Comparing the sustainability of active and passive groundwater containment systems for the treatment of PFAS plumes

Comparaison de la durabilité des systèmes actifs et passifs de confinement des eaux souterraines pour le traitement des panaches de PFAS

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Per- and Polyfluoroalkyl Substances

Widely used

- Commercial and domestic products/coatings

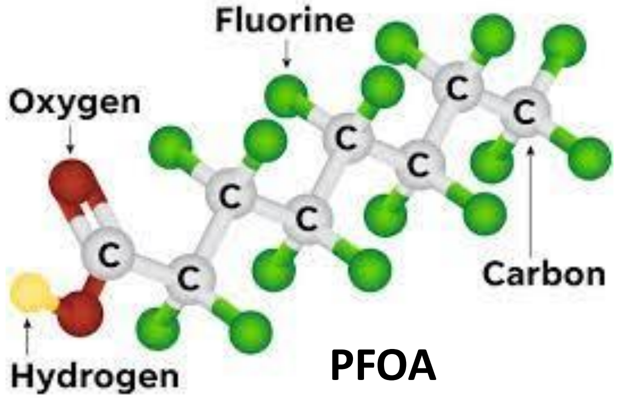
Recognised spill history

- Aqueous Film Forming Foams

Challenging behaviour of some PFAS

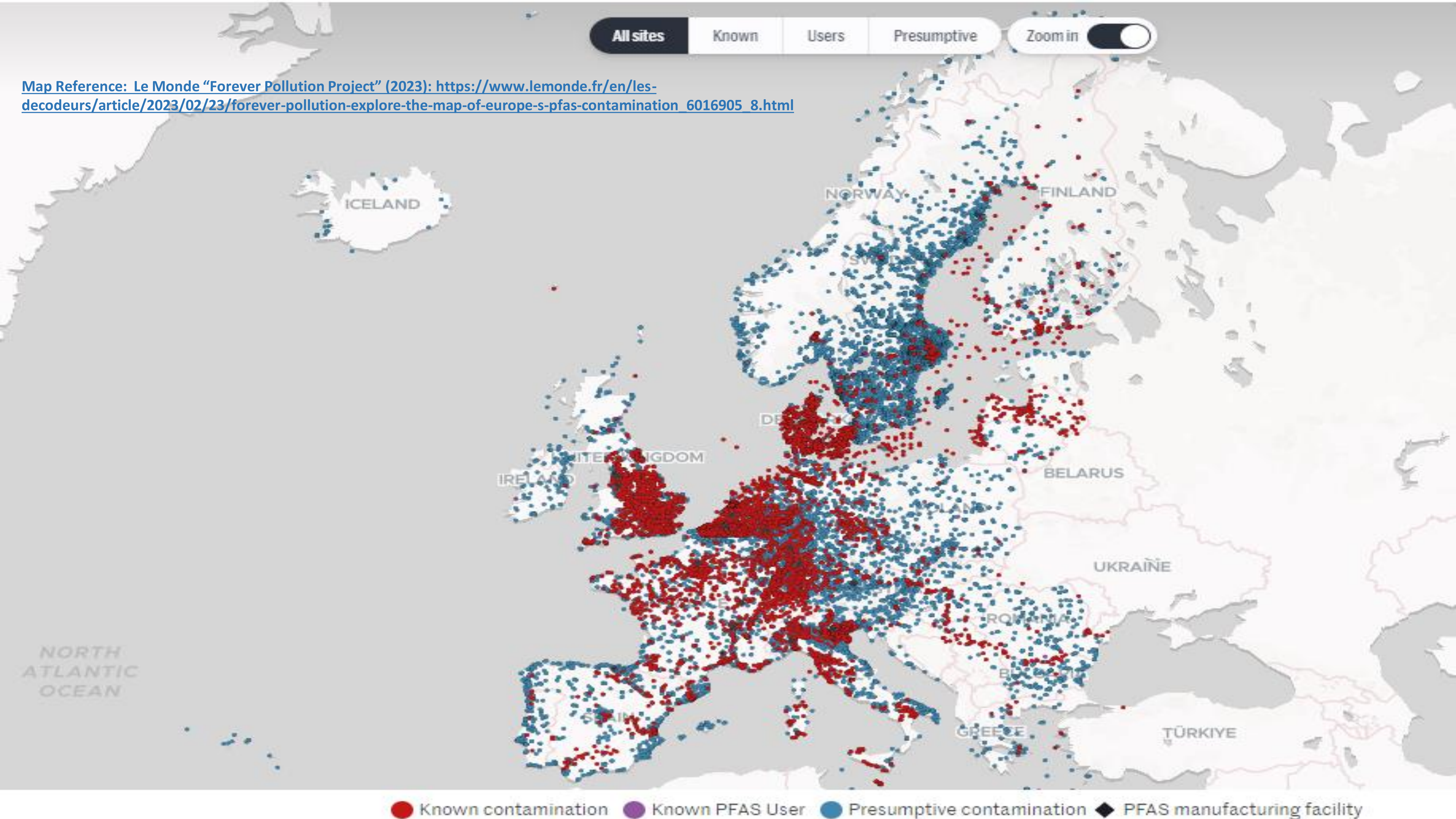
- Retained in soils for decades
- Very mobile once in groundwater
- Recalcitrant to degradation
- Some reported to be toxic
- Potential for large very dilute plumes
- Potential to impact large areas

And so…PFAS are widespread in the environment



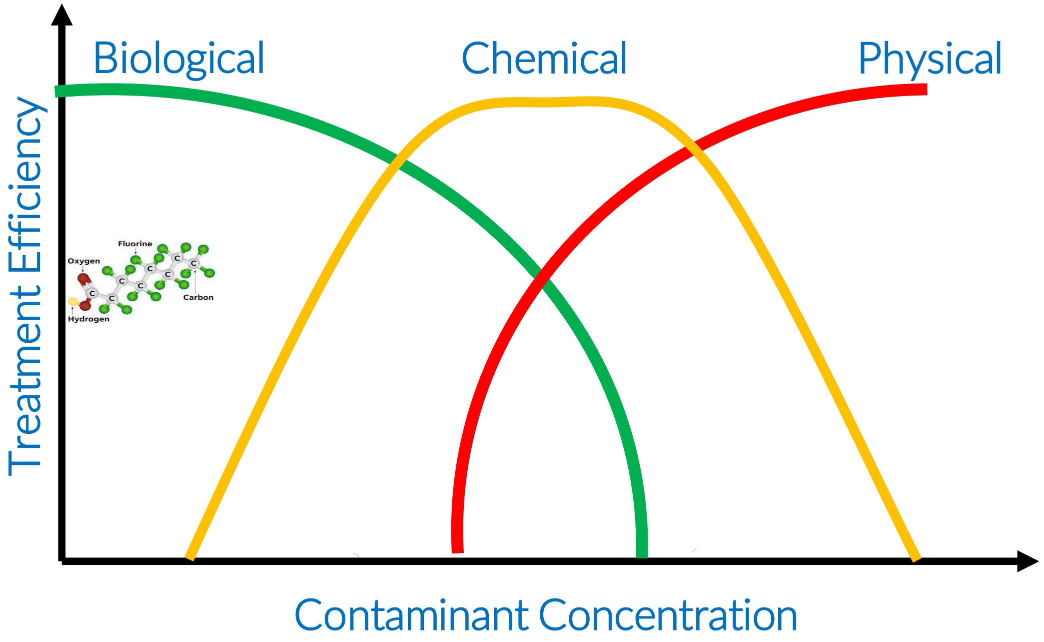
PFOA

Map Reference: Le Monde "Forever Pollution Project" (2023): https://www.lemonde.fr/en/les-decodeurs/article/2023/02/23/forever-pollution-explore-the-map-of-europe-s-pfas-contamination_6016905_8.html



How can PFAS be treated or managed?

