

# THERMAL DESTRUCTION OF PFAS DURING THE FULL-SCALE REACTIVATION OF PFAS-LADEN GRANULAR ACTIVATED CARBON (GAC)

Dana Farmer (dana.farmer@kuraray.com) and Rebecca DiStefano, Andrew Harris, Timothy Knowlton, Martin O'Brien

Calgon Carbon Corporation, Moon Township, PA 15108



## ABSTRACT

Calgon Carbon has been facilitating the removal of per- and polyfluoroalkyl substances (PFAS) from water for over 20 years. The demand for PFAS treatment has increased dramatically since 2016 when the U.S. EPA issued a health advisory level of 70 ng/L for combined concentration of the two most prevalent PFAS compounds, PFOA and PFOS. Since then, granular activated carbon (GAC) has shown to be a cost-effective solution for PFAS removal from water and air. Calgon Carbon is also able to offer customers peace of mind by taking their spent carbon, used GAC with adsorbed PFAS, and thermally treating it in a process called reactivation. Reactivation processes and abatement systems are designed to remove contaminants from GAC and destroy the compounds at high temperatures both in the reactivation furnace and in off-gas treatment systems. However, due to the lack of clear regulations and difficulty in quantifying PFAS emissions, there has been lingering uncertainty, conflicting messages in the marketplace, and many questions from customers and regulators about the fate of the PFAS that are adsorbed on the GAC when it is reactivated. Through full-scale test results, this poster will detail Calgon Carbon's progress on this key topic and show how we are now able to reassure customers of the effectiveness of our reactivation process for the thermal destruction of PFAS.

## ACTIVATED CARBON FOR PFAS REMOVAL

GAC is a proven treatment solution for PFAS removal and has become a prevalent PFAS removal technology from water and air. Calgon Carbon's FILTRASORB GAC, for example, is proven and capable of meeting non-detect for a range of PFAS.

