Vertex Environmental Inc.

Treating PFAS In-Situ

December 6, 2023

ESAA PFAS Symposium

Bruce Tunnicliffe, M.A.Sc., P.Eng.

Outline

- Why is PFAS remediation difficult?
- In-Situ Remediation of PFAS
  - Comparison of 2 Amendments
- Closing

Background

Bruce Tunnicliffe, M.A.Sc., P.Eng.

- Masters – U of Waterloo. Remediation
- Founder – Vertex Environmental Inc.
- Founder – SMART Remediation

Vertex Environmental Inc.

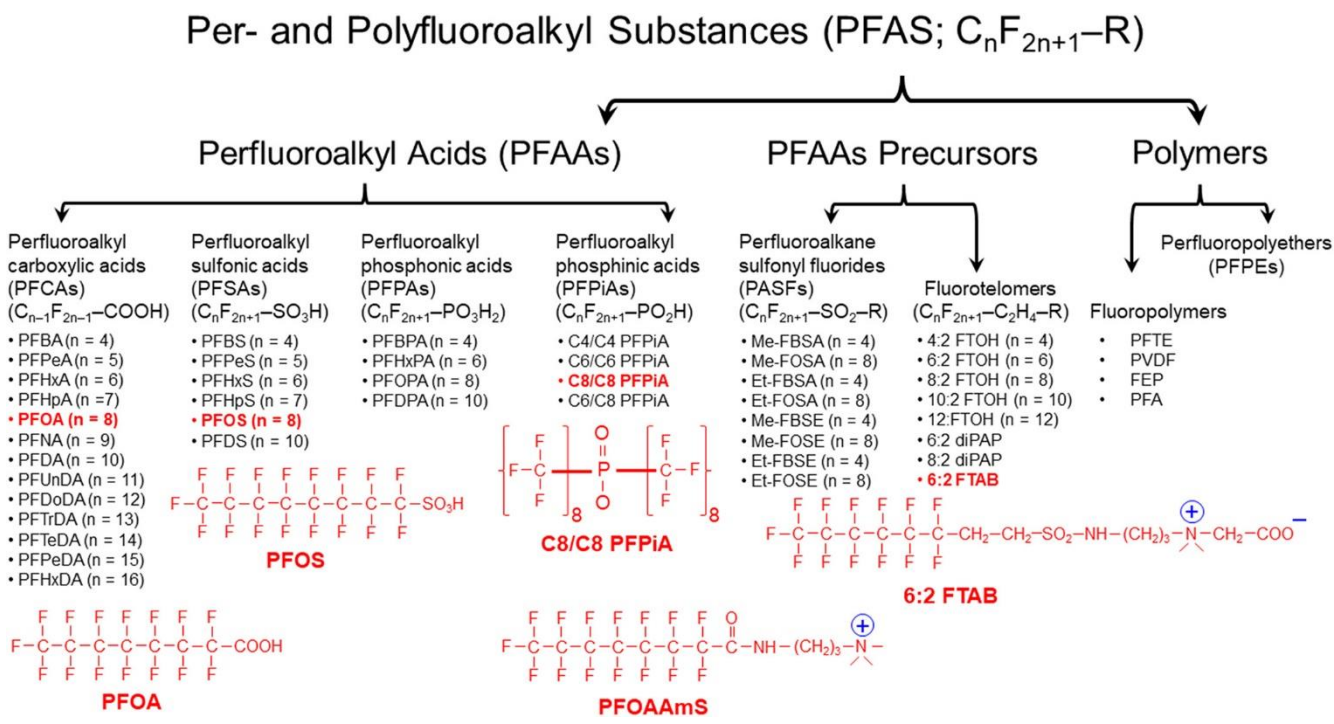
- Started July 2003
- Environmental Contractor

Why is PFAS Remediation Difficult?

Why is PFAS Remediate Difficult?

PFAS is a Group of Chemicals

- Some say more than 4,500
- Laboratories report ~40 PFAS
- PFAS = Dark Matter?
  - you don't know what you have
- Long chain can degrade to short chain
- Generally short chains are more toxic and mobile than long chains
- Documented water treatment issues
  - e.g. hydrogen peroxide is added during water treatment, the short chained PFAS effluent concentration is higher than influent conc.



