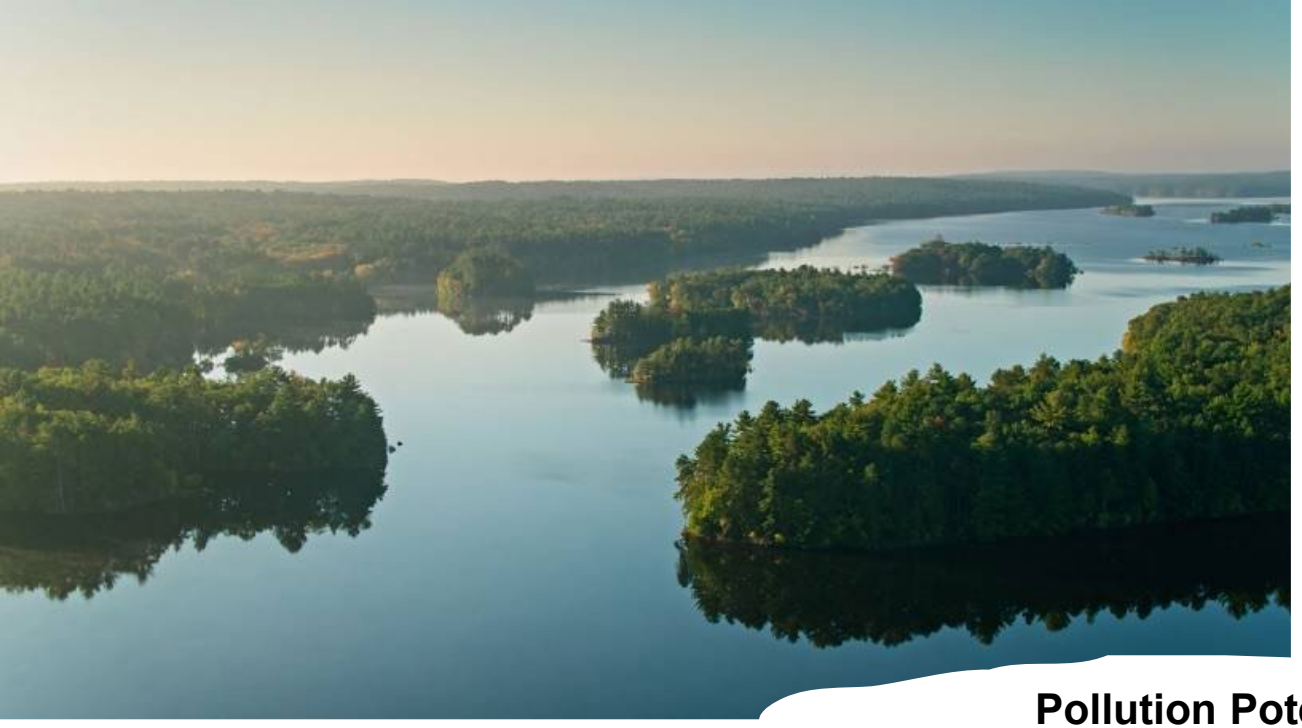
# Clean Harbors
# PFAS Destruction Test Program Results

# Presentation Overview

- Aragonite facility overview
- Test program overview
- Test objective
- Plan test conditions
- Sampling & analytical program
- PFAS spiking protocol
- PFAS mass balance and DRE calculations
- PFAS stack emissions
- Conclusions
- Take-aways

# Broad Asset Infrastructure

- **More than 100 Waste Management Facilities**
  - 9 Incinerator units
  - 11 Landfill Sites, 5 Closed Loop
  - 18 Treatment, Storage & Disposal Facilities (TSDF)
  - 9 Wastewater Treatment Operations
  - 16,000+ Company Vehicles
- **Key Acquisitions:**
  - HydroChem PSC 2021
  - Thompson Env 2023
  - Hepaco Env 2024
- **Recognized as a Global 100 Most Sustainable Corporation**

**Pollution Potential- A single** 5 - gallon bucket of AFFF Concentrate at 30,000 ppm can bring 140 million cubic meters of water above the drinking water criteria of 4ppt