### PFAS REMOVAL WITH FILTRASORB 400 GAC

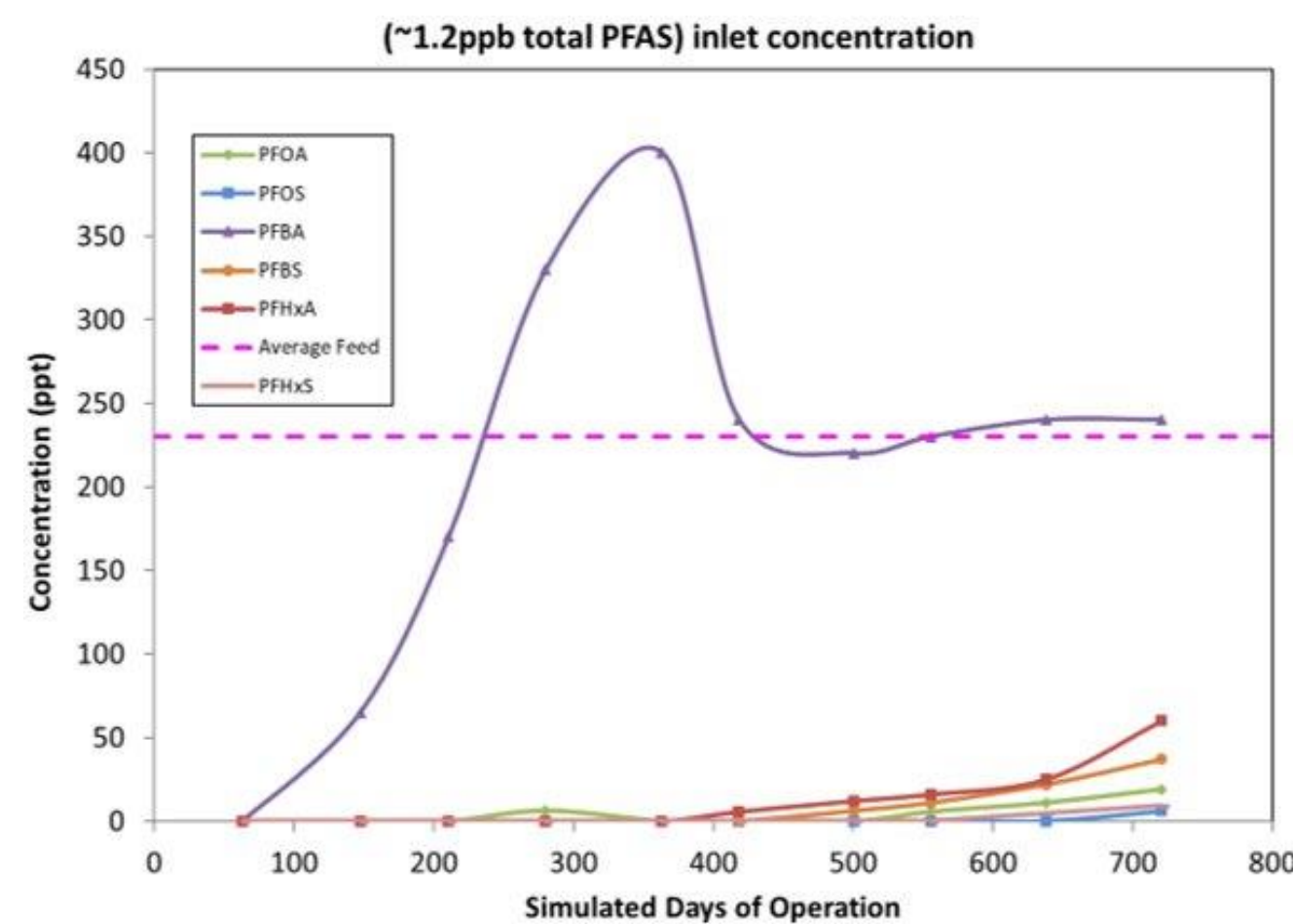


Figure 1. Removal of a Range of PFAS with FILTRASORB 400 GAC<sup>1</sup>

Testing has shown that the reagglomerated activated carbons produced from bituminous coal sources adsorb per- and poly-fluoroalkyl substances (PFAS) better than carbons produced to similar specifications from coconut shell sources. Although, activated carbon has been proven to be effective for both long and short chain PFAS removal, activated carbon has a higher capacity for long-chain PFAS.

