HEARTLAND WATER TECHNOLOGY

SWANA FLORIDA

Assured PFAS Separation

Proven, Reliable On-Site Evaporation Technology

Heartland Water Technology

Established 2008

Centers of Excellence:

- Head Office: Hudson, MA
- Engineering: Stoughton WI
- Technical Center: Murfreesboro, TN

Markets

- Landfill Leachate
- O&G Produced Water
- Power FGD
- Municipal Biosolids

Experience: 20+ Installations across the U.S.

Recognition: 2022 GWI's Industrial Project of the year

Heartland Concentrator™

Two decades of proven performance

Award-winning, globally recognized solution

COVAP: Cogen using waste-heat from engines

ROVAP: Evaporating RO concentrate

HelioStorm™ Gasifier

Ultra-high temperature ionic gasifier

20 years in development at Idaho National Labs

Launching for Residuals in 2023

Provides Assured PFAS Destruction™

Assured PFAS Separation for Landfill Leachate

The Heartland Concentrator is an effective separation technology for long and short chain PFAS from wastewater

Multi-site testing data demonstrates the vast majority of PFAS is retained in the system residuals (PFAS mass balance confirmation)

PFAS in system residuals can be safely contained within the landfill or further fed to destruction technologies

Agenda

1 Regulatory Overview

2 PFAS Overview

3 PFAS Behavior in Heartland System

4 Heartland PFAS Testing

5 Conclusions

Targeted PFAS Compounds by Developing Regulations

CASRN	PFAS Compound	CERCLA	RCRA	SDWA
335-67-1	PFOA	Proposed	Proposed hazardous constituents	Proposed MCL: 4 ppt
1763-23-1	PFOS	Proposed	Proposed hazardous constituents	Proposed MCL: 4 ppt
375-95-1	PFNA	ANPRM (Intent to Propose)		Proposed Hazardous Index
355-46-4	PFHxS	ANPRM (Intent to Propose)		Proposed Hazardous Index
375-73-5	PFBS	ANPRM (Intent to Propose)	Proposed hazardous constituents	Proposed Hazardous Index
13252-13-6	HFPO DA	ANPRM (Intent to Propose)	Proposed hazardous constituents	Proposed Hazardous Index
375-22-4	PFBA	ANPRM (Intent to Propose)		
307-24-4	PFHxA	ANPRM (Intent to Propose)		
335-76-2	PFDA	ANPRM (Intent to Propose)		

>9,000 known PFAS compounds; little agreement on which compounds should be regulated

Toxicology data will drive regulatory standards

Heartland tracking key regulations – CERCLA, RCRA, SDWA

Florida Regulatory Environment

SB 1692 - PFAS and 1,4-Dioxane Pretreatment Initiative

- Preventing contaminants of emerging concern from discharging into wastewater facilities and waters of the state.
- Requires wastewater facilities to conduct inventory of industrial users that are probable sources of specified contaminants
- Authorizes wastewater facilities to develop and propose local limits for PFOS, PFOA, or 1,4-dioxane

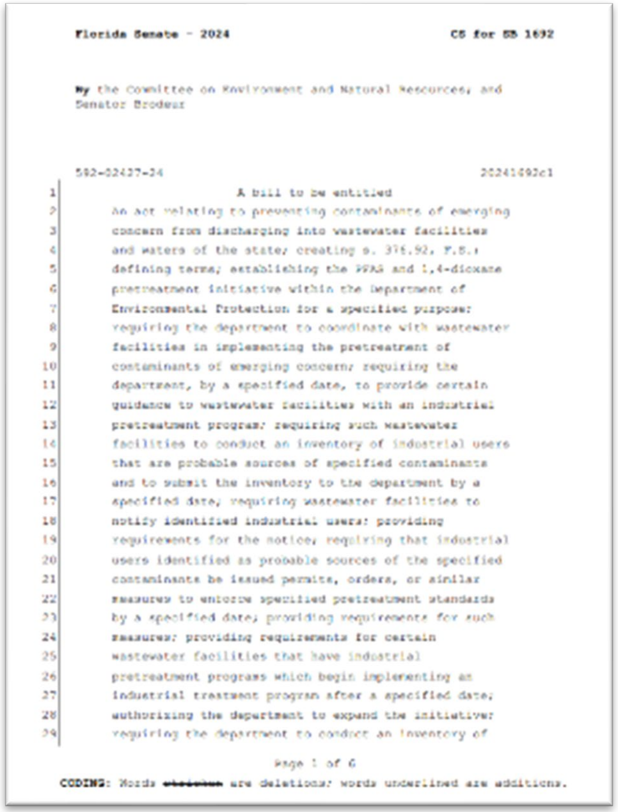
If adopted,

Starting July 2025, Interim specific discharge limits for industrial users:

PFOS, 10 nanograms per liter (10 ppt)

PFOA, 170 nanograms per liter (170 ppt)

1,4-dioxane, 200,000 nanograms per liter (0.2 ppm)


Florida Senate - 2024 CS for SB 1692

By the Committee on Environment and Natural Resources; and Senator Brodeur

592-02437-24 20241692c1

A bill to be entitled

An act relating to preventing contaminants of emerging concern from discharging into wastewater facilities and waters of the state; creating s. 376.92, F.S.; defining terms; establishing the PFAS and 1,4-dioxane pretreatment initiative within the Department of Environmental Protection for a specified purpose; requiring the department to coordinate with wastewater facilities in implementing the pretreatment of contaminants of emerging concern; requiring the department, by a specified date, to provide certain guidance to wastewater facilities with an industrial pretreatment program; requiring such wastewater facilities to conduct an inventory of industrial users that are probable sources of specified contaminants and to submit the inventory to the department by a specified date; requiring wastewater facilities to notify identified industrial users; providing requirements for the notice; requiring that industrial users identified as probable sources of the specified contaminants be issued permits, orders, or similar measures to enforce specified pretreatment standards by a specified date; providing requirements for such measures; providing requirements for certain wastewater facilities that have industrial pretreatment programs which begin implementing an industrial treatment program after a specified date; authorizing the department to expand the initiative; requiring the department to conduct an inventory of

Page 1 of 6

CODING: Words ~~stricken~~ are deletions; words underlined are additions.