ARFF truck bladders average 370-1800 liters of AFFF concentrate

# Clean Harbors Aragonite Utah

# Combustion and Emission Control Systems

- Combustion System
  - Slagging rotary kiln (2,006-2,233°F / 1,097-1,223ºC)
  - Afterburner (2,048-2096°F / 1,120-1,147°C)
- Emission Control System
  - Spray dryer
  - Baghouse
  - Saturator
  - Wet Scrubber
  - Induced draft fan
  - Stack

# Testing Team

- EPA ORD (Office of Research and Development)
- DoD SERDP (Strategic Environmental Research & Development)
- EA Engineering, Science & Technology
- Focus Environmental
- Alliance Source Testing
- Eurofins
- Spectrum Environmental
- Superior Spiking Industries
- Sanborn Head and Associates

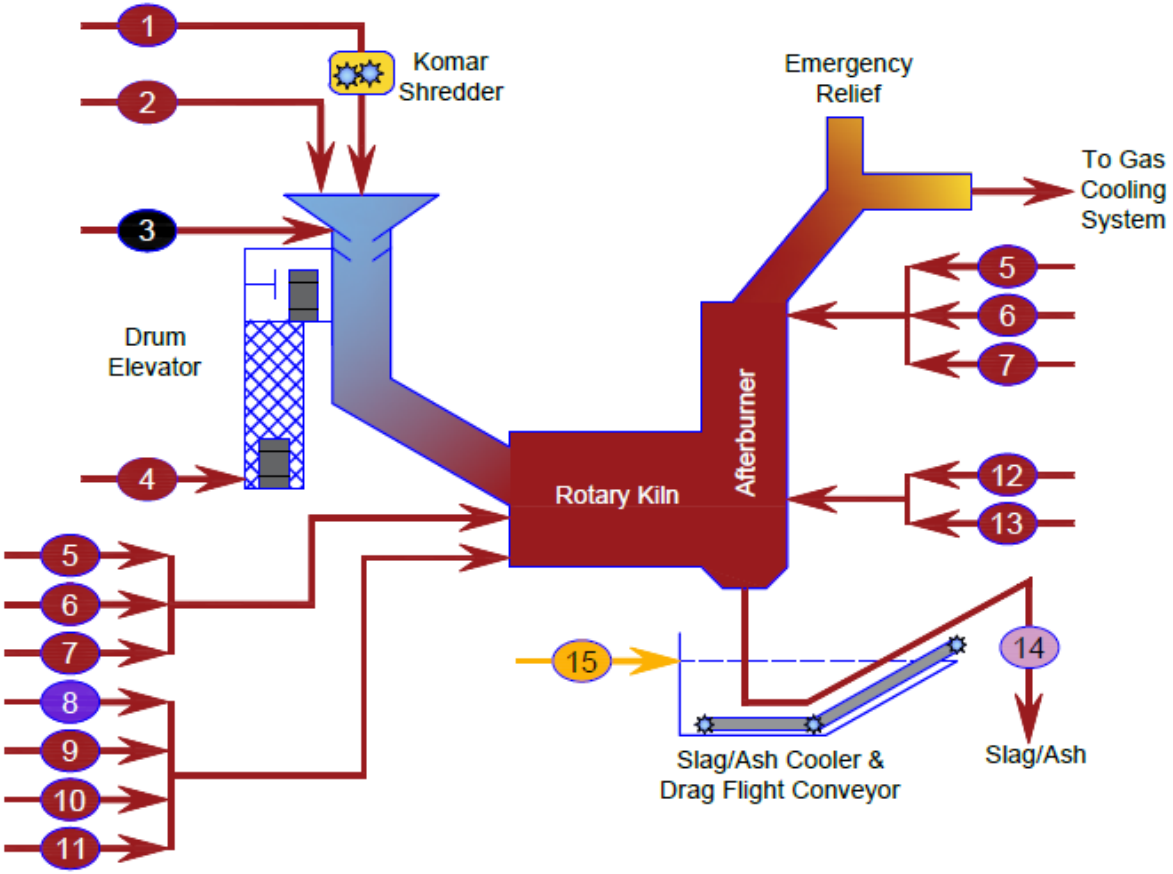
# Project Objectives

- Measure destruction and removal efficiency (DRE) for nine spiked PFAS compounds (PFHxA, PFOA, PFNA, PFDA, PFBS, K-PFBS, K-PFHxS, K-PFOS, HFPO-DA)
- Fed AFFF concentrate
- Perform PFAS mass balance for waste feed streams, process water, chemical reagents, process residuals, and stack gas
- Test using OTM-45 (49 target analytes) LC/MS/MS
- Test using OTM-50 (30 target analytes)GC/MS
- Test using 0010/8270 (106 target analytes plus unknown characterization) GC/MS
- FTIR monitoring
- $C_2F_6$ spiking – possible test surrogate
- Risk Assessment Modeling