## CARBON REACTIVATION

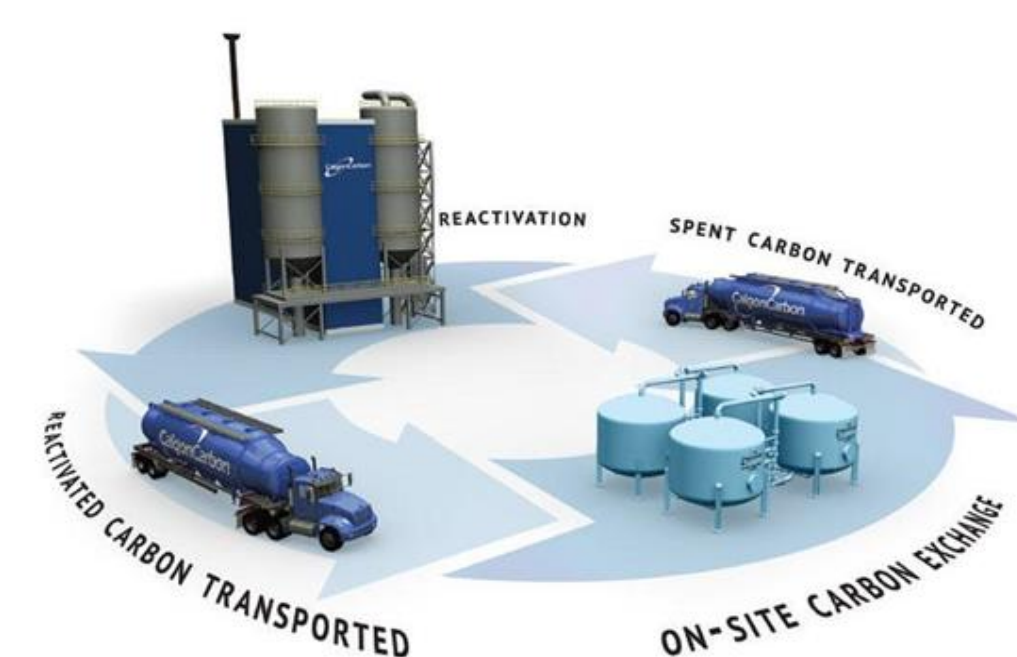


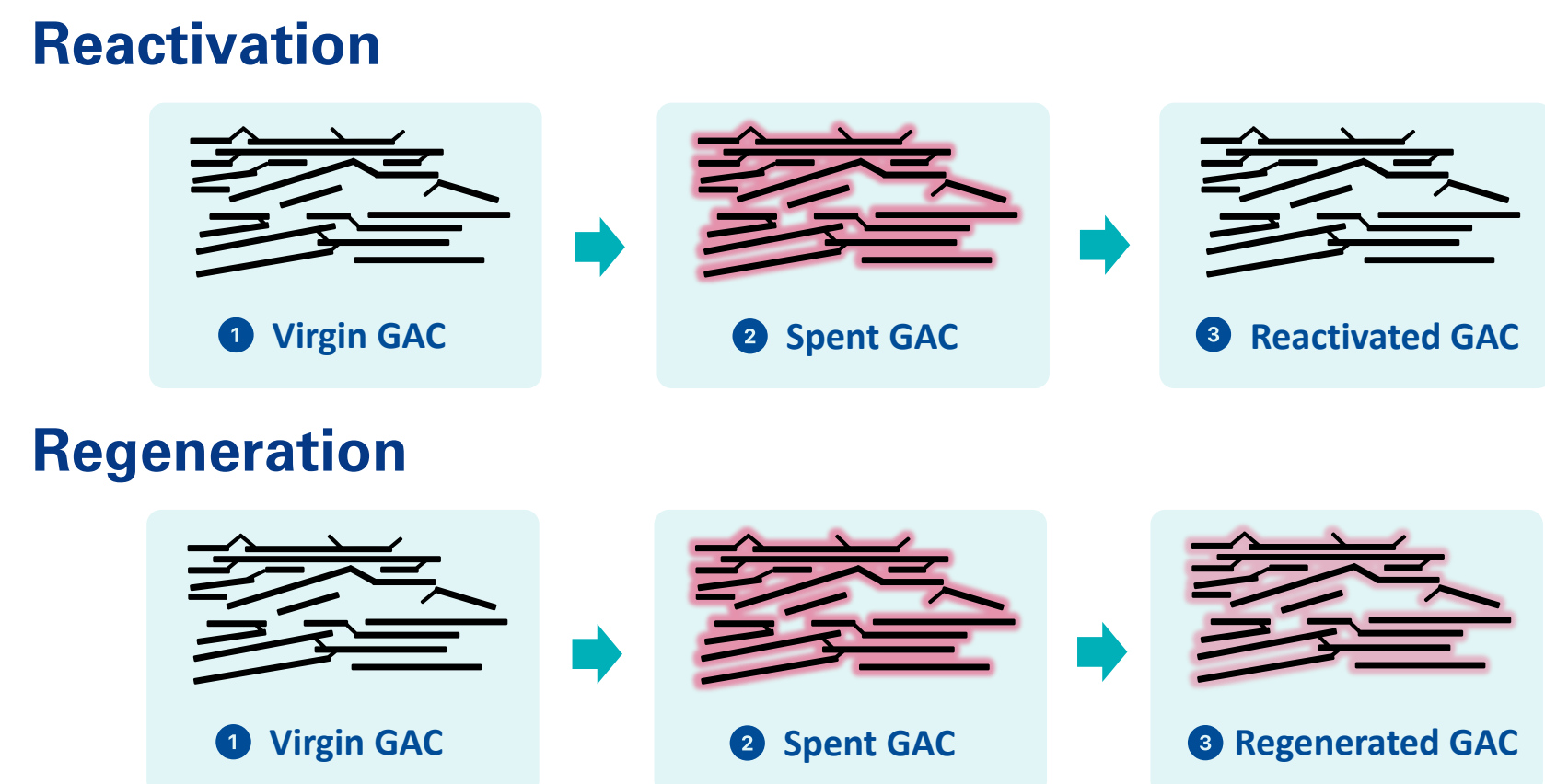
Figure 2. Illustration of a Carbon Reactivation Cycle

