

PFAS Degradation During Hazardous Waste Incineration: A Pilot-Scale Study with Comprehensive Analytical Approach

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SUMMARY

1 | Context & objectives

2 | Pilot description

3 | Analytical strategy

4 | Test results

5 | Conclusions

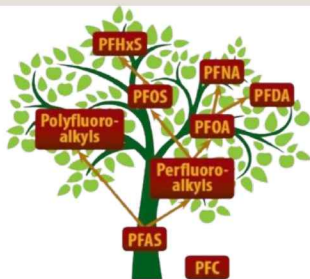
6 | Veolia PFAS offer
Beyond PFAS

1 - Context & objectives



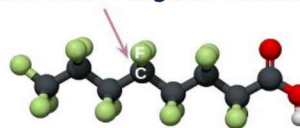
More than 10,000 man-made chemicals

A large family of Polymers & Non polymers



With a common structure

Carbon-Fluor bond = one of the strongest chemical bonds in organic chemistry



e.g. **PFOA** (Perfluorooctanoic acid = 8 C)

Widely used in industries & commercial products



Health & environment impacts

Mobile

Bioaccumulative

Persistent

Toxic

*Growing evidence on
some pfas of their
impact on health and
environment**

*Source : HBM4EU PFAS Factsheet, Agency for
Toxic Substances and Disease Registry,US,
November 2022*

Complex treatment requirements and disposal conditions (break-down difficulty)

The main PFAS sources in the industrial waste



Products or by-products contaminated with PFAS to treat in hazardous waste incineration

Fate of PFAS during hazardous waste incineration

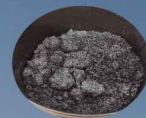
R&I project main goals



- **Reproduce** high temperature incineration at **pilot scale**
- **Evaluate the Destruction and Removal Efficiency (DRE)**
- Implement an **innovative and complete analytical strategy** to go further targeted PFAS and evaluate the potential **products of incomplete combustion (PICs)**
- **Wastes:**
 - AFFF
 - Spent adsorption media (GAC, IEX)



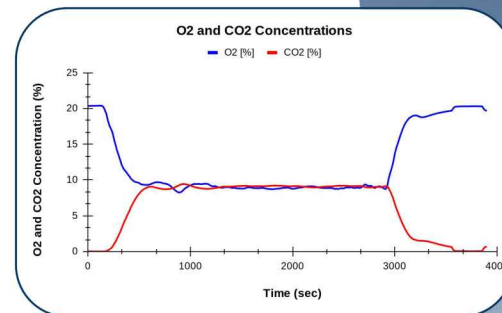
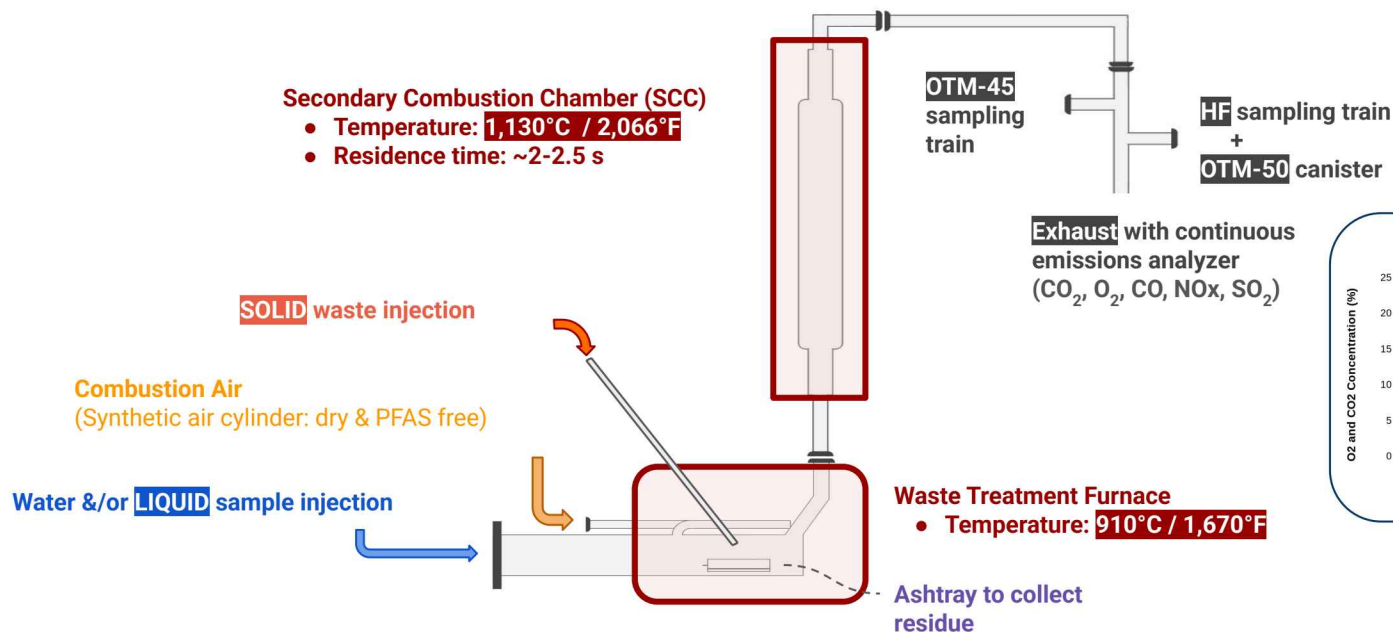
Mimic operational conditions of a Veolia industrial Hazardous Waste Incinerator in **US (Port Arthur - Texas)**