A Take Away

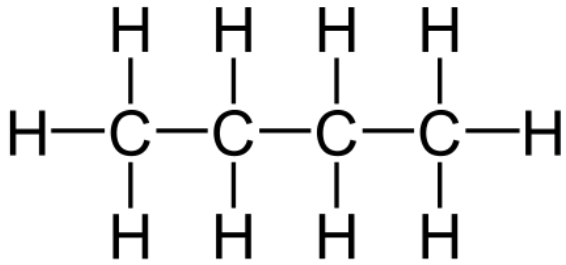
Be careful with in-situ PFAS destruction approaches, you have to consider precursors

Xiao, F. "An overview of the Formation of PFOA and PFOS in Drinking-Water and Wastewater Treatment Processes", Journal of Environmental Engineering. April 2022

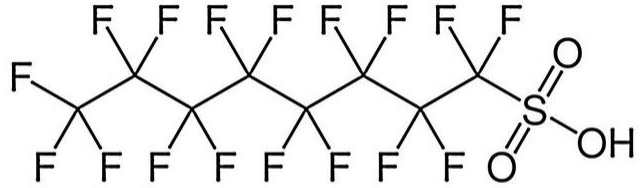
Why is PFAS Remediate Difficult?

How They Are Made

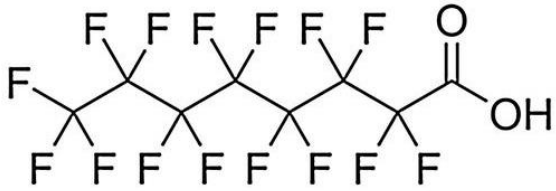
- Human made
- A fossil fuel derivative
- To make PFAS, replace the hydrogen with fluorine
- Carbon-Fluorine (C-F) bond:
  - strongest covalent bond in organic chemistry
- Low to no degradation under natural conditions
- PFAS thermally degrades at >800^{o}C



Aliphatic Compound



Perfluorooctane sulfonic acid (PFOS)



Perfluorooctanoic acid (PFOA)

A Take Away

Traditional in-situ remediation approaches will be very difficult to apply due to PFAS characteristics

Remediating PFAS In-situ

What Can We Do Right Now?

Remediating PFAS, in-situ

Adsorption / Stabilization:

Amendments exist that can be injected into the subsurface:

Activated Carbon

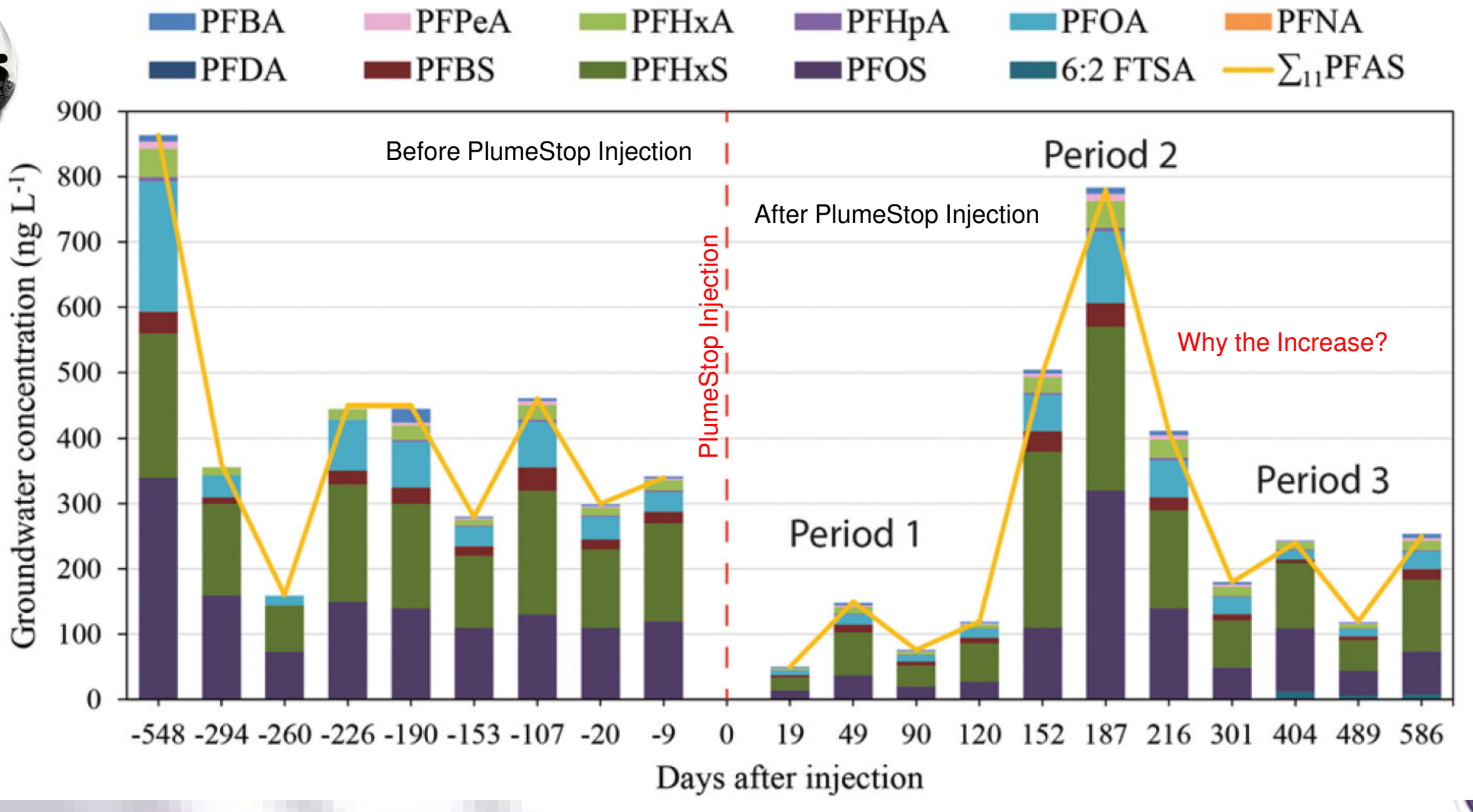
PlumeStop®

Modified Clay

Fluoro-Sorb®

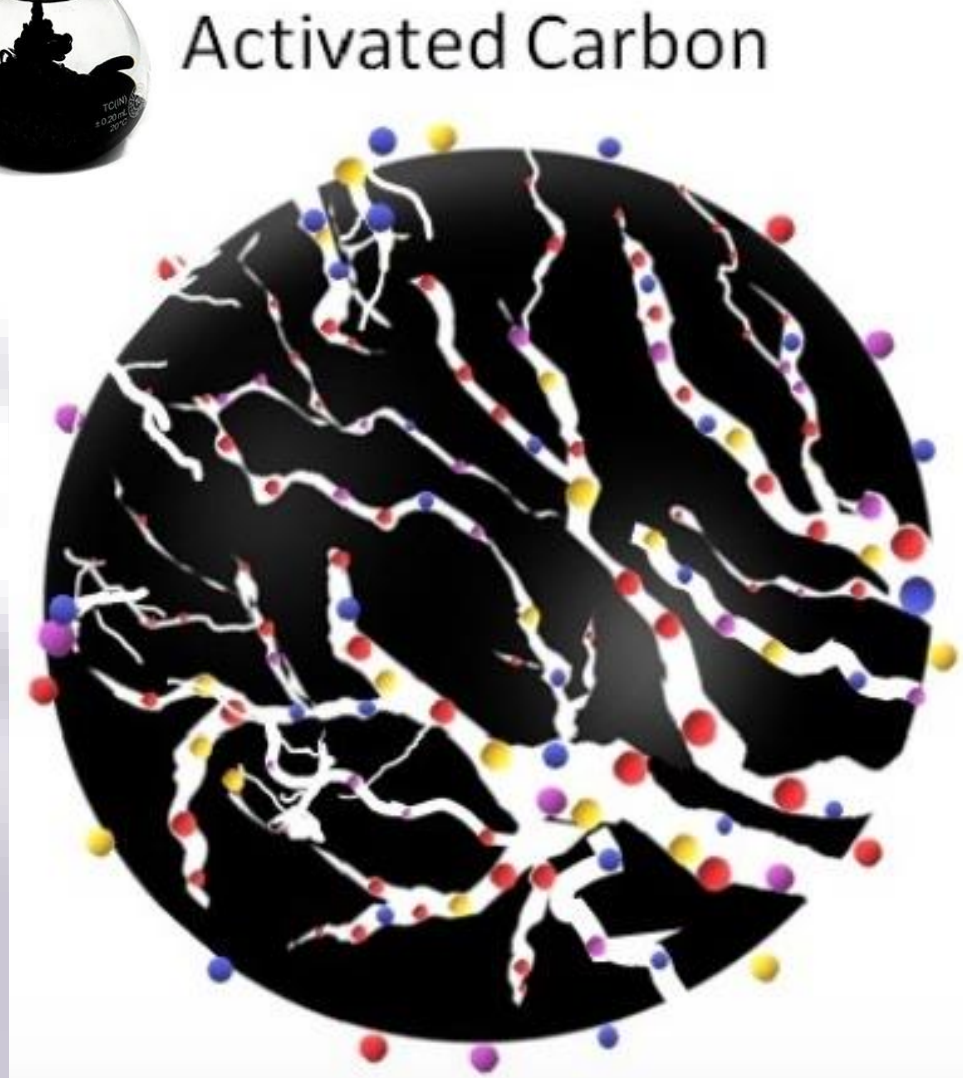
In-situ with Activated Carbon

Colloidal Activated Carbon (PlumeStop) Published Case Study 2023