Once the GAC is spent, the carbon can be returned to Calgon Carbon for reactivation. Carbon reactivation, an alternative to landfill or incineration for disposal of spent GAC, can ensure destruction of contaminants and only generates 20% of the CO<sub>2</sub> of virgin carbon production. Before return, spent carbon will be profiled according to our Carbon Acceptance testing procedures. The spent carbon is thoroughly evaluated to ensure it meets CCC's requirements for safety/toxicity regulatory compliance in protection of the environment, plant personnel, process equipment, and quality of reactivated carbon product.

## REACTIVATION vs. REGENERATION

The terms carbon reactivation and carbon regeneration are often used interchangeably, but they are distinct processes. This research focus on carbon reactivation, which is a thermal treatment process at high temperatures, up to 1800°F, to remove and destroy adsorbed contaminants from spent GAC. Contaminants that are not devolatilized are converted to char on the carbon<sup>2</sup>. The process is designed to return the carbon to a virgin-like state for reuse and ensure no contaminants remain on the carbon. In contrast, carbon regeneration utilizes low temperature treatment, typically <400°F, with steam, nitrogen, or other hot gas or low temperature chemical treatment to remove only a portion of the adsorbed contaminants<sup>2</sup>. The regeneration process is typically performed in situ and involve cycling adsorption and desorption. As a result, regeneration produces a partially spent carbon containing some, and potentially all, of the original contaminant.

Figure 3. Comparative Illustration of Differences between Reactivation and Regeneration



## MATERIALS AND METHODS

Reactivation of PFAS-laden spent carbon was conducted at a carbon reactivation facility owned and operated by Calgon Carbon Corporation<sup>3</sup>. Alliance Source Testing LLC, a third-party vendor specializing in manufacturing emissions testing, was contracted to determine the emission rates of PFAS and hydrogen fluoride (HF) per established USEPA methodology. Three 4-hour emission tests were conducted over the course of 2 days with gas-phase sample locations before and after the process abatement system. Additional sampling of solid and liquid-phase process inputs and outputs was conducted to define all sources of PFAS potentially entering or exiting the system. During testing, all standard operating procedures for the facility were followed to represent typical furnace and abatement conditions for the reactivation of GAC.

## EXPERIMENTAL CONDITIONS

The reactivation process was conducted in a gas-fired multi-hearth Herreschoff furnace. The carbon gradually moved from hearth to hearth continuously being exposed to the reactivation gases. The residence time in the furnace is several hours and the carbon is exposed to higher temperatures as it moves through the furnace from the top to the bottom. The off-gas from the furnace is discharged through the top and directed to the abatement system for treatment.

The abatement system for this reactivation furnace consists of a three-stage direct fire thermal oxidizer. The thermal oxidizer is followed by a spray quench cooler, dry injection scrubber, a baghouse for particulate removal, and a stack.

## EMISSIONS TESTING

Emissions testing was performed at two locations in the facility. The first location was at the furnace discharge prior to the abatement system. The second location was at the discharge of the emissions stack. In addition to the testing, the volumetric flow rate of gas at each point was determined per US EPA Methods 1 and 2 with full velocity traverses (UP EPA, 2017a, 2017b). Additional sampling was performed around the abatement system to verify PFAS were not introduced from sources other than the furnace off-gas.