2 - Veolia R&I thermal treatment pilot scale unit



Pilot settings and sampling trains



Waste, water and air flow set to maintain the SCC residence time and reproduce thermal treatment conditions of the large scale plant

A combustion test bench (pilot scale unit)

Solid & liquid injection modules

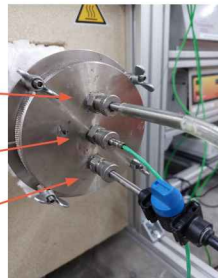
Injection of **LIQUID** waste under agitation using a dosing pump

Injection of **SOLID** waste with a screw conveyor



OTM-45 sampling train

Liquid injection tube
Thermocouple
Air injection



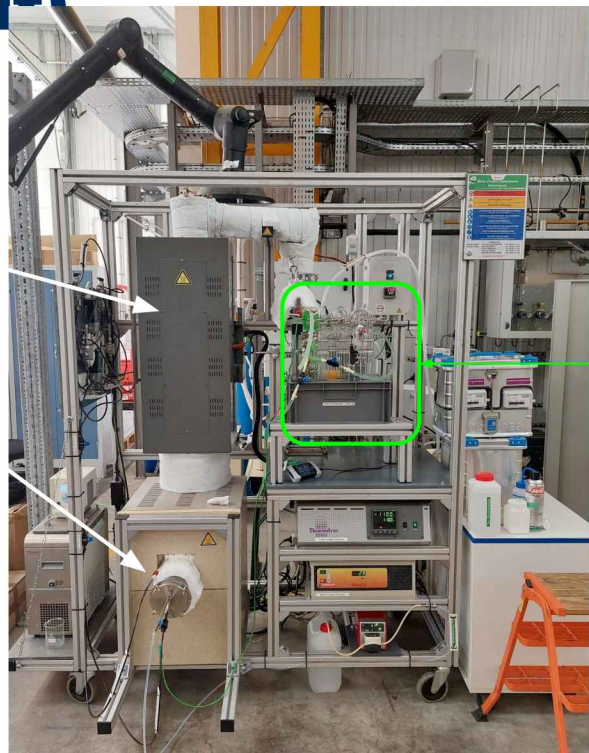
Furnace inlet flange

Secondary Combustion Chamber (SCC)

[up to 1,200°C]

Furnace

[up to 950°C]



3 - Analytical strategy

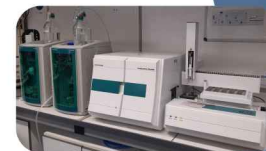


A complete and innovative analytical strategy (Targeted PFAS, Total Fluorine & NTS)

01

Total fluorine analysis & HF measurement by C-IC & IC

- Fluorine balance



Combustion & Ion Chromatography

02

Targeted PFAS in LC-MS/MS (OTM-45 for flue gas)

- Waste, solids, gas characterization
- DRE & DE calculation

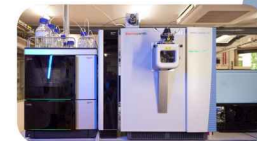


LC-MS/MS

03

Non-Targeted Screening (NTS) by LC-HRMS & Volatile fluorinated comp. canister - GC/MS (OTM-50)