GENERAL BILL by Environment and Natural Resources ; **Brodeur** (CO-INTRODUCERS) **Stewart**

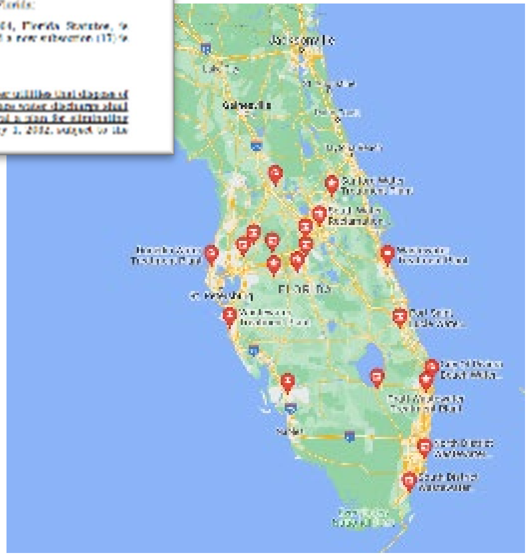
Florida Regulatory Environment

Florida SB 64 – Elimination of Surface Water Discharge

- Domestic wastewater utilities required to produce a plan to reduce and eliminate non-beneficial surface water discharges by 2032.
- Approx 162 domestic wastewater facilities subject to the law and will be required to propose alternate use such as deep-water injection or indirect potable water reuse.
- This will strain WW operators with high TDS effluent levels and could be a contributing factor to cutting off Landfill leachate.
    - CITY OF TAMPA - HOWARD F. CURREN WWTP is a prime example as they <u>no longer accept leachate</u> due to TDS levels.

CHAPTER 2021-168

Committee Substitute for Senate Bill No. 64



PFAS Management Within the Landfill

- Landfills do not generate PFAS. Landfills are **passive receivers**
- PFAS levels in Landfills will reflect a composite of historic and ongoing levels of disposed materials.
- Landfills are an important repository for safely sequestering PFAS from the environment.
  - Landfilling is presented as one of three technologies commercially available and have the potential to control the migration of PFAS to the environment(1)
  - *"Modern MSW landfills, when constructed with appropriate controls can control the migration of PFAS into the environment"*

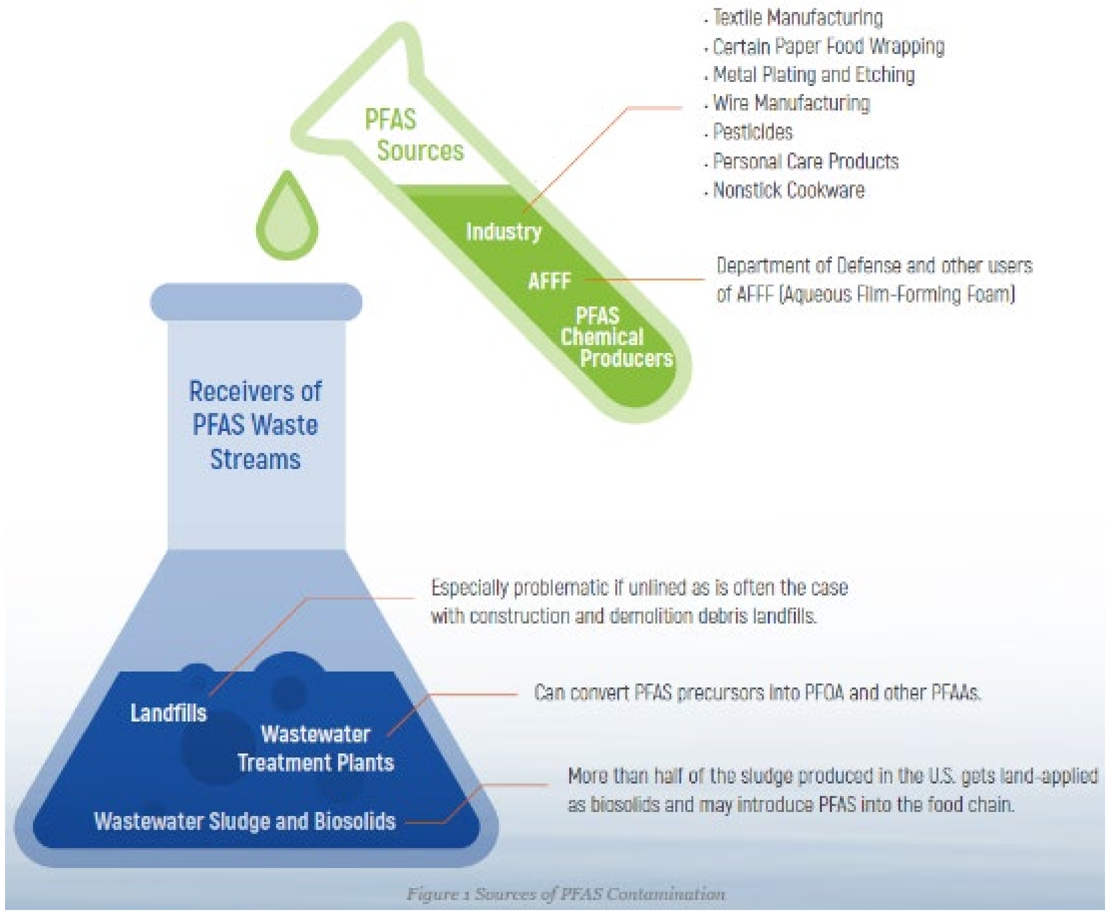


Figure 1 Sources of PFAS Contamination

Pace Analytical, Municipalities Guide to PFAS Contamination and Testing

(1) *December 2020 – USEPA Interim Guidance on the Destruction and Disposal of PFAS*