Removal and destruction

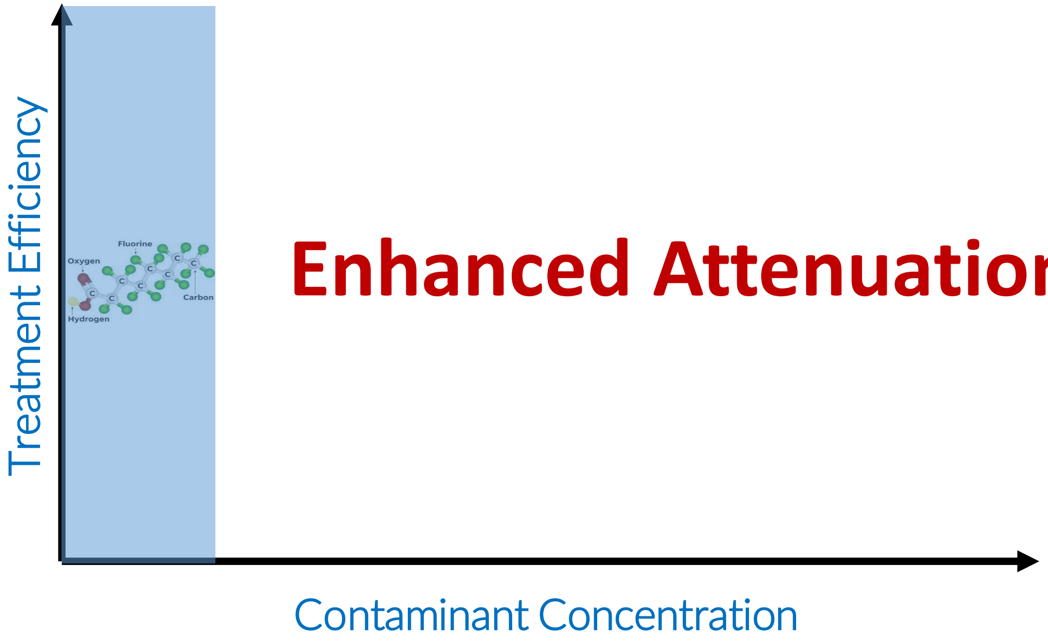


Pumping huge volumes, Landfill, Energy, Equipment, Transport, Cost

High ongoing carbon footprint

An alternative way to manage PFAS

Adopt a sustainable remediation approach



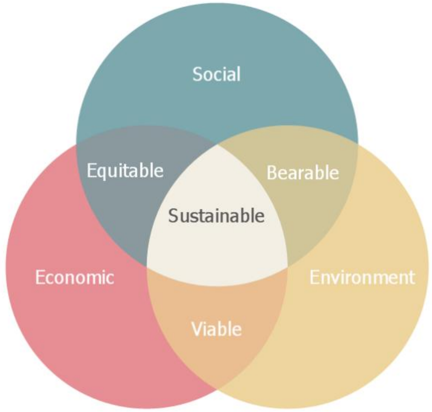
(ISO 18504:2017) definition:

Sustainable Remediation is the

*'elimination and/or **control** of unacceptable **risks** in a safe and timely manner **whilst***

optimizing the environmental, social and economic value

of the work.'



REGENESIS

What is Enhanced Attenuation?

PFAS don't biodegrade?

Natural Attenuation ***doesn't*** just mean biological degradation:

- Diffusion
- Dispersion
- Volatilisation
- Sorption
- Chemical (abiotic) degradation

Increase the ability of the aquifer to sorb PFAS
'Retention'
= **Enhanced Attenuation** of the PFAS plume
=> The PFAS is stored in the environment so that it remains isolated from potential receptors for a "period of time"