- Hidden part of feedstock
- Products of Incomplete Combustion (PICs)



LC-HRMS



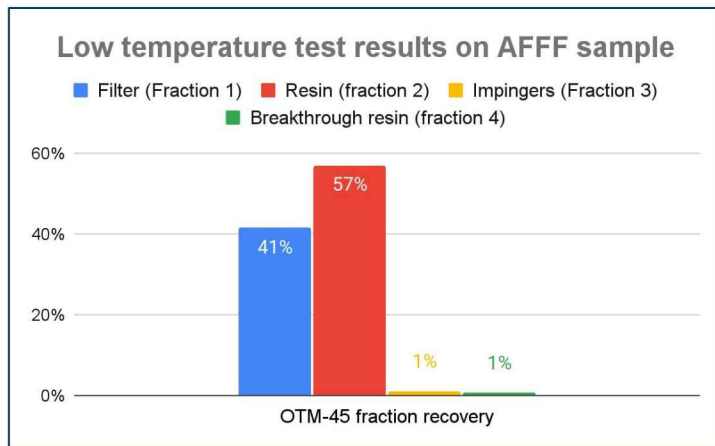
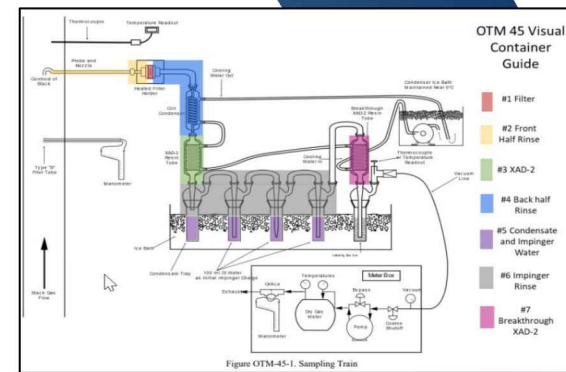
Canister & GC/MS

4 - Test results



Pre testing trials - OTM-45 check

- **OTM-45 sampling efficiency test**
 - 2 runs at low temperature (350°C) on AFFF sample
⇒ PFAS desorption and transport in flue gas



Results:

Large amount of targeted PFAS collected in OTM-45 (sum PFAS = 240,000 ng)

More than 95% of targeted PFAS recovered in filter & resin (fraction 1&2)

No breakthrough, with less than 1% in breakthrough resin (fraction 4)

Sampling train efficiency of OTM-45 on the pilot validated for high PFAS concentrations in fumes without breakthrough!

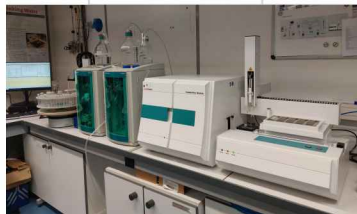


AFFF rinsing solution (waste)

Matrix characterization

Total fluorine

Parameters	Method	Result (mg/g)
Total Fluor (TF)	C-IC	0.9
Total Inorganic Fluorine (TIF)	IC	< 2
Total Organic Fluorine (TOF)	Calculated	0.9



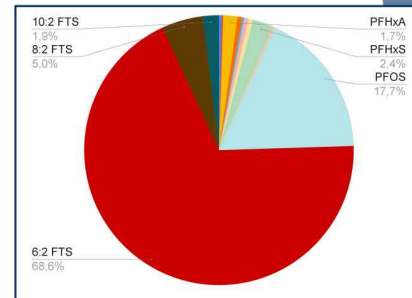
C-IC



Targeted PFAS

Targeted PFAS
sum = 31,000 µg/L
(< 3% of TOF)

PFAS	Result (µg/L)
Perfluoroalkylcarboxylic acids (PFCAs)	
PFBA	101
PFPeA	60
PFHxA	555
PFOA	186
PFNA	43
PFDA	42
Perfluorinated sulfonic acids (PFSAs)	
PFBS	163
PFPeS	174
PFHxS*	789
PFHpS	85
PFOS*	5,730
Fluorotelomer sulfonates (FTSAs)	
6:2 FTS*	22,200
8:2 FTS	1,610
10:2 FTS	616