## ANALYTICAL

The air samples were analyzed for 36 PFAS compounds by Eurofins Environmental Services, using EPA Method 537 (modified). Solid samples (spent carbon, reactivated carbon, abatement dust, and bicarbonate raw material) were tested by Eurofins Lancaster Laboratories for extraction and targeted PFAS analyses by EPA Method 537 (modified) (US EPA, 2020c). Well water, used for cooling, and plant motive water were sampled and tested by Eurofins Lancaster Laboratories for PFAS analysis by EPA Method 537 (modified) (US EPA, 2020c) with isotope dilution.

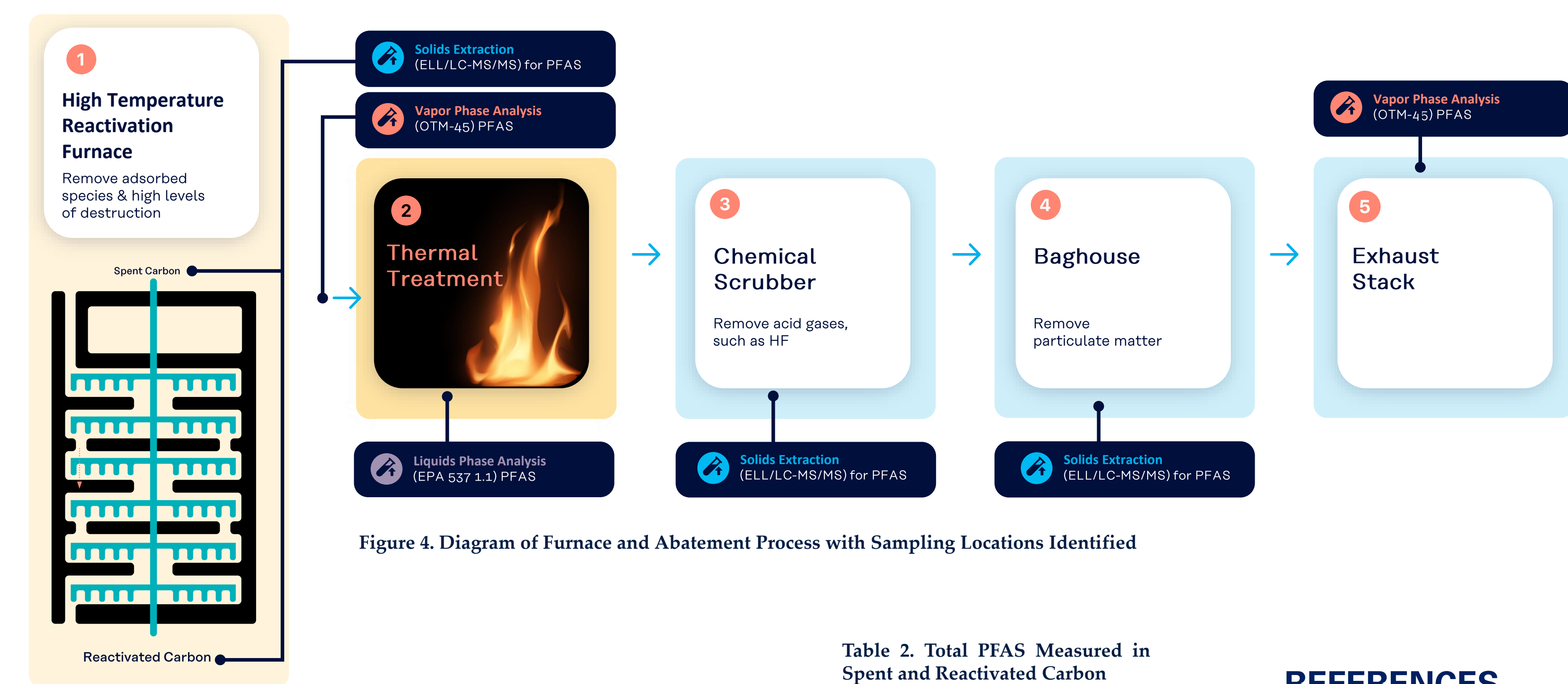


Figure 4. Diagram of Furnace and Abatement Process with Sampling Locations Identified