DOI: 10.1002/rem.21731

RESEARCH NOTE

WILEY

Enhanced attenuation (EA) to manage PFAS plumes in groundwater

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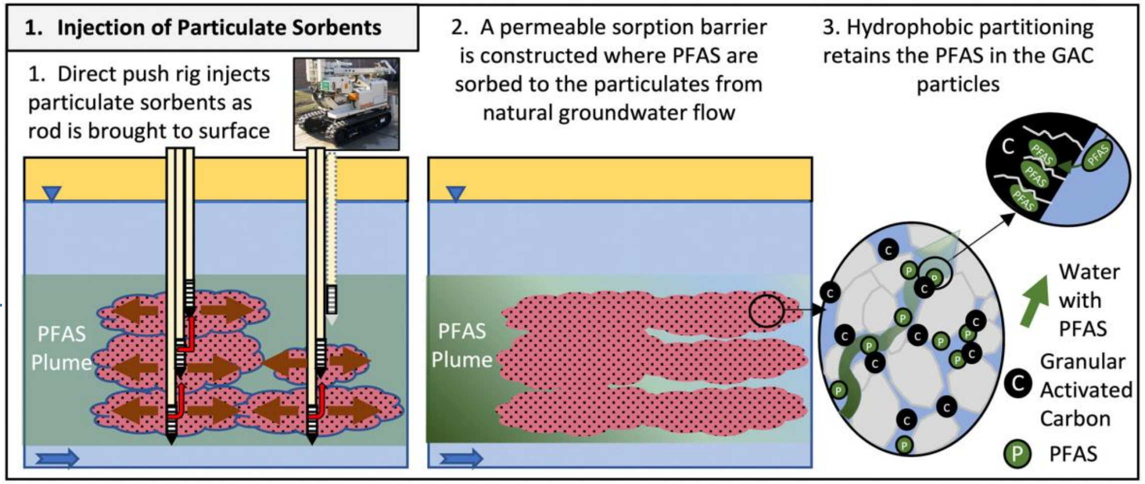
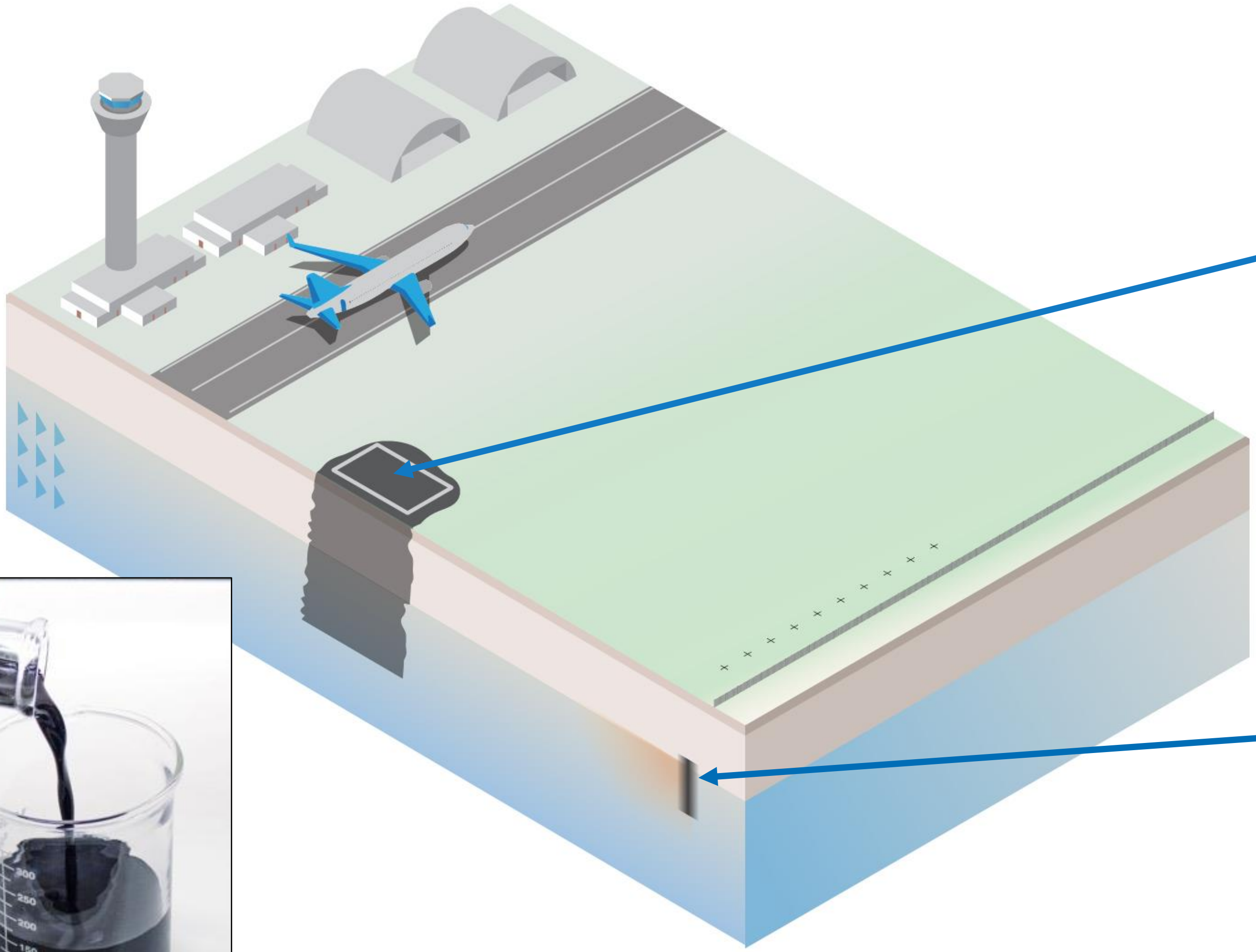
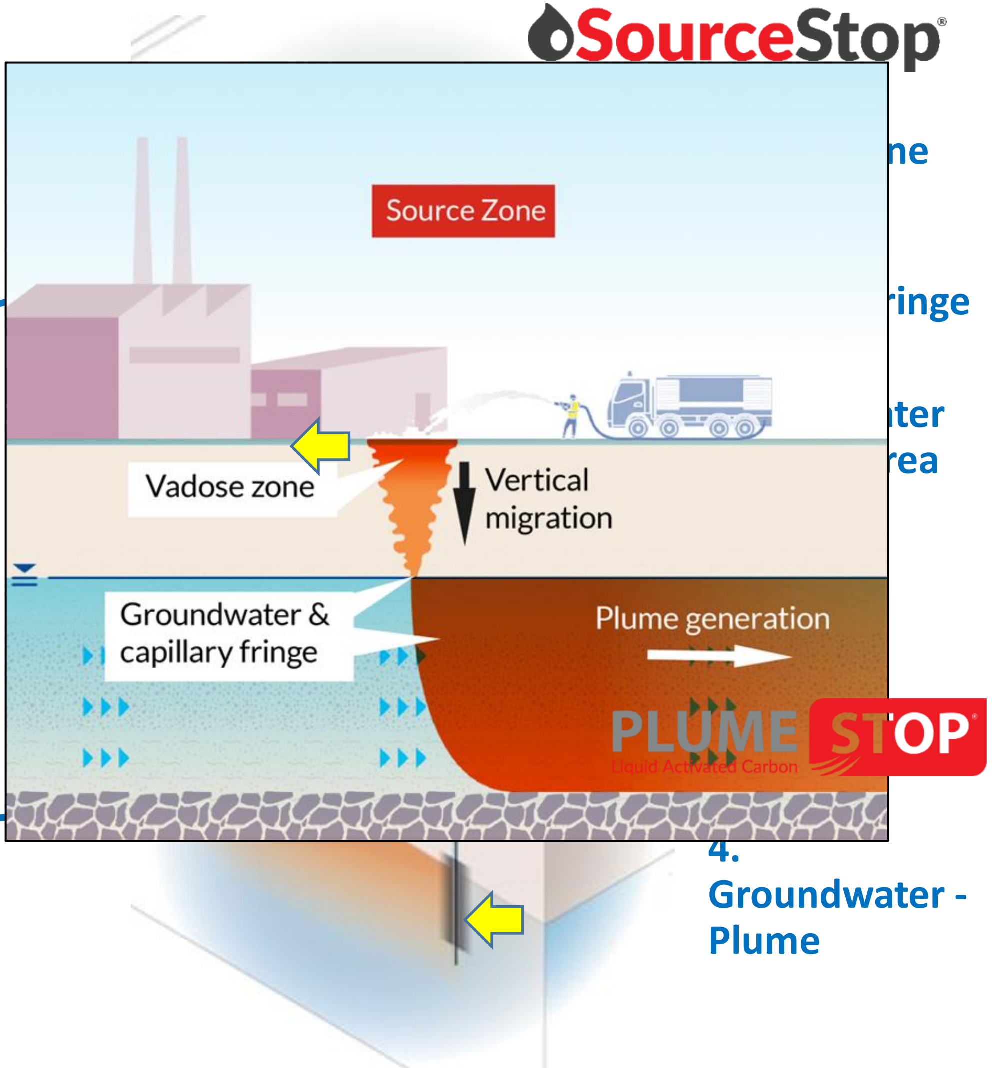