PFAS Treatment Technologies

PFAS Technology Landscape		
Destruction	**Separation**	
	PFAS Separation	**Wastewater Volume Reduction[4]**
Electrochemical Oxidation	Low Temperature Thermal Evaporation[2]	
Hydrothermal Alkaline Oxidation	Membrane Filtration	
Sono Chemical Oxidation	Foam Fractionation[3]	
Gasification	Activated Carbon	
Incineration[1]	Ion Exchange	
Supercritical Water Oxidation	Clay/Zeolite Sorption	
Plasma Treatment	Solidification/ Stabilization	

1. Incineration has been used for PFAS destruction, but certain states have banned its use based on questions regarding incomplete destruction of PFAS.
2. The HWT Concentrator evaporates wastewater at temperatures ranging from 130 to 160°F.
3. Foam fractionation is more selective toward PFAS treatment relative to all other technologies that are less or non-selective (i.e., they treat other co-contaminants).
4. These technologies separate PFAS and reduce leachate volume (i.e., produce "clean" permeate or water vapor with very minimal residual contamination.

Commercial Stage
Mature
Early Commerical
Developing

Source: GWI Water Data Treatment and Destruction options for PFAS

The Heartland Concentrator

1. Heat Source
2. Induced Draft Fan
3. Waste Heat Transfer System
4. Evaporation Zone
5. Feed and Recirculation
6. Droplet Separator
7. Sump and Blowdown
8. Exhaust

Left: Process fluids as they exit the concentrator.

Right: Solids accumulating in a settling tank. Liquid recycled back to the concentrator.

Properties Affecting PFAS behavior

Chemical Form

- Determination of Ionic vs acid form is pH dependent
- Above a pH of 5, dominant PFAS in leachate exist nearly entirely in the ionic form
- Typical operating pH range of the Heartland Concentrator is 6.5 to 8.5, in the pH range, **PFOA and PFOS are in the non-volatile ionic form**

Low Vapor Pressure

- The vapor pressure of most PFAS are low, making these compounds **non-volatile**

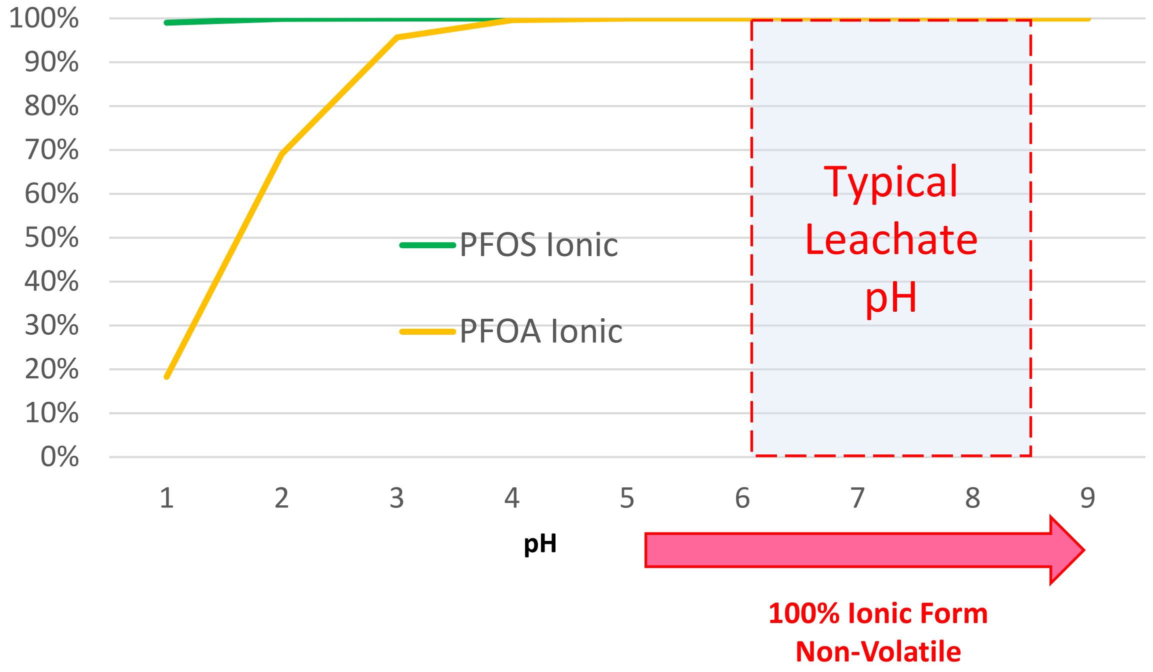
High Solubility

- The **solubility of PFAS are generally high**, and therefore remain dissolved in liquid

Chemical Form is pH Dependent

Ionic Form	Neutral to high pH	Non-Volatile
Acid Form	Low pH	More Volatile

Ionic vs Acid form of PFOA & PFOS



Heartland Design Features Leading to PFAS Concentration

Operational pH:

- Heartland Concentrator™ operates in a pH range of 6.5 to 8.5. Within this range, PFAS are in their non-volatile ionic form (water soluble), and therefore remain in the concentrated liquid residuals.

Operational Temperature:

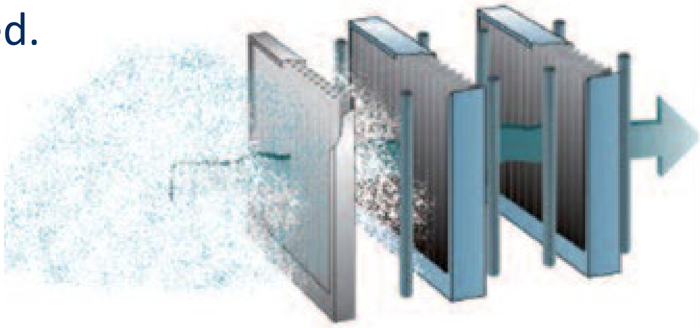
- 130-160 deg F result in efficient evaporation while maintaining temperatures below the boiling point of each PFAS compound, avoiding PFAS volatilization.