## RESULTS/LESSONS LEARNED

Table 1. Inlet Total PFAS and DRE at Furnace Off-Gas and 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 × 10 <sup>-5</sup>	99.989%	
Stack emissions (36 compound list) <sup>2</sup>	4.88 × 10 <sup>-5</sup>	42.024%	99.993%

- Demonstrated > 99.99% destruction for total PFAS (36 PFAS list measurable) across the furnace and abatement systems.
- Demonstrated > 99.999% destruction for PFAS currently listed in the US EPA's Drinking Water Health Advisory Limits (PFOA, PFOS, GenX, and PFBS) across process and abatement systems
- Significant HF generation post-furnace (5.56 lb/h) and pre-abatement system supports a high degree of mineralization of PFAS under CCC reactivation conditions. HF is removed downstream in an acid gas scrubber, which is why it is reported at the furnace.
- Analysis resulted in non-detect for all measurable PFAS on the reactivated carbon, indicating that PFAS is effectively removed from the spent carbon during CCC's proprietary reactivation process.

Table 2. Total PFAS Measured in Spent and Reactivated Carbon

	Spent carbon sample average from 3 tests (ng/L)	Reactivated carbon sample average from 3 tests (ng/L)
PFBA	4,467	<1.9 (ND)
PFPeA	2,200	<0.58 (ND)
PFHxA	2,733	<0.58 (ND)
PFHpA	1,173	<0.58 (ND)
PFOA	12,600	<0.58 (ND)
PFNA	71	<0.58 (ND)
PFDA	48	<0.58 (ND)
PFUnDA	31	<0.58 (ND)
PFDoDA	<9.7	<0.58 (ND)
PFTriDA	39	<0.58 (ND)
PFTetDA	<9.7	<0.58 (ND)
PFBS	8,500	<1.9 (ND)
PFPeS	4,200	<0.58 (ND)
PFHxS	20,300	<0.58 (ND)
PFHpS	3,003	<0.58 (ND)
PFOS	11,567	<0.58 (ND)
PFNS	26	<0.58 (ND)
PFDS	109	<0.58 (ND)
PFDoS	<30	<1.9 (ND)
PFOA	353	<0.58 (ND)
NMeFOA	610	<1.9 (ND)
NEFOA	523	<1.9 (ND)
GenX	32,167	<1.9 (ND)
4:2 FtS	<32	<1.9 (ND)
6:2 FtS	400	<1.9 (ND)
8:2 FtS	<48	<2.9 (ND)
10:2 FtS	<32	<1.9 (ND)
PFHxDA	<9.7	<0.58 (ND)
PFODA	<9.7	<0.58 (ND)

## REFERENCES

- Westreich, P, Mimna, R, Brewer, J, Forrester, F. The removal of short-chain and long-chain perfluoroalkyl acids and sulfonates via granular activated carbons: A comparative column study. *Remediation*. 2018; 29: 19–26. <https://doi.org/10.1002/rem.21579>
- Kempisty, D. M., Xing, Y., & Racz, L. (2019). *Perfluoroalkyl substances in the environment theory, practice, and innovation*. CRC Press.
- DiStefano, R., Feliciano, T., Mimna, R. A., Redding, A. M., & Matthis, J. (2022). Thermal destruction of PFAS during full-scale reactivation of PFAS-laden granular activated carbon. *Remediation*, 32, 231–238. <https://doi.org/10.1002/rem.21735>