REGENESIS

Considering the PFAS Source-Plume system





Efficacy

Completed > 51 sites so far

USA, Canada, UK, Norway, Sweden, Middle East, Australia

Third party study of 17 PFAS sites treated with PlumeStop

- Data available ranges 0.3-6 years
- 16 sites have data
  - 1 pilot site inappropriate for technology
  - 1 site 82 to >99% reduction (seasonal gw flow direction)
  - 14 sites >90% to >99% reduction

RESEARCH ARTICLE

WILEY

Longevity of colloidal activated carbon for in situ PFAS remediation at AFFF-contaminated airport sites

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Funding information
Porewater Solutions, Ontario Centers for Excellence, and Natural Sciences and Engineering Research Council

Abstract

A review of state per- and polyfluoroalkyl substances (PFAS) guidelines indicates that four long-chain PFAS (perfluorooctanesulfonic acid [PFOS] and perfluorooctanoic acid [PFOA] followed by perfluorohexanesulfonic acid [PFHxS] and perfluorononanoic acid [PFNA]) are the most frequently regulated PFAS compounds. Analysis of 17 field-scale studies of colloidal activated carbon (CAC) injection at PFAS sites indicates that in situ CAC injection has been generally successful for both short- and long-chain PFAS in the short-term (0.3–6 years), even in the presence of low levels of organic co-contaminants. Freundlich isotherms were determined under competitive sorption conditions using a groundwater sample from an aqueous film-forming foam (AFFF)-impacted site. The median concentrations for these PFAS of interest at 96 AFFF-impacted sites were used to estimate influent concentrations for a CAC longevity model sensitivity analysis. CAC longevity estimates were shown to be insensitive to a wide range of potential cleanup criteria based on modeled conditions. PFOS had the greatest longevity even though PFOS is present at higher concentrations than the other species because the CAC sorption affinity for PFOS is considerably higher than PFOA and PFHxS. Longevity estimates were directly proportional to the CAC fraction in soil and the Freundlich K_f, and were inversely proportional to the influent concentration and average groundwater velocity.

Case study

Site description

Background

- International UK airport – fire training ground
- Known PFOS issue identified in 2019
- Voluntary remediation scheme – protection of offsite SSSI

Geology / Hydrogeology

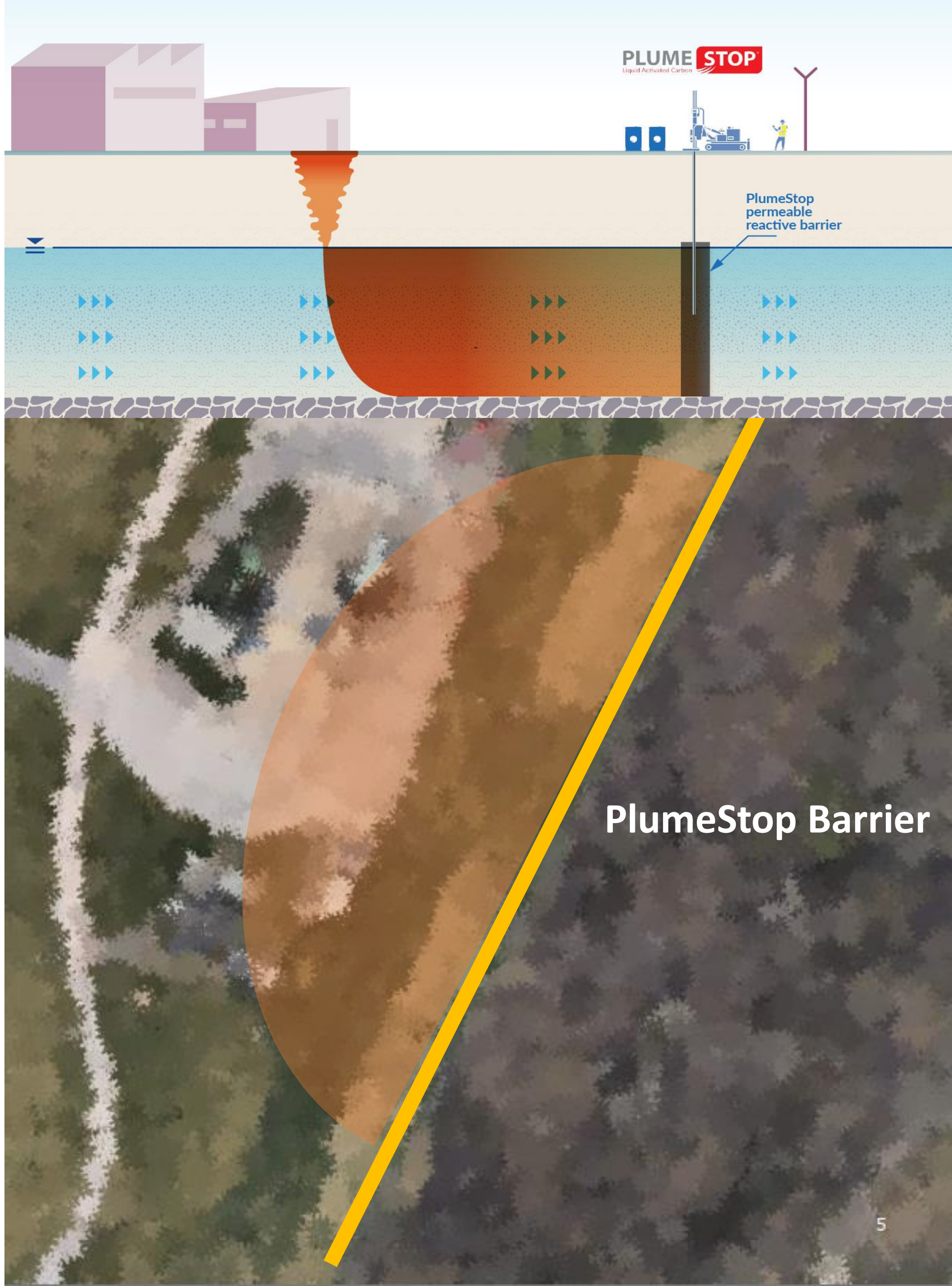
- Alluvium, RTGs onto London clay
- Groundwater at approx. 2m bgl
- Mean groundwater flow (Darcy flux): 48 m/yr