# Planned Test Conditions – Feed Streams

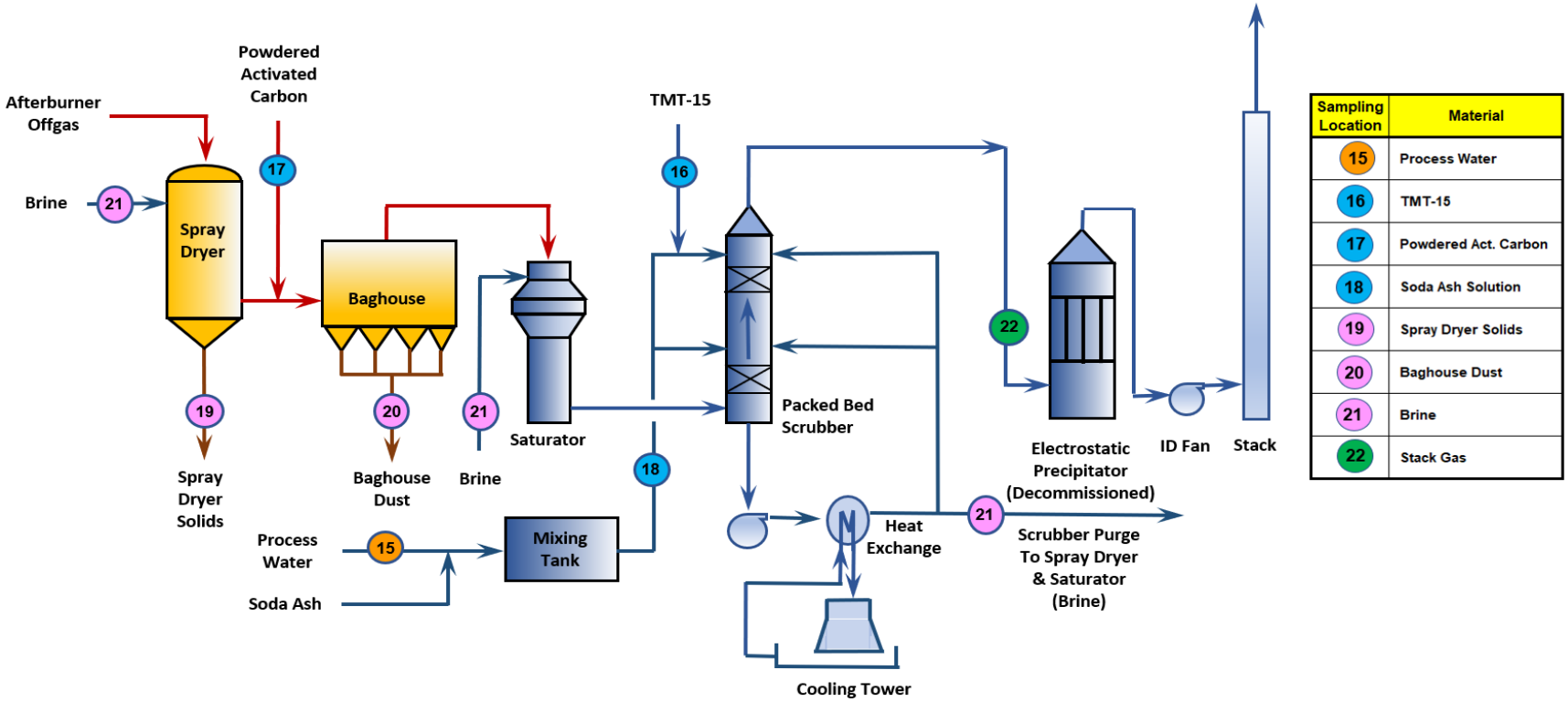
| Run No. | Feed Materials | | | | Stack Sampling Methods | | | |
|---|---|---|---|---|---|---|---|---|
| | Normal Waste Feeds | AFFF Feed | PFAS Spiking | $C_2F_6$ Spiking | OTM-45 | Method 0010 | OTM-50 | ASTM D-6348-12 |
| 1A | X | X | X | --- | X | X | X | X |
| 1B | X | --- | --- | --- | X | X | X | X |
| 1C | X | --- | --- | X | X | X | X | X |
| 2A | X | X | X | --- | | | X | X |
| 2B | X | --- | --- | --- | | | X | X |
| 2C | X | --- | --- | X | | | X | X |
| 3A | X | X | X | --- | | | X | X |
| 3B | X | --- | --- | --- | | | X | X |
| 3C | X | --- | --- | X | | | X | X |