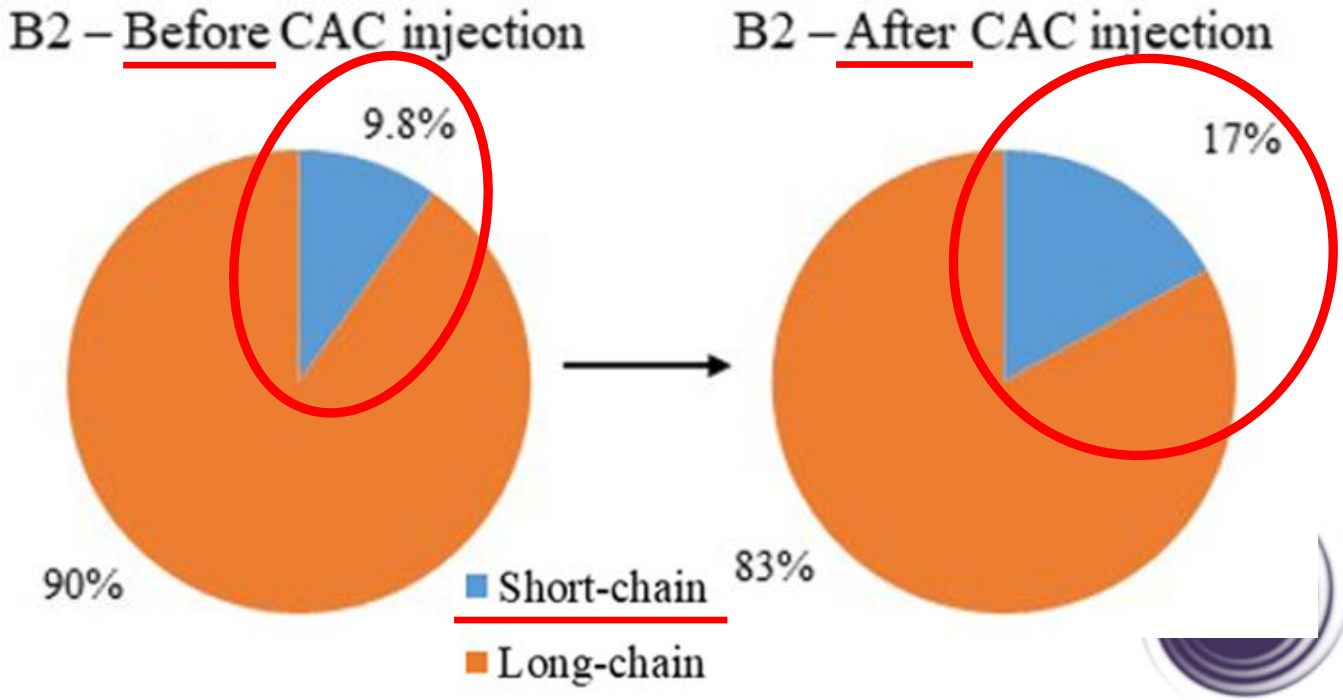
G.Niarchos *et al.*, 2023 – "In-situ application of colloidal activated carbon for PFAS-contaminated soil and groundwater: A Swedish case study"