Contamination

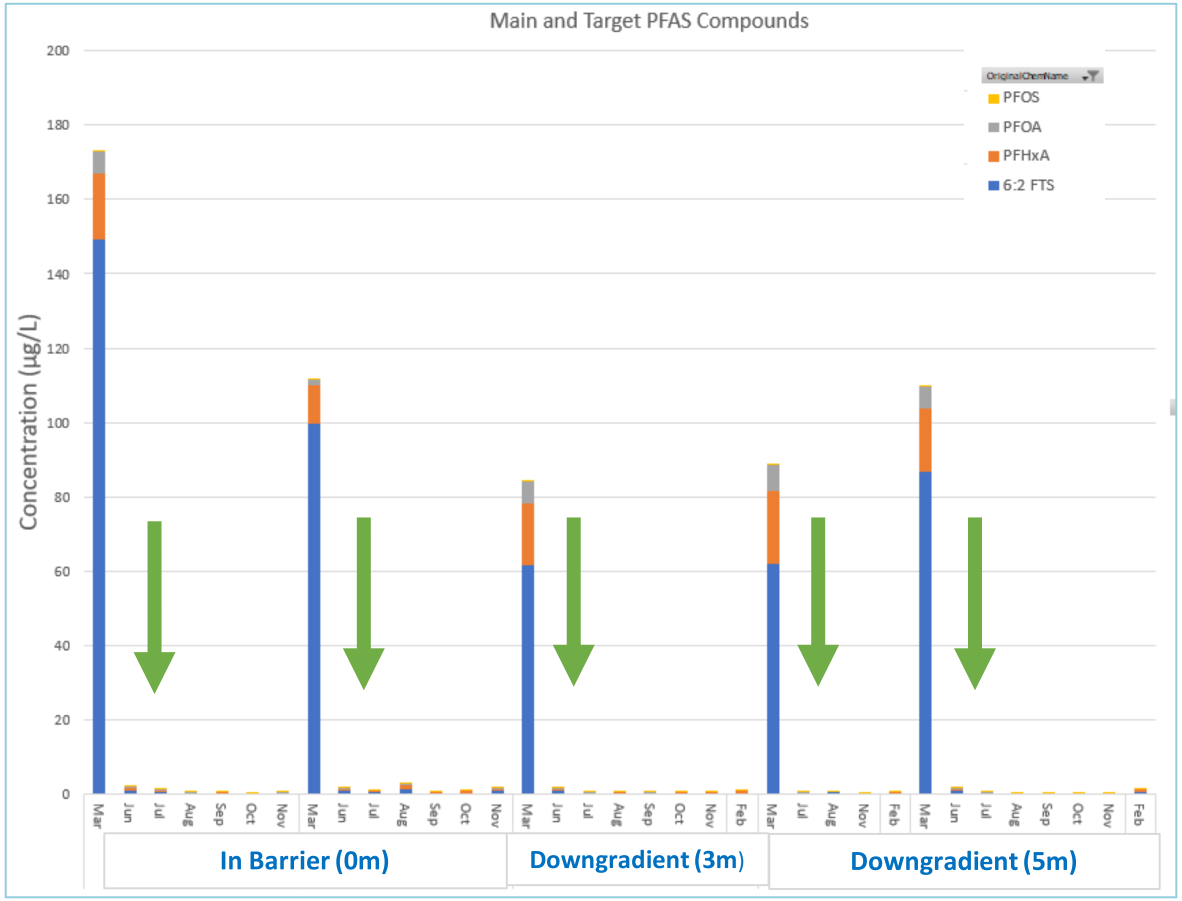
- Total PFAS >200 ug/L
- TPH at 20 mg/L

Objectives

- Target values for PFOA and PFOS are 0,1 µg/L
- No objectives on short-chain PFAS



Case study



So,

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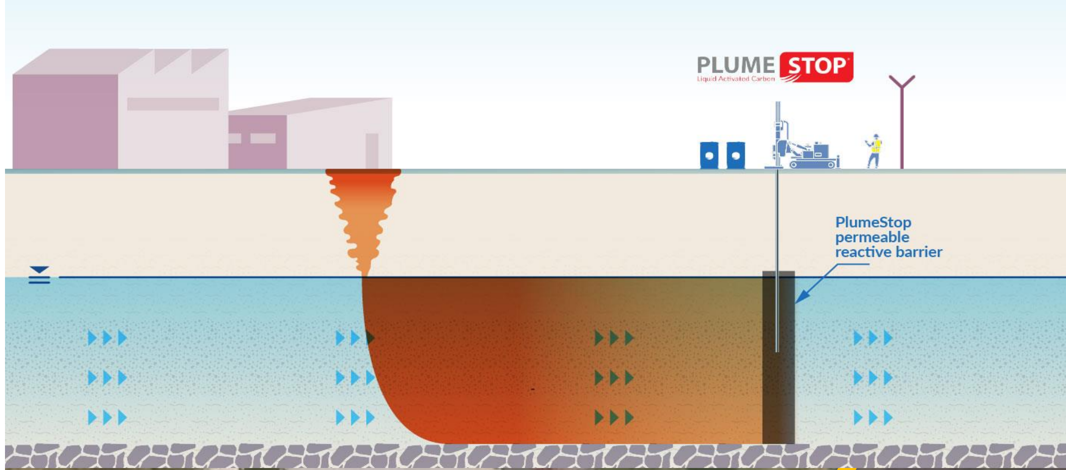
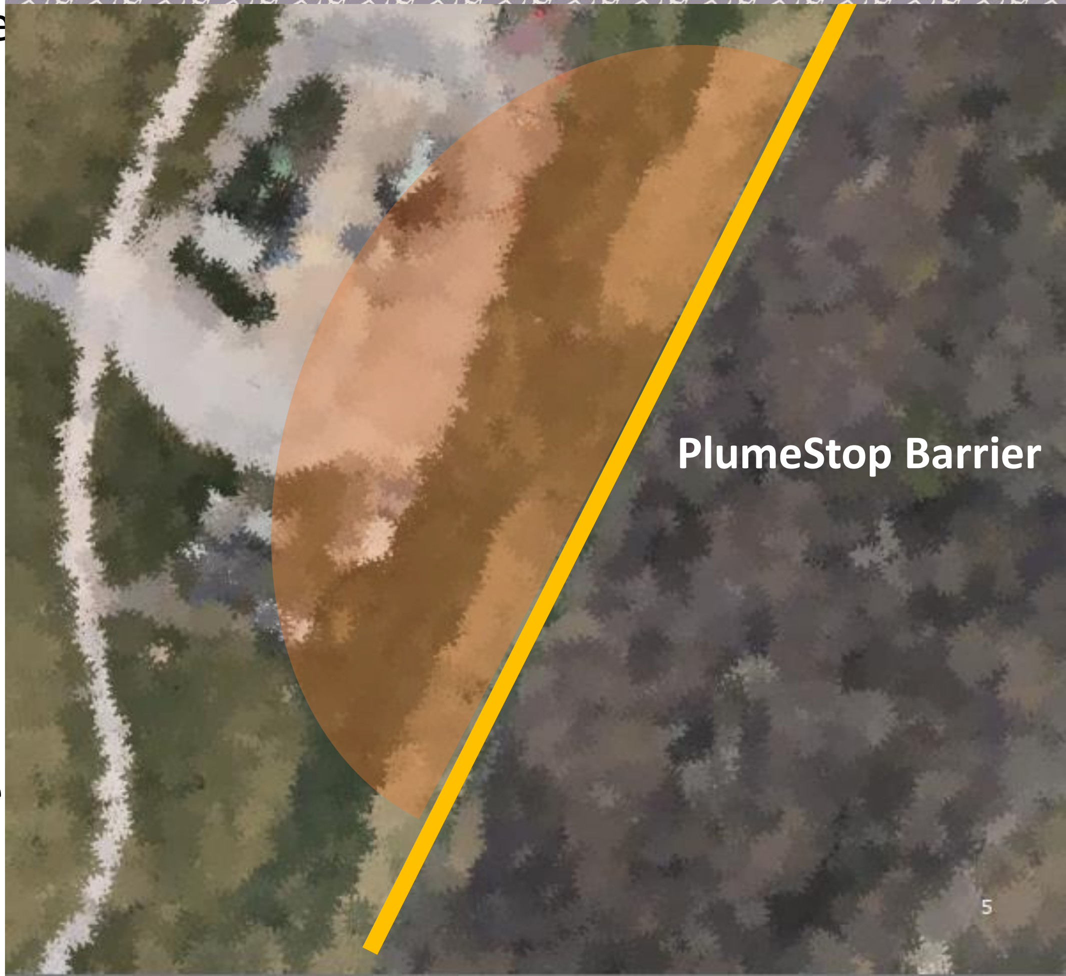