# Combustion System Sampling Points




| Sampling Point | Stream |
|---|---|
| 1 | Komar Solids |
| 2 | Bulk Solids (incl. Soil) |
| 3 | PFAS Spike |
| 4 | Containerized Solids |
| 5 | Waste Blend Liquid |
| 6 | Fuel Oil (Not Used) |
| 7 | Used Motor Oil |
| 8 | $C_2F_6$ Spike |
| 9 | Direct Burn - Drums |
| 10 | Direct Burn - Tote |
| 11 | Direct Burn - Tank Truck (AFFF) |
| 12 | Aqueous Liquid |
| 13 | Corrosive Waste |
| 14 | Slag/Ash |
| 15 | Process Water |

# Emission Control System Sampling Points




| Sampling Location | Material |
|---|---|
| 15 | Process Water |
| 16 | TMT-15 |
| 17 | Powdered Act. Carbon |
| 18 | Soda Ash Solution |
| 19 | Spray Dryer Solids |
| 20 | Baghouse Dust |
| 21 | Brine |
| 22 | Stack Gas |

# Sampling and Analytical Methods

- Stack gas sampling methods
  - EPA OTM-45
  - EPA OTM-50
  - SW 846 – 0010/8270

- Analytical methods
  - EPA Method 1633 – 40 analytes (LC/MS/MS)
  - OTM-45 – 49 target analytes (LC/MS/MS)
  - OTM-50 – 30 target analytes (GC/MS)
  - Method 0010/ 8270 (GC/MS)
  - FTIR

# PFAS Spiking Calculations

- Calculate mass of each PFAS compound required to demonstrate DRE based on:
  - Stack gas detection limit of PFAS compound
  - Stack gas flow rate
  - Stack gas sample volume
  - Include contingency for unknowns
- Use Reagent grade PFAS compounds
- Calculate required mass feed rate of PFAS compound based on purity and chemical form (acid or salt)

# PFAS Spiking Material Preparation


Pre-weighed bottles of spiking materials to be bundled in cardboard box


Process for inserting PFAS spiking bottles into numbered cardboard boxes

# Mass Balance & DRE Calculation Basis

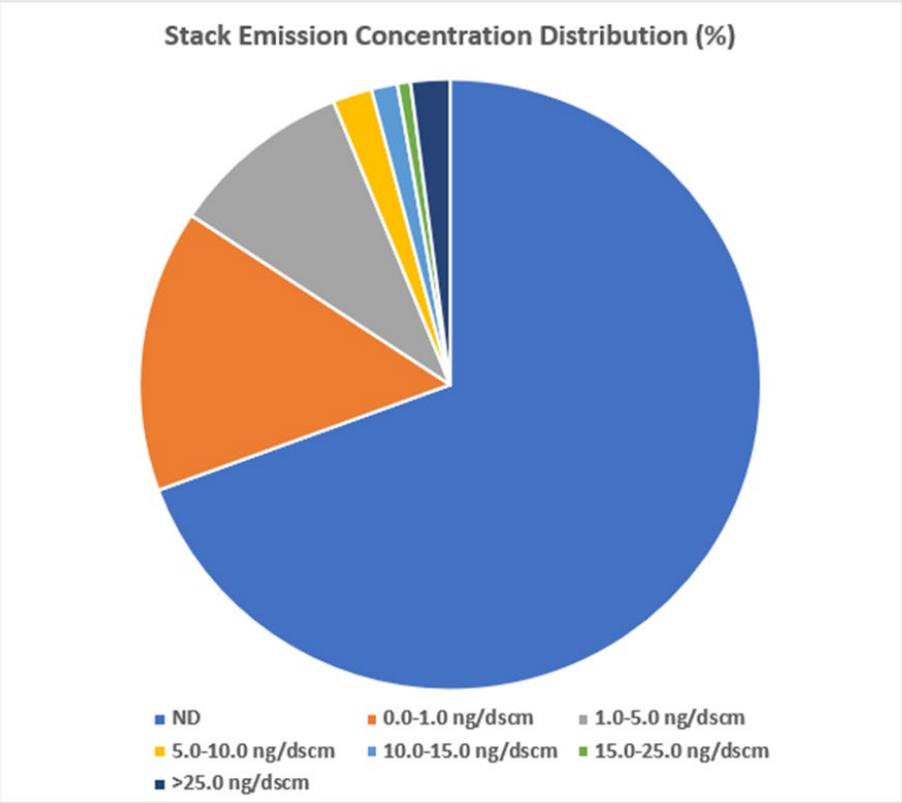
- PFAS not measured in solid waste feed streams
- PFAS in process water and chemical inputs to the gas cleaning systems were included in mass balances, but not included in DRE calculations (per RCRA definition of DRE)
- PFAS non-detects in waste feed, chemical, process water, and residual streams assumed concentration value of zero
- PFAS non-detects in stack gas assumed to be present at the method detection limit
- PFAS DREs reported are lowest possible values based on conservative assumptions listed above
- Fluorine concentration in waste solids calculated from Clean Harbors' waste profiles