In-situ with Activated Carbon

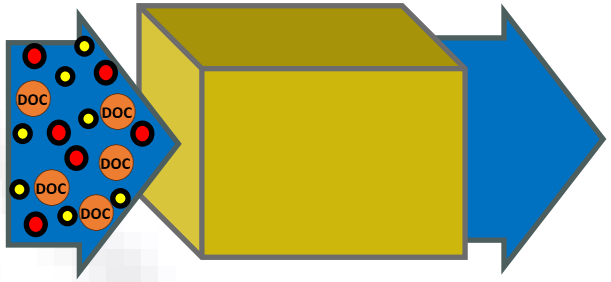


Activated Carbon – Roll Over, or Competitive Adsorption

- PFAS >4,500 compounds
- Long Chain PFAS
  - Preferentially adsorbed
- Short Chain PFAS
  - Get “kicked off” the carbon

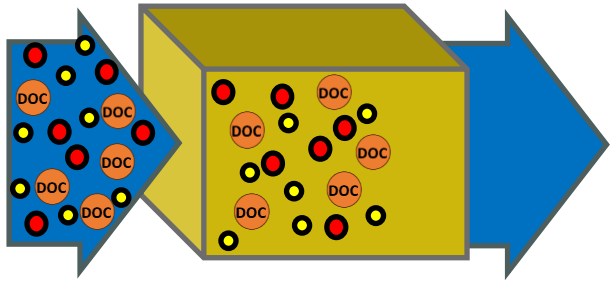


In-situ with Activated Carbon



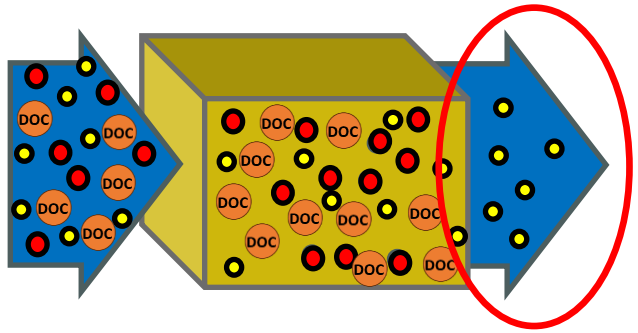
PFAS Contaminated Water enters aquifer with Activated Carbon

Start Time



PFAS is Initially Adsorbed

Early Time



Roll-Over

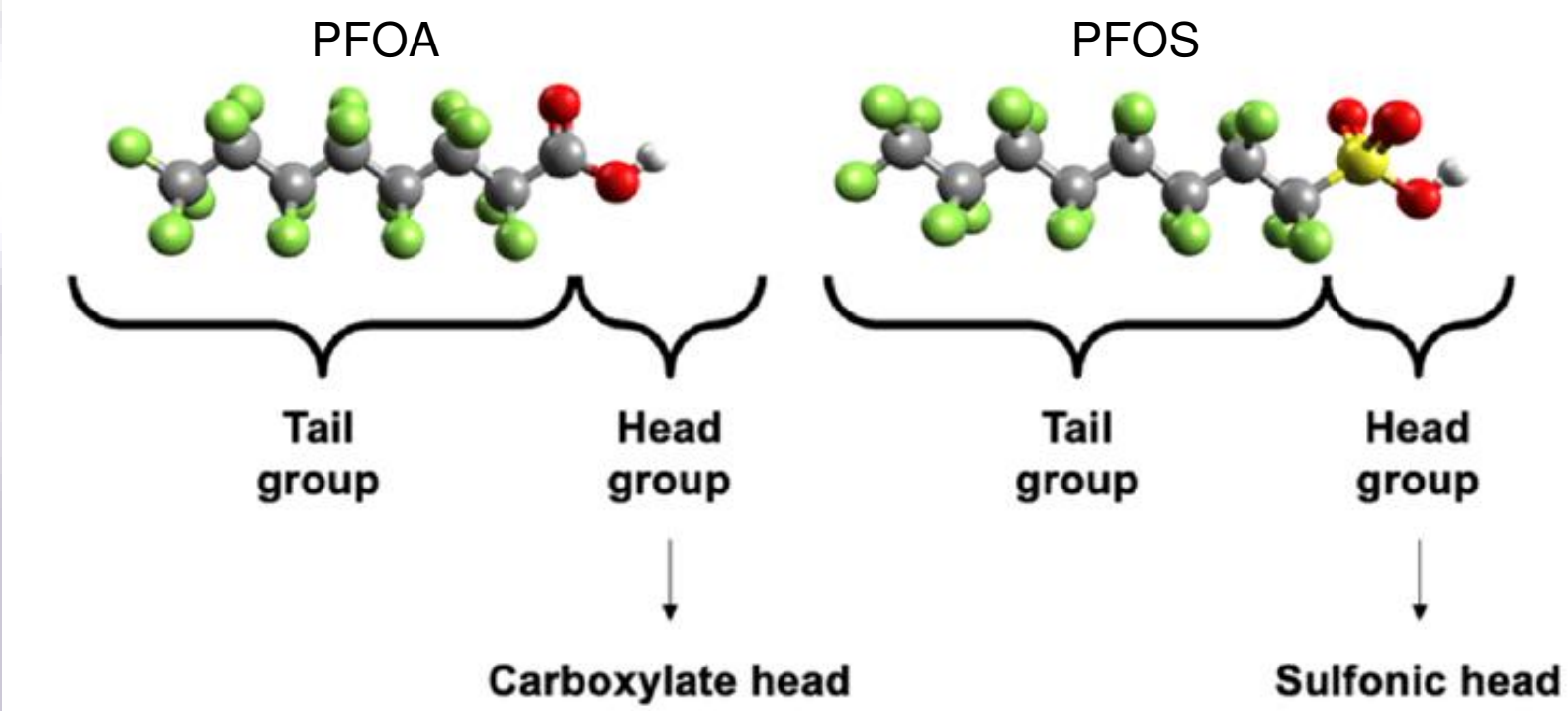
Side Note: There have been some interesting developments with surface modified AC

