS DRE** was achieved using the most conservative calculation methodology
- The DREs for PFOA and PFOS were **> 99.99%** in both trials.
- **PIC/PIDs emissions were ND** at the kiln and stack outlets



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