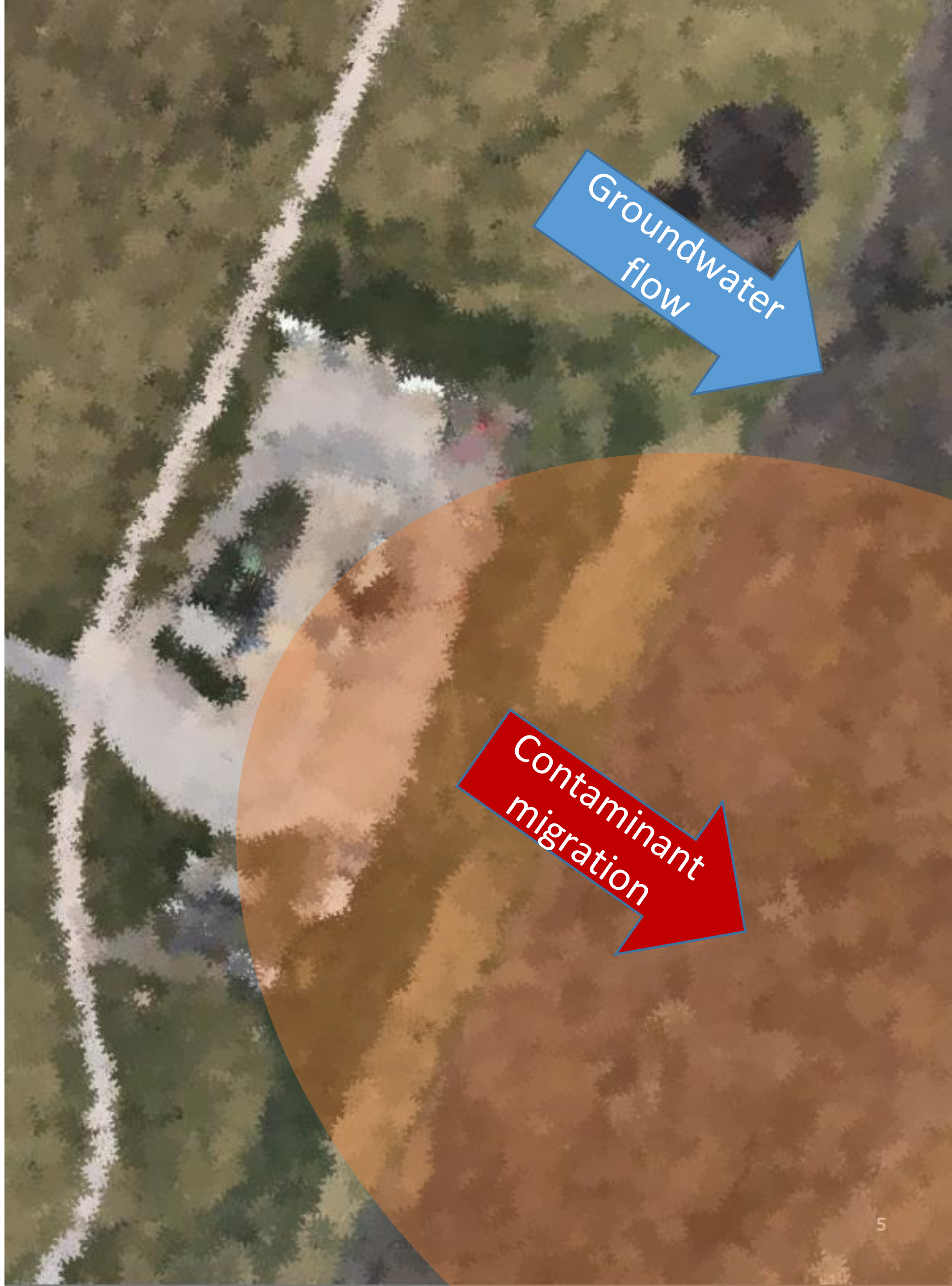


Overview of RAMBOLL Study

Compare the Life Cycle Analysis (LCA) for two remedial approaches that reach project objectives (PFOA and PFOS: 0,1 µg/L):

Note: no objectives on ultra short-chain PFAS more difficult to treat with GAC/CAC technologies

- **In Situ Sorption and Retention Barrier**
  - ✓Passive barrier of colloidal activated carbon (CAC, PlumeStop)
  - ✓Recently implemented at the site
- **Ex Situ Pump and Treat**
  - ✓Utilized granular activated carbon (GAC)
  - ✓Theoretical, best-practice design