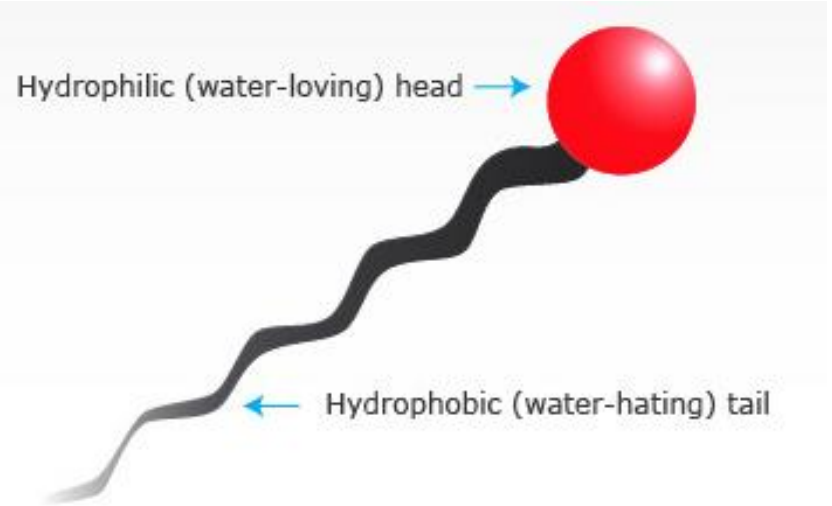
DOC Dissolved Organic Carbon (DOC) Short Chain PFAS Long Chain PFAS

Remediating PFAS, in-situ with Modified Clay

FLUORO-SORB® 100

- The modified clay adsorption is ion exchange as well as hydrophobic attraction
- PFAS is surfactant-like, thus partially hydrophobic