LC-MS/MS

Short chain / Long chain

PFAS in blue are classified as POP (Stockholm convention)

PFAS* in purple are predominant in the AFFF

AFFF rinsing solution (waste) Thermal treatment tests



Feeding
Continuous injection
Inject° ~10 g/min
during ~1h
i.e. a total of ~600 g



Furnace: 910°C
SCC: 1,130°C,
~2.3 s



No Solid Residue

Test repeated 3 times



Exhaust Gas
HF, OTM-45 &
OTM-50



AFFF rinsing solution (waste) Fluorine balance

Feeding
TF = 0.9 mg/g

Fluorine (TF)
566 - 695 mg



Furnace: 910°C
SCC: 1,130°C,
~2.3 s



Exhaust Gas

Fluorine (HF)
454 - 658 mg



No Solid Residue
No Fluorine

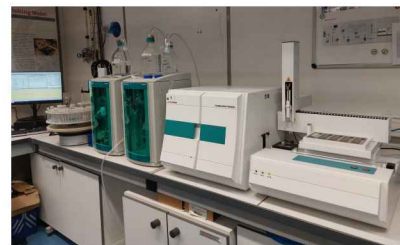
80% to 95%
of Fluorine
retrieve into
HF



Findings:

In average **88% of Fluorine** converted
and retrieve in HF

=> Some PICs expected ?



C-IC & IC analysis



AFFF rinsing solution (waste)

Targeted PFAS

Matrix characterization

PFAS	Result (µg/L)
Perfluoroalkylcarboxylic acids (PFCAs)	
PFBA	101
PFPeA	60
PFHxA	555
PFOA	186
PFNA	43
PFDA	42
Perfluorinated sulfonic acids (PFSAs)	
PFBS	163
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Inject° ~10 g/min
i.e. a total of 600 g



Furnace: 910°C
SCC: 1,130°C,
~2.3 s



DRE (%)* for targeted PFAS (3 replicates)

Average	%RSD
PFCAs	
99.9488	0.04%
99.7517	0.12%
99.9630	0.01%
99.9792	0.01%
99.9849	0.02%
99.9688	0.01%
PFSAs	
99.9909	0.01%
99.9977	0.001%
99.9994	0.0002%
99.9946	0.002%
99.9992	0.00005%
FTSAs	
99.9976	0.001%
99.9931	0.002%
99.9919	0.003%

Result in fumes < MDL (not detected)

Short chain / Long chain

PFAS in blue are classified as POP (Stockholm convention)

PFAS* in purple are predominant in the AFFF

* DRE calculated with MDL value when results < MDL
DRE = {1 - (Wout/Win)} x 100



Findings:

DRE for the most concentrated PFAS

- PFOS: DRE > **99.9999%**
- PFHxS: DRE > **99.999%**
- 6:2 FTS: DRE > **99.99%**

PFASs & FTSAs

DRE are all > **99.99%**

For all targeted PFAS:

DRE > **99.9%** (except for PFPeA)

Pilot bench allows **good reproducibility** of tests

AFFF rinsing solution (waste)

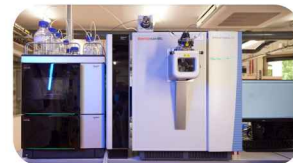
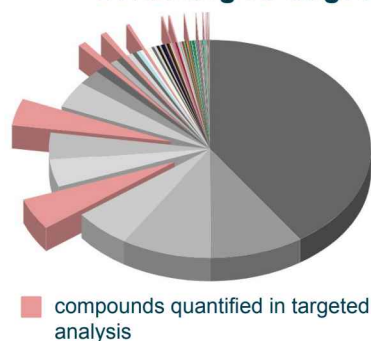
Non Targeted Screening NTS



LC/HRMS analysis => 92,829 spectra



Screening vs targeted analysis



LC HRMS
(Orbitrap)