# PFAS Mass Balance

- The Tanker Direct Burn Stream, which was an AFFF concentrate material, had high concentrations of many PFAS and included approximately 78 to 82 percent of the total PFAS mass fed to the HWI during the tests.
- The PFAS spiking compounds comprised approximately 18 to 22 percent of the total PFAS mass fed to the HWI.
- All other input waste feed streams that were analyzed accounted for 0.001 to 0.003 percent of the total PFAS input.

# Ambient Air Impacts

- Using EPA AERSCREEN dispersion application, modeled ambient air concentrations were compared to regulatory limits or guidelines from state regulatory agencies.
- The analysis shows that the maximum ambient impacts for the 12 PFAS that were modeled range from two to eight orders of magnitude below any state ambient limit or guideline.




| Concentration Range | Number of Data Points | Distribution (%) | Cumulative (%) |
|---|---|---|---|
| ND | 102 | 69.4 | 69.4 |
| 0.0-1.0 ng/dscm | 22 | 15.0 | 84.4 |
| 1.0-5.0 ng/dscm | 14 | 9.5 | 93.9 |
| 5.0-10.0 ng/dscm | 3 | 2.0 | 95.9 |
| 10.0-15.0 ng/dscm | 2 | 1.4 | 97.3 |
| 15.0-25.0 ng/dscm | 1 | 0.7 | 98.0 |
| >25.0 ng/dscm | 3 | 2.0 | 100.0 |
| Total | 147 | 100.0 | |

# Stack Emissions

- 96% of analytes detected had < 10 ng/m³
- HFPO-DA was detected and believed to be from contamination. Perplexing since HFPO-DA is destroyed at 194F.
- Stresses the importance of identifying potential PFAS sources beyond the destruction phase

# Conclusions

- DRE values in the range of 99.999 to greater than 99.9999 percent were achieved for all spiked PFAS except HFPO-DA, which ranged from 99.95 to 99.998 percent.
- OTM–50 - No potential PIDs in the stack gas above the MDL were identified.
- 0010/8270 – No fluorinated compounds identified.
- DRE values for $C_2F_6$ were 99.99 to >99.9999%.
- Air emission modeling 2 to 8 orders of magnitude lower than any state air limit or guideline.

# PFAS Disposal Facilities

- Closed Loop Landfills
  - Lone Mountain, OK
  - Grassy Mountain, UT
  - Buttonwillow, CA
  - Sawyer, ND
  - Lambton (Sarnia), ON Canada
- Landfill leachate never leaves the custody of Clean Harbors
- 5 Incineration sites, 8 Rotary Kilns
  - Aragonite, UT (RCRA/ TSCA)
  - Deer Park, TX (RCRA/ TSCA)
  - El Dorado, AR (RCRA)
  - Sarnia, ON liquid incinerator, TDU
  - Kimball, NE (RCRA)


**12 Billion Gallons PFAS Water Treated**

**200,000 Tons PFAS Soil Removed**

**95 Treatment Systems Installed**

**85 Large Remediation Projects**

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