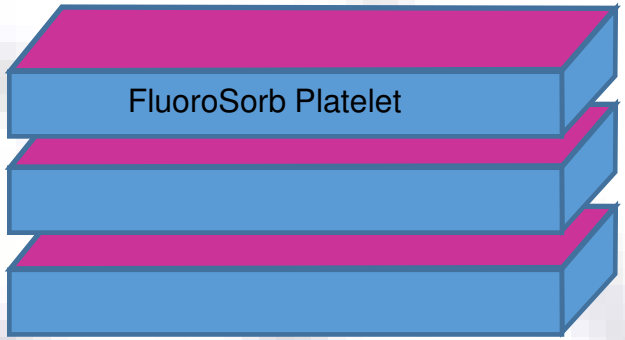
VERTEX

Remediating PFAS, in-situ with Modified Clay

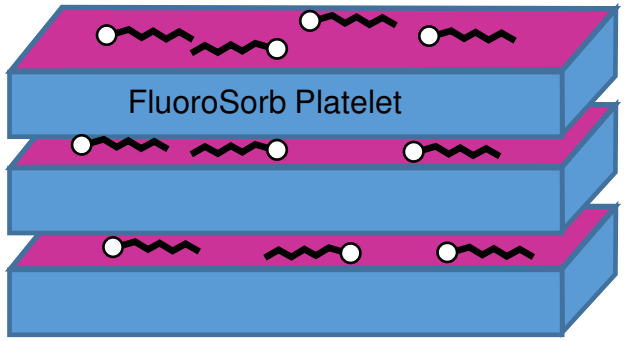
FLUORO-SORB® 100

- Modified Clay Sorption Mechanism

Modified Clay:
Platelet-like structure

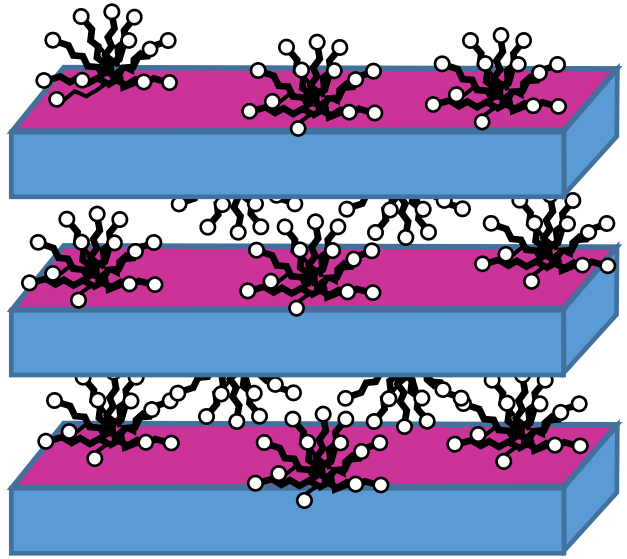


How PFAS is Sorbed



= PFAS Moledule

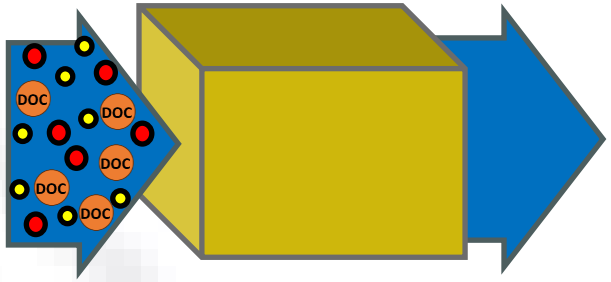
Increasing PFAS Adsorption



Credit: CETCO

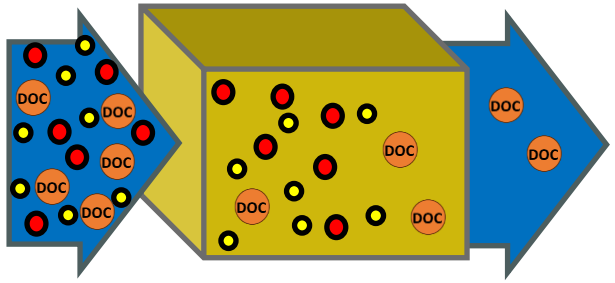
In-situ with Modified Clay

FLUORO-SORB® 100



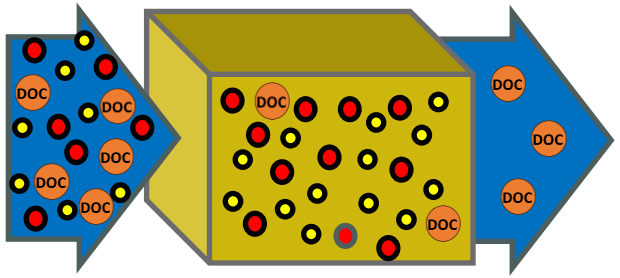
PFAS Contaminated Water enters aquifer with Modified Clay