LM-HT Evaporation Zone Design:

- Large "macro-droplets" are reduced to smaller droplets in a highly wetted evaporation zone.
- By design, this approach avoids spray drying, a process that involves rapidly drying a liquid or slurry at high temperatures to form a dry particle that could be volatized.

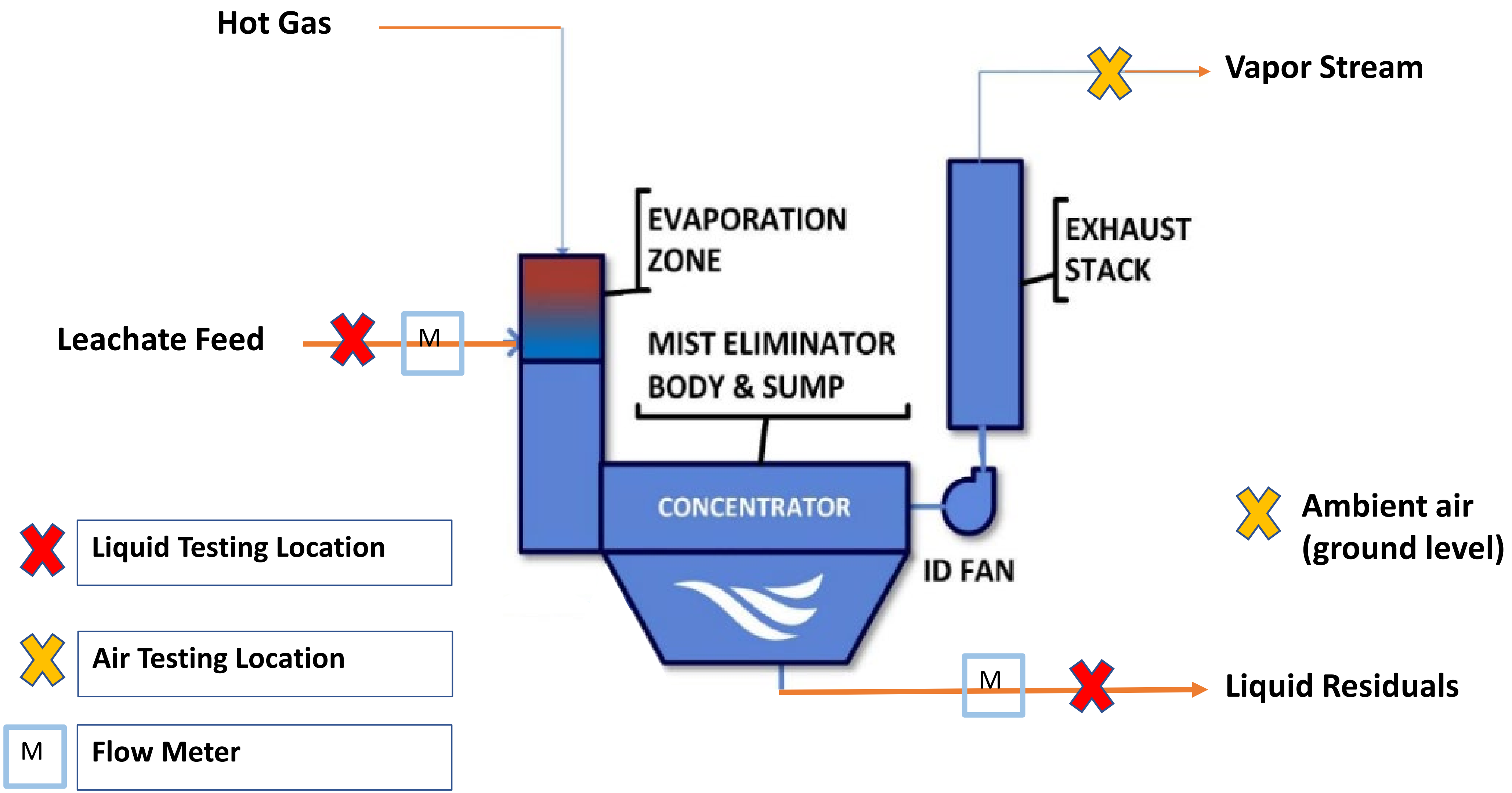
3-Stage High Efficiency Mist/PM Elimination:

- Minimizes PFAS vapor emissions from PM and airborne droplets/aerosols
  - ➢ Removes liquid droplets from air stream
  - ➢ Removes PM from air stream
  - ➢ Removes PFAS associated with droplets/PM



3-Stage Mist Elimination System

PFAS Testing Locations for Mass Balance Development



PFAS Process Testing - Mass Balance Approach

Liquid Testing Summary

- Analytical Method - Draft EPA Method 1633 (3rd Party Certified Lab)
- Process sample locations - Raw leachate feed and final system residuals
- (2) MSW Landfill Sites
- Duplicate samples collected; results averaged from 2 data points

Mass Balance Approach

- PFAS Mass in Feed (lb/hr) = **Inlet (Concentration x Flow)**
- PFAS Mass in Residuals (lb/hr) = **Residuals (Concentration x Flow)**

PFAS Mass Balance Summary from 2 Case Studies

PFAS Compound	Site #1		Site #2	
	Leachate **Feed**	System **Residuals**	Leachate **Feed**	System **Residuals**
	lb/hr	lb/hr	lb/hr	lb/hr
PFOA	0.000021	0.000021	0.000017	0.000017
PFOS	0.000004	0.000005	0.000003	0.000003
PFBS	0.000009	0.000009	0.000087	0.000088
PFHxS	0.000017	0.000018	0.000010	0.000010
PFNA	0.000001	0.000001	0.0000009	0.0000010
PFBA	0.000028	0.000027	0.000013	0.000018
PFHxA	0.000037	0.000032	0.000074	0.000064
HFPO-DA	<0.000001	<0.000001	<0.000002	0.0000004
PFDA	0.000000	0.000000	0.000001	0.000001
Total	**0.000115**	**0.000113**	**0.000204**	**0.000203**
lb/yr PFAS	1.0		1.8	

Conclusion

The mass of PFAS entering the system is equivalent to the mass in the system residuals, within the error of measurement

PFAS Liquid Testing – Leachate Case Study Site 1

- System was operated at ~96% volume reduction (~25x Concentrator Factor)
- PFAS concentrated similar to non-volatile indicator parameters (metals)
- **Summary** – PFAS was retained in the system residuals.