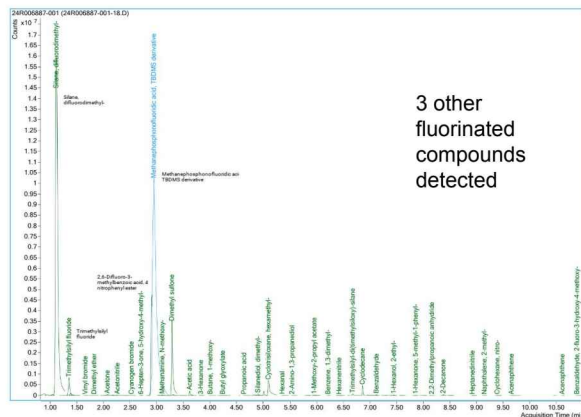
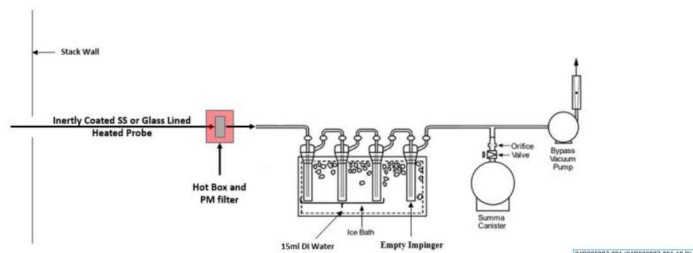


Findings:

- **NTS show lots of PFAS not identified on waste with the “usual” targeted PFAS analysis**
Especially the predominant one (6:2 FTAB - Capstone B)
- **And NTS apply on OTM-45 fractions show no more PFAS in the fumes**

AFFF rinsing solution (waste) OTM-50

- Implemented at the end of HF sampling train



Findings:

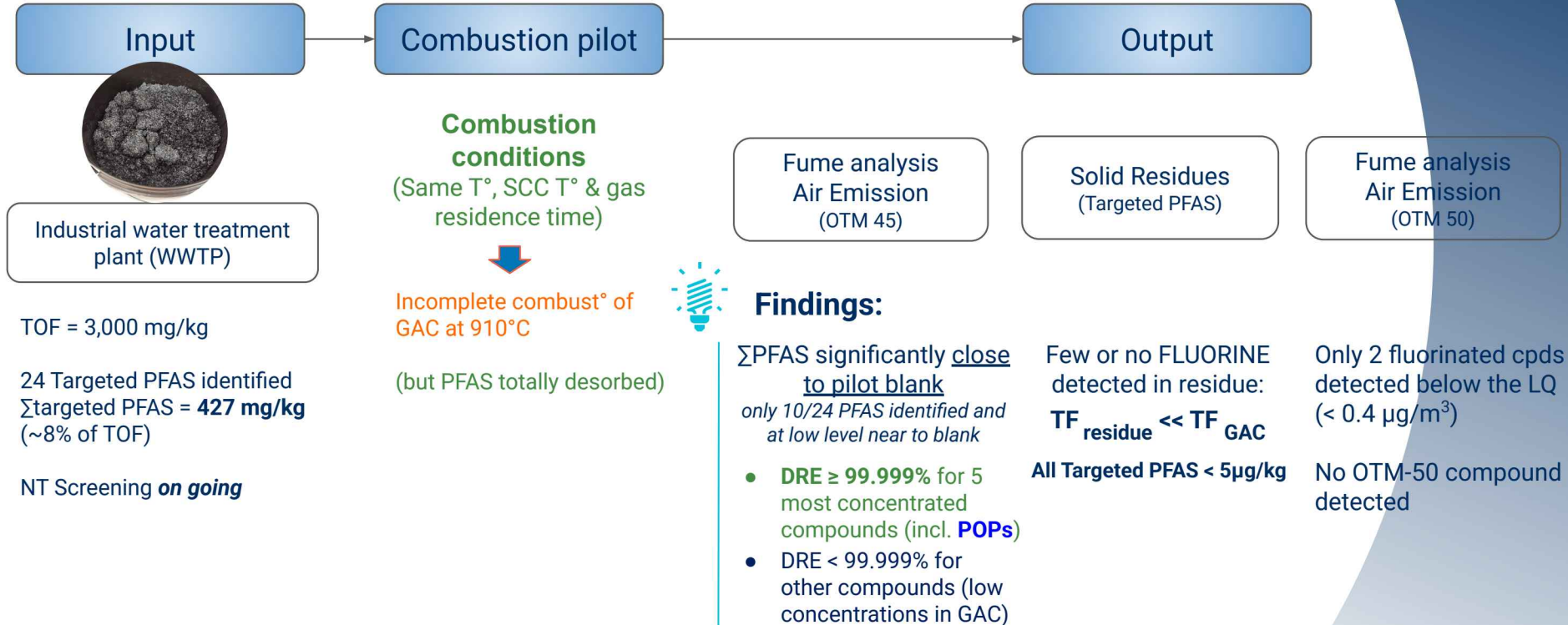
OTM-50 results:

- CF₄, C₂F₆ Non detected
- Only 1 PFAS from the OTM-50 list C₃F₆ (hexafluoropropane) near to LoQ & also identify in the blank => Sampling line contamination!
- Some silane derivative compounds (probably reaction products with quartz)

=> But not enough to explain HF losses!