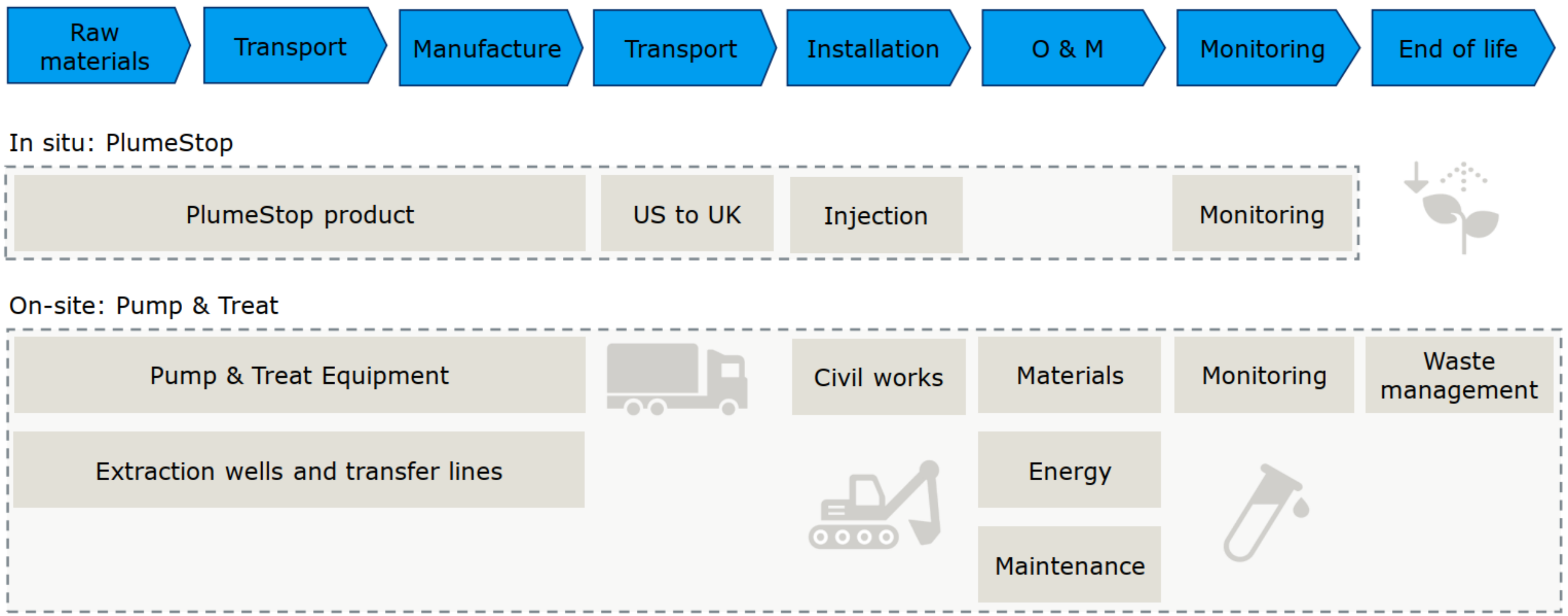


Assessment methodology (Carbon footprint)

- The methods applied in this assessment were based on the international standards for life cycle- and carbon footprint assessment
- The assessment was carried out in the following four stages:
  - ✓Goal and Scope
  - ✓Life Cycle Inventory
  - ✓Life Cycle Impact Assessment
  - ✓Interpretation
- The assessment also focused on other relevant sustainability factors, including general level:
  - ✓Life cycle cost assessment
  - ✓Sustainability assessment (Ramboll SURE tool)

Scope of Assessment: Cradle to Grave

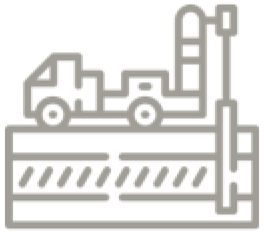
System boundary



Methods/Software

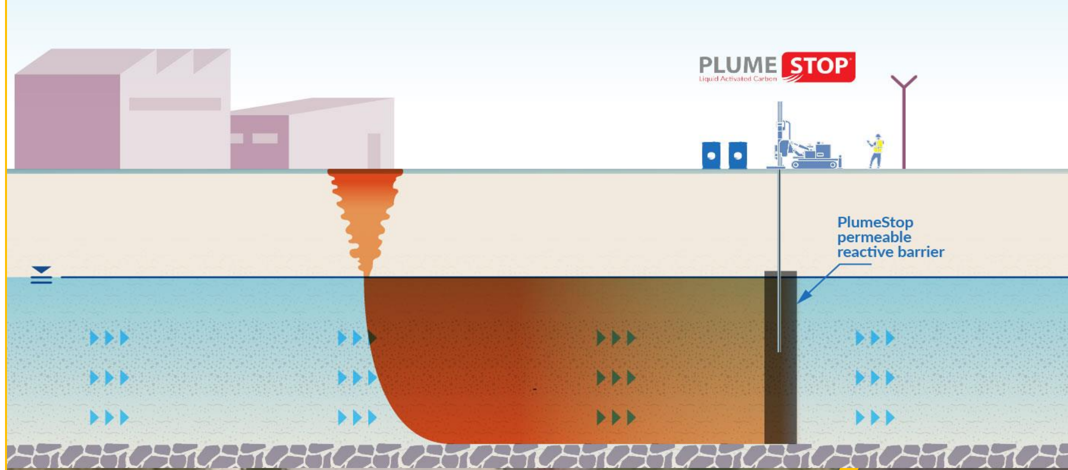
- ISO 14040:2006, ISO 14044:2006, ISO 14067:2018, PCR for Basic Chemicals
- Software: GaBi 10 Professional
- Life cycle inventory datasets: Sphera, Ecoinvent 3.8