		Landfill Leachate - Site 1 July 2022		
Compound	Unit	System **Feed**	System **Residuals**	Concentration Factor
PFOA	ng/l	1,145	28,950	
PFOS	ng/l	219	7,025	
PFBS	ng/l	466	11,550	
PFHxS	ng/l	908	23,650	
PFNA	ng/l	58	1,735	
PFBA	ng/l	1,505	35,700	
PFHxA	ng/l	1,995	43,650	
HFPO-DA	ng/l	<2.85	<475	
PFDA	ng/l	10	337	
Total	ng/l	6,305	152,597	**24.2**
Total Metals / Solids				
Total Metals	mg/l	4,050	99,613	**24.6**
Total Solids	mg/l	13,600	324,000	**23.8**

PFAS Liquid Testing – Leachate Case Study Site 2

- System was operated at ~94.2% volume reduction (~17.2 x Concentrator Factor)
- PFAS concentrated similar to non-volatile indicator parameters (metals)
- **Summary** – PFAS was retained in the system residuals.

		Landfill Leachate - Site 2		
Compound	Unit	System **Feed**	System **Residuals**	Concentration Factor
PFOA	ng/l	1,900	34,380	
PFOS	ng/l	330	5,660	
PFBS	ng/l	10,000	174,580	
PFHxS	ng/l	1,100	20,070	
PFNA	ng/l	99	1,890	
PFBA	ng/l	1,500	35,850	
PFHxA	ng/l	8,500	125,910	
HFPO-DA	ng/l	<200	1,600	
PFDA	ng/l	70	1,330	
Total	ng/l	23,499	401,270	**17.1**
Total Metals / Solids				
Total Metals	mg/l	2,672	45,327	**17.0**
Total Solids	mg/l	10,900	189,236	**17.4**

PFAS Testing– Liquid vs Air

Liquid Testing

Contaminant	CASRN[1]	MRL[2] (µg/L)
25 PFAS: EPA Method 533		
11-chloroeicosafluoro-3-oxaundecane-1-sulfonic acid (11Cl-PF3OUdS)	763051-92-9	0.005
1*H*,1*H*, 2*H*, 2*H*-perfluorodecane sulfonic acid (8:2FTS)	39108-34-4	0.005
1*H*,1*H*, 2*H*, 2*H*-perfluorohexane sulfonic acid (4:2FTS)	757124-72-4	0.003
1*H*,1*H*, 2*H*, 2*H*-perfluorooctane sulfonic acid (6:2FTS)	27619-97-2	0.005
4,8-dioxa-3H-perfluorononanoic acid (ADONA)	919005-14-4	0.003
9-chlorohexadecafluoro-3-oxanonane-1-sulfonic acid (9Cl-PF3ONS)	756426-58-1	0.002
hexafluoropropylene oxide dimer acid (HFPO-DA)(GenX)	13252-13-6	0.005
nonafluoro-3,6-dioxaheptanoic acid (NFDHA)	151772-58-6	0.02
perfluoro (2-ethoxyethane) sulfonic acid (PFEESA)	113507-82-7	0.003
perfluoro-3-methoxypropanoic acid (PFMPA)	377-73-1	0.004
perfluoro-4-methoxybutanoic acid (PFMBA)	863090-89-5	0.003
perfluorobutanesulfonic acid (PFBS)	375-73-5	0.003
perfluorobutanoic acid (PFBA)	375-22-4	0.005
perfluorodecanoic acid (PFDA)	335-76-2	0.003
perfluorododecanoic acid (PFDoA)	307-55-1	0.003
perfluoroheptanesulfonic acid (PFHpS)	375-92-8	0.003
perfluoroheptanoic acid (PFHpA)	375-85-9	0.003
perfluorohexanesulfonic acid (PFHxS)	355-46-4	0.003
perfluorohexanoic acid (PFHxA)	307-24-4	0.003
perfluorononanoic acid (PFNA)	375-95-1	0.004
perfluorooctanesulfonic acid (PFOS)	1763-23-1	0.004
perfluorooctanoic acid (PFOA)	335-67-1	0.004
perfluoropentanesulfonic acid (PFPeS)	2706-91-4	0.004
perfluoropentanoic acid (PFPeA)	2706-90-3	0.003
perfluoroundecanoic acid (PFUnA)	2058-94-8	0.002
4 PFAS: EPA Method 537.1		
N-ethyl perfluorooctanesulfonamidoacetic acid (NEtFOSAA)	2991-50-6	0.005
N-methyl perfluorooctanesulfonamidoacetic acid (NMeFOSAA)	2355-31-9	0.006
perfluorotetradecanoic acid (PFTA)	376-06-7	0.008
perfluorotridecanoic acid (PFTrDA)	72629-94-8	0.007