Start Time



PFAS is Initially Adsorbed, DOC is not

Early Time

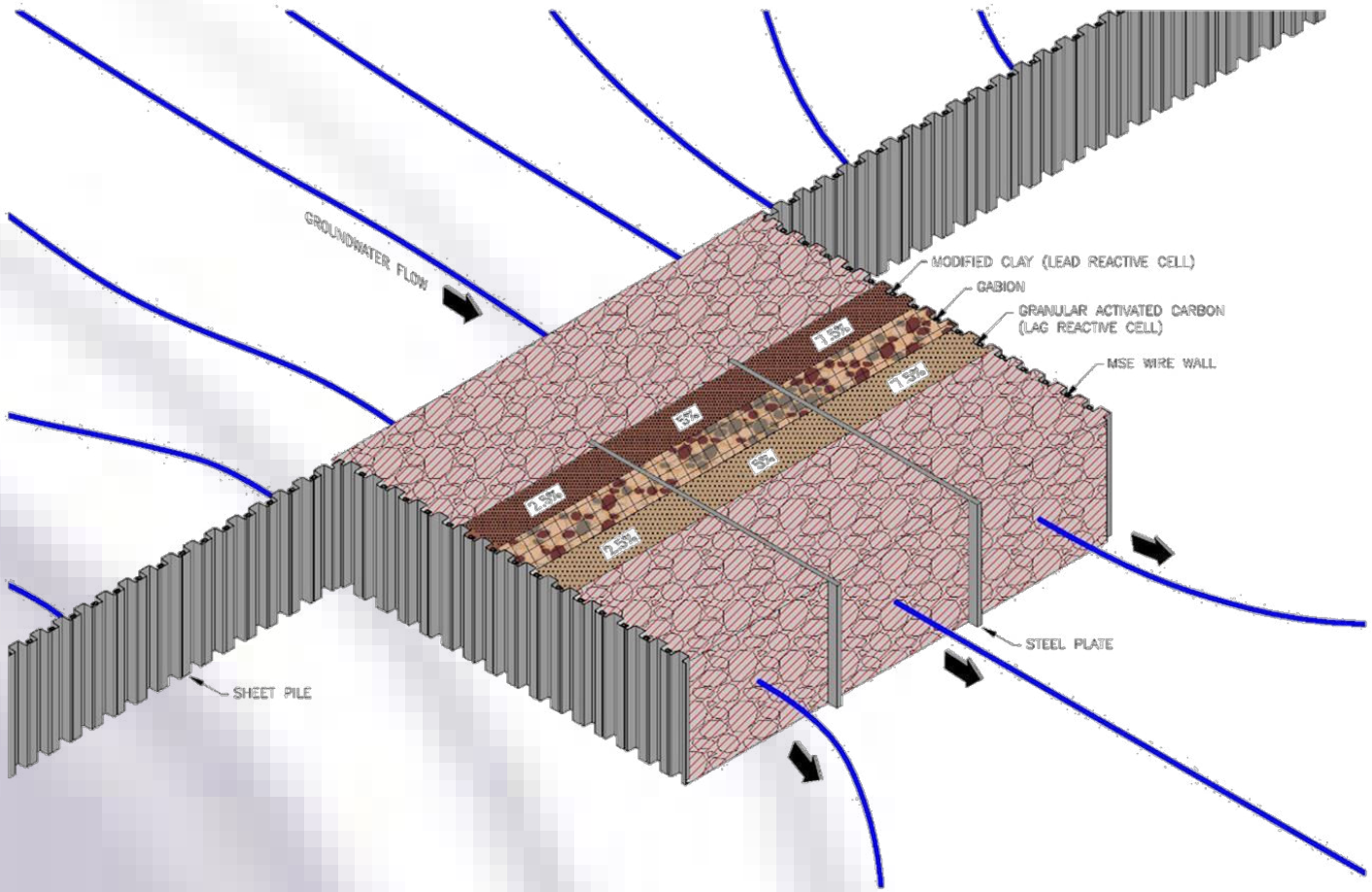


PFAS Adsorbed

DOC Dissolved Organic Carbon (DOC) Short Chain PFAS Long Chain PFAS

VERTEX

Remediating PFAS, in-situ with Modified Clay



Credit: SNC-Lavalin

Groundwater Results
11 Months After Install

	2.5% MC	5% MC	7.5% MC
Vol. of Treated Water (m^3)	~50	~48	~47
Adsorbed ∑PFAS (mg)	~1,021	~1,233	~1,216
Removal Efficiency (%)	**98.1%**	**95.3%**	**97.4%**

Closing Thoughts

In-Situ Remediation of PFAS

- PFAS remediation is in a development stage
  - Research, experimentation, pilot tests
  - Very exciting times
- PFAS Destruction is difficult
  - We have to be careful with precursors
- Two proven in-situ injectable approaches, using:
  - Activated Carbon (specifically, colloidal activated carbon)
  - Modified Clay (specifically, Fluoro-Sorb®)
- Current Assessment:
  - Activated Carbon – In-Situ PFAS Remediation Approach 1.0
  - Modified Clay – In-Situ PFAS Remediation Approach 2.0

Questions?

Thank You for
Your Time

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