Spent GAC from an industrial WWTP

Test overview



5 - Conclusions



Summary & learnings

Learnings



High DRE reached in High Temperature Incineration conditions of Port Arthur plant (**SCC at 1,130°C and 2.3s**) without fumes treatment

- **DRE \geq 99.999%** for **POPs (PFOA, PFOS, PFHxS)**
- **DRE \geq 99.99%** for several PFAS, short and long chains from different families
- **Only few PICs** identified by **OTM-50 & NTS**
- **DRE test are limited by quantification limits in gas or blank level**
Need for higher PFAS concentration in waste to reach **DRE > 99.9999%** expected for POPs

Take care to blank & cleaning procedure to avoid contamination!

Further steps



Tests **new matrices & new conditions** with the pilot unit

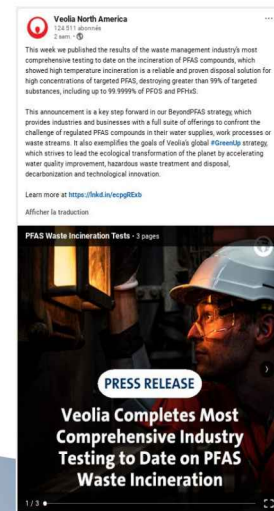
Apply this methodology **on real incineration plant with fumes treatment step**

A first campaign in Port Arthur (US) - Results presented in the PFAS Forum in Orlando (April 25)

→ [LinkedIn](#)

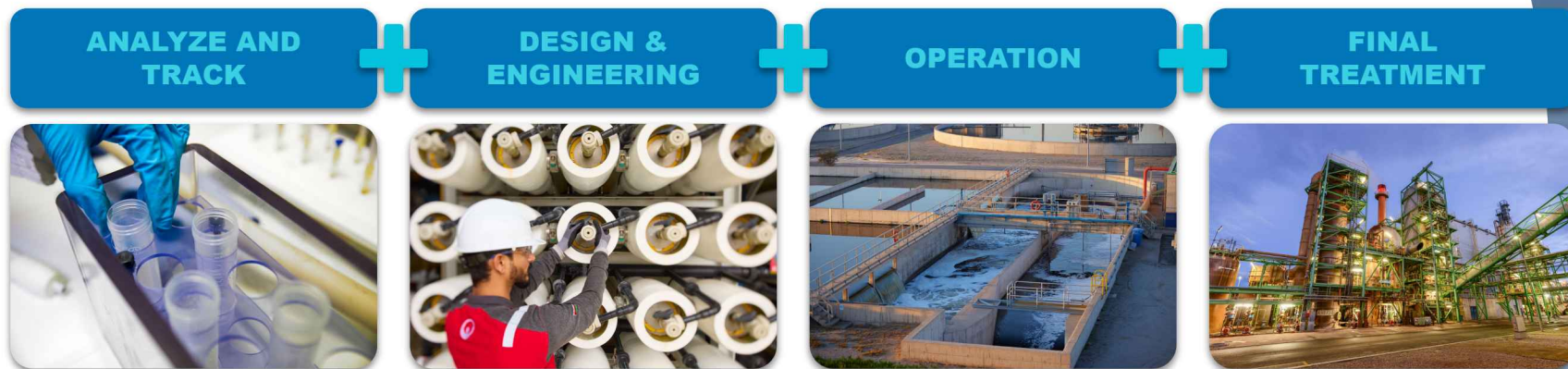
→ [VNA website](#)

Port Arthur (US) testing on PFAS waste incineration



Veolia PFAS treatment and management offer

Veolia's End-to-End Solutions to Tackle PFAS & Protect Health and Environment



Beyond**PFAS**
by **VEOLIA**

[Weblink](#)

Thank you for your attention

Questions?

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