Ambient Air Testing

High volume PUF XAD Resin Ambient Air Samplers

Testing Method: Modified 537

46 Total Compounds
PFAS Families Measured

PFCAs	PFECAs
PFSAs	FASAs
FTCAs	FASAAs
FTSAs	PFECAs

Vapor Stack Testing

Air Sampling Train – OTM 45

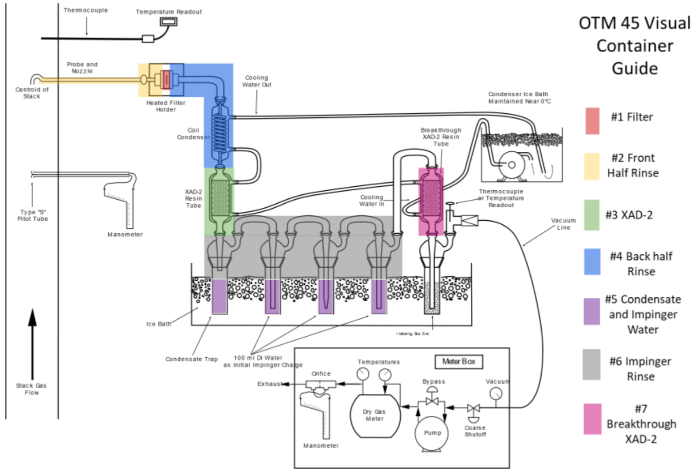
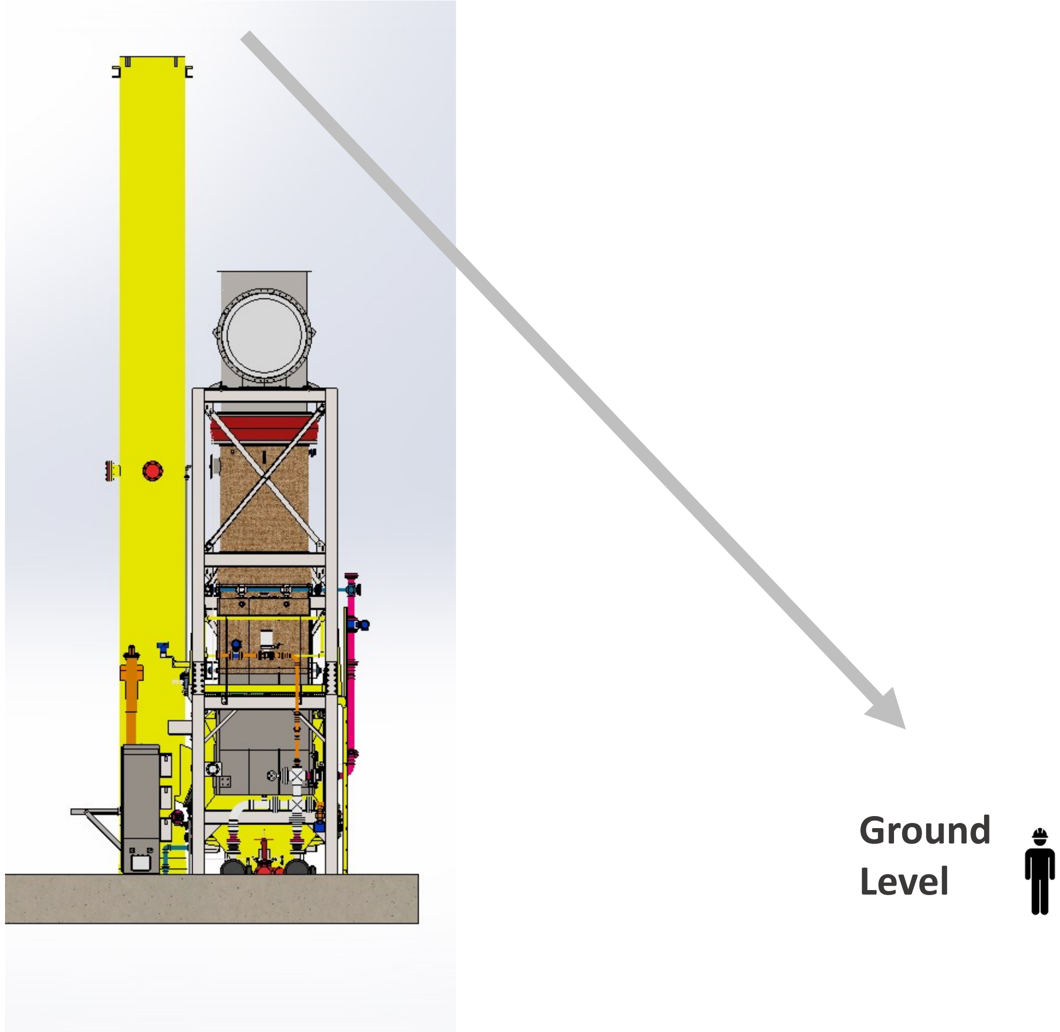


Figure OTM-45-1. Sampling Train

PFAS Ambient Air Sampling



Key Results:

All amb. Air PFAS below detection limits

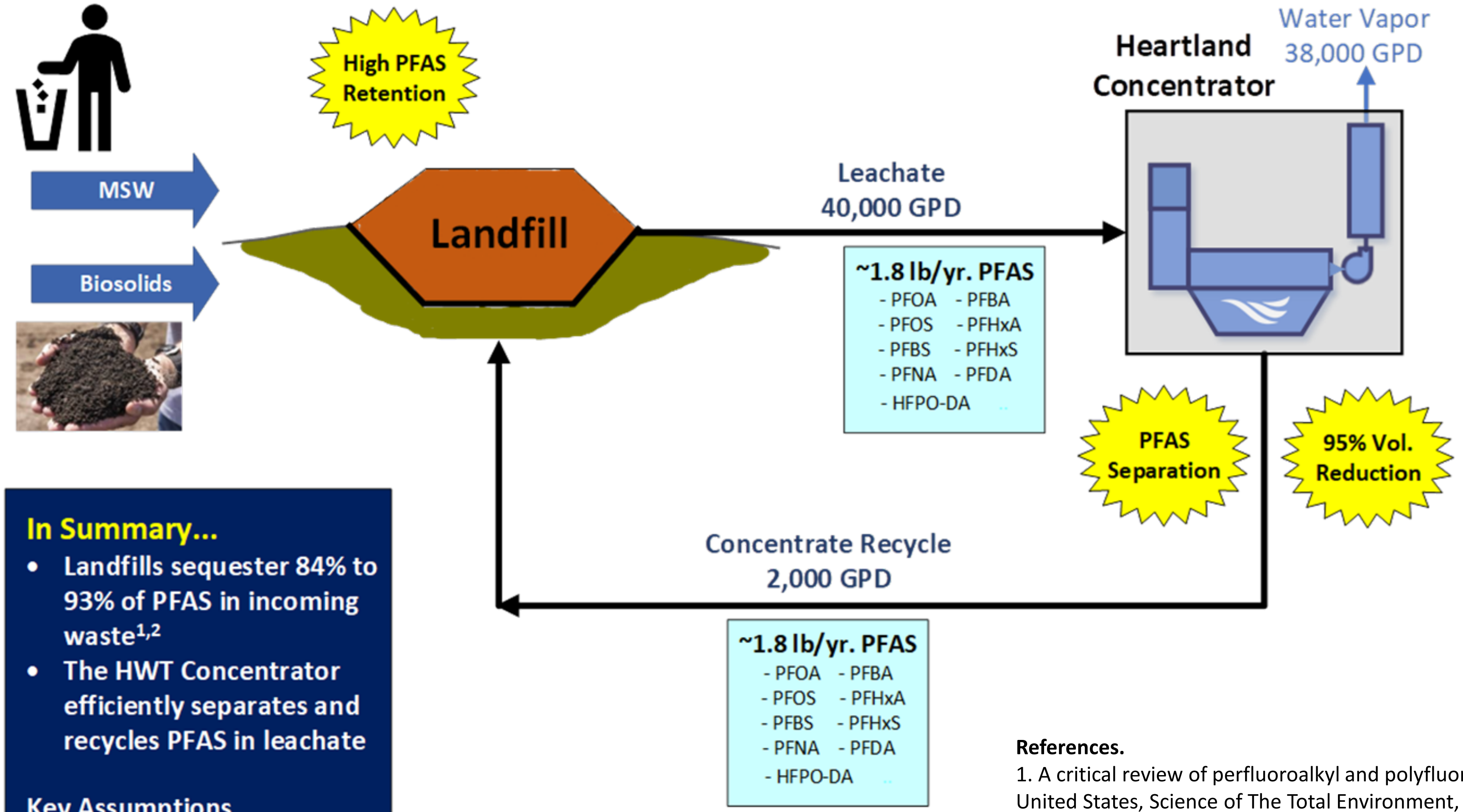
Assured PFAS Separation for Landfill Leachate

The Heartland Concentrator is an effective separation technology for long and short chain PFAS from wastewater

Multi-site testing data demonstrates the vast majority of PFAS is retained in the system residuals (PFAS mass balance confirmation on target 9 compounds)

PFAS in system residuals can be safely contained within the landfill or further fed to destruction technologies

Onsite PFAS Treatment & Retention



In Summary…

- Landfills sequester 84% to 93% of PFAS in incoming waste[1,2]
- The HWT Concentrator efficiently separates and recycles PFAS in leachate

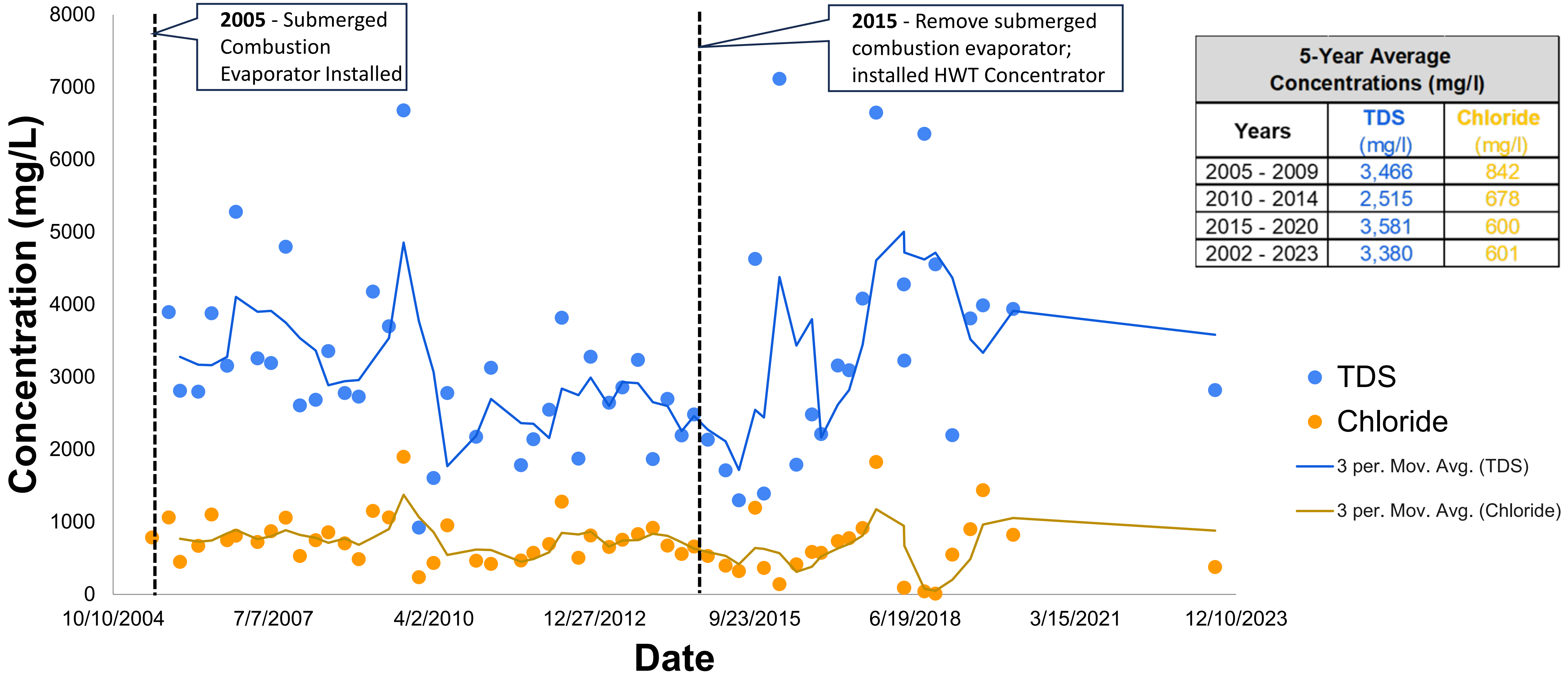
Key Assumptions

- 1,000 ton/day MSW Landfill
- 40,000 GPD Leachate
- PFAS concentrations are ave. from case studies 1 & 2

References.

1. A critical review of perfluoroalkyl and polyfluoroalkyl substances (PFAS) landfill disposal in the United States, Science of The Total Environment, Volume 905, 2023,Thabet Tolaymat, Nicole Robey, Max Krause, Judd Larson, Keith Weitz, Sameer Parvathikar, Lara Phelps, William Linak, Susan Burden, Tom Speth, Jonathan Krug,
2. PFAS in municipal solid waste landfills: Sources, leachate composition, chemical transformations, and future challenges. Environmental Health and Health. Coffin, Reeves, Cassidy. 2023

Concentrate Recirculation – 2005 to Present



5-Year Average Concentrations (mg/l)		
Years	TDS (mg/l)	Chloride (mg/l)
2005 - 2009	3,466	842
2010 - 2014	2,515	678
2015 - 2020	3,581	600
2002 - 2023	3,380	601

From 2005 to present, approximately 100% of the evaporator residual was recirculated to the landfill's open face. TDS and Chloride levels have fluctuated but show no sign of elevated concentration. PFAS is anticipated to behave similarly.

Assured PFAS Separation Through Evaporation

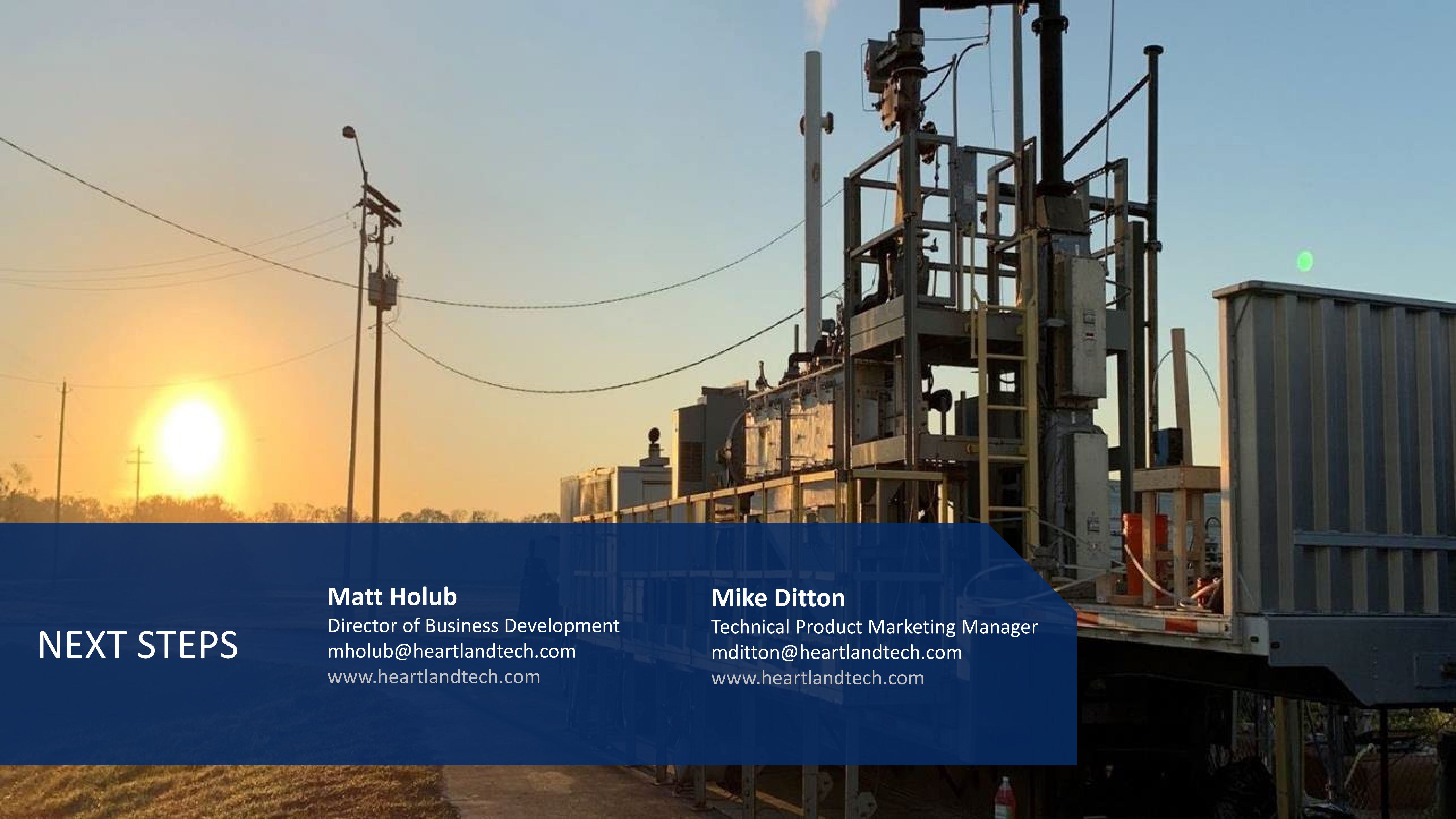
The Heartland Concentrator is an effective separation technology for long and short chain PFAS from wastewater

Multi-site testing data demonstrates the vast majority of PFAS is retained in the system residuals (PFAS mass balance confirmation

Ambient Air tests below detection limits

PFAS in system residuals can be safely contained within the landfill or further fed to destruction technologies

Request the Whitepaper



NEXT STEPS

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