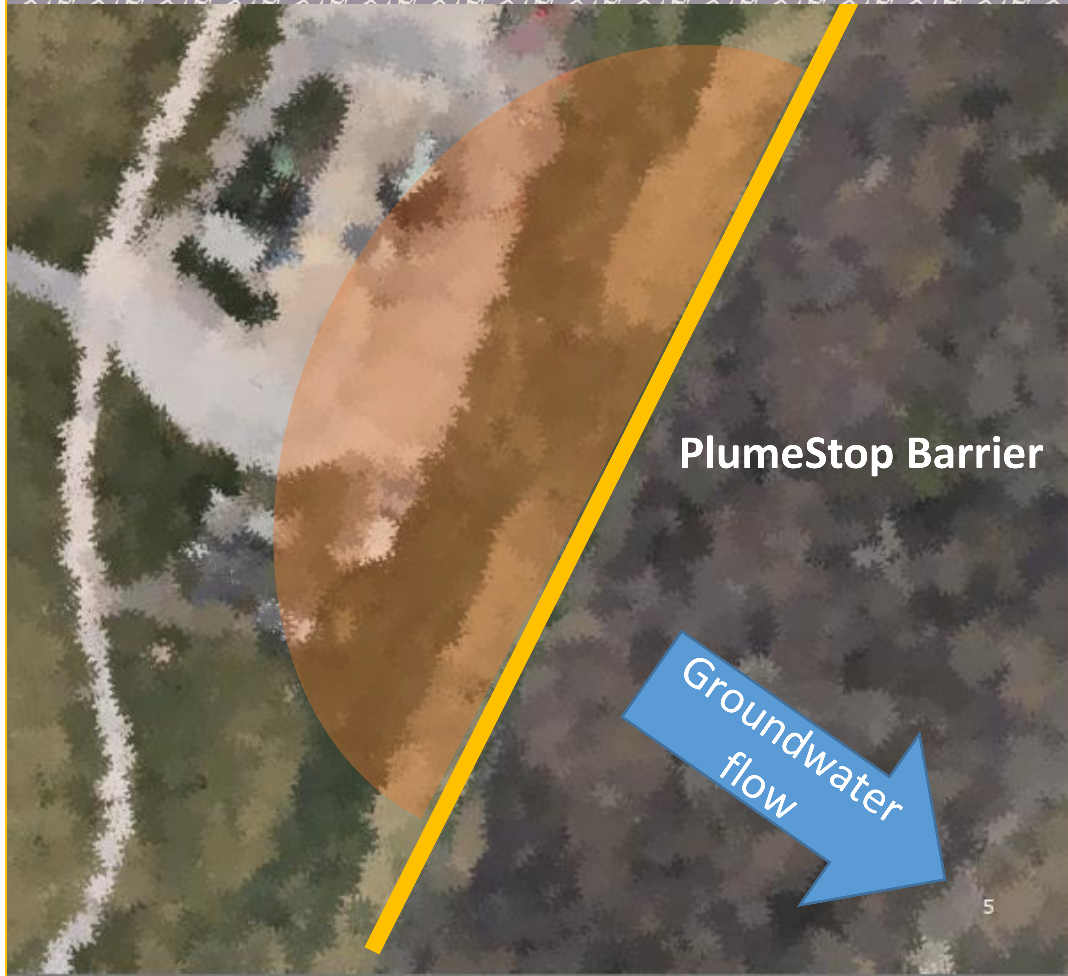
Life Cycle Inventory Analysis



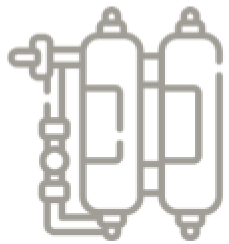
Immobilization with PlumeStop ®

- Single injection round
- Designed for minimum 15 years of efficacy (breakthrough point)
- 102 injection points
- 110 meters long
- 33,600 kg CAC
- 1,600 liters fuel used for injection
- 3 monitoring wells, 10 meters deep
- Environmental monitoring: 2 times/yr



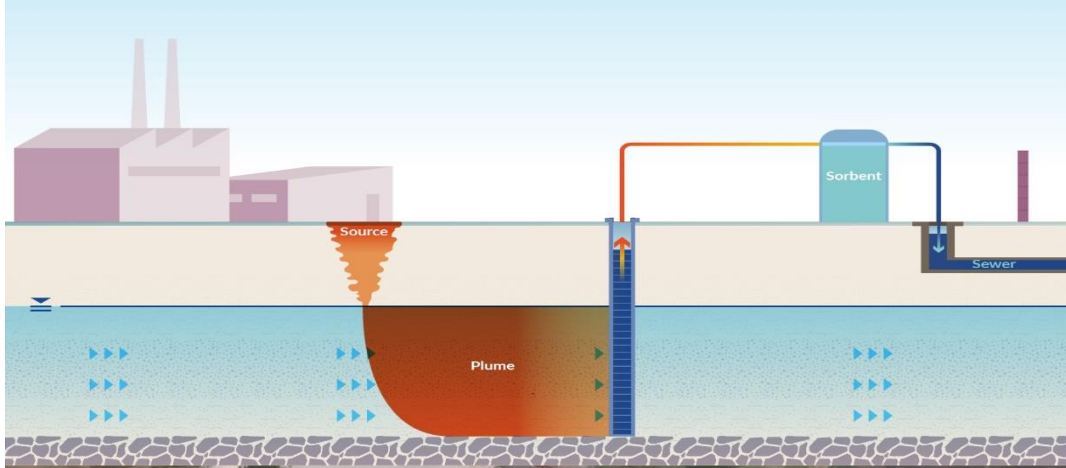


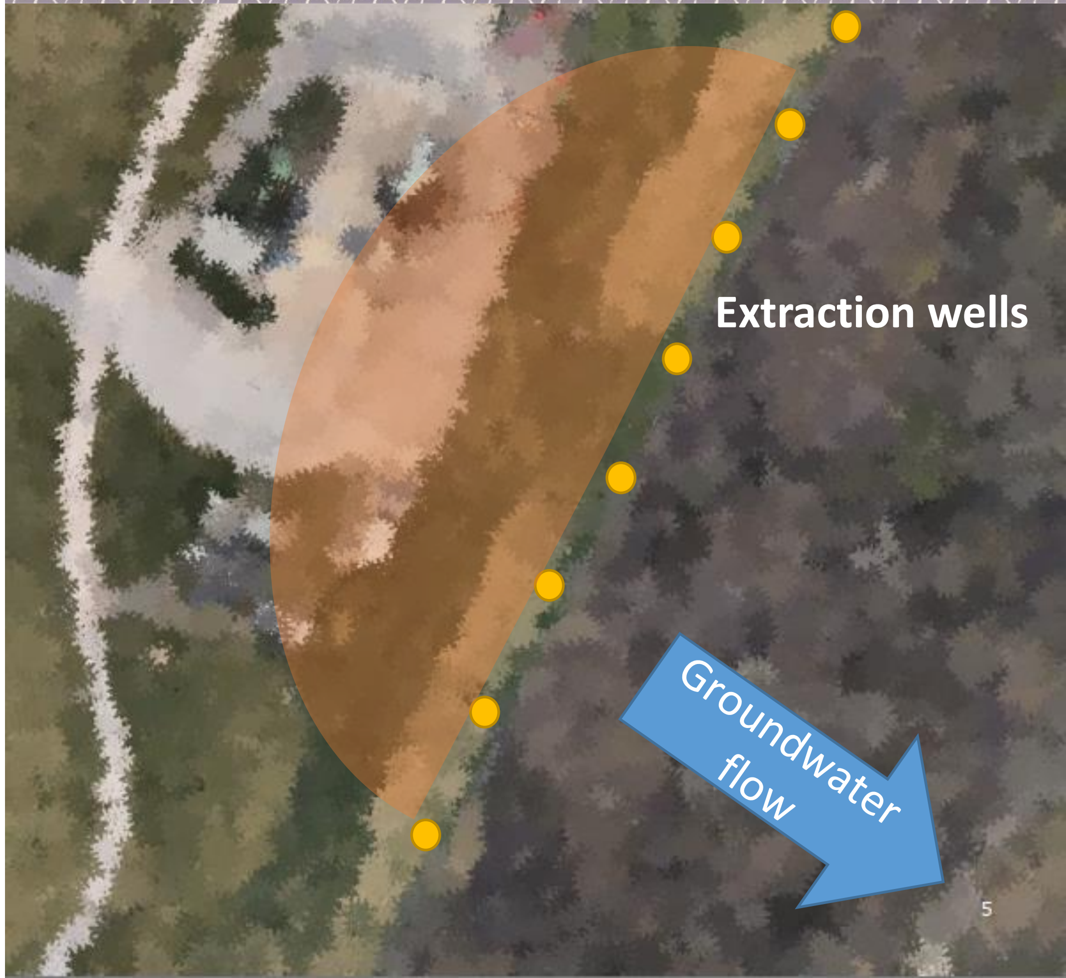
Life Cycle Inventory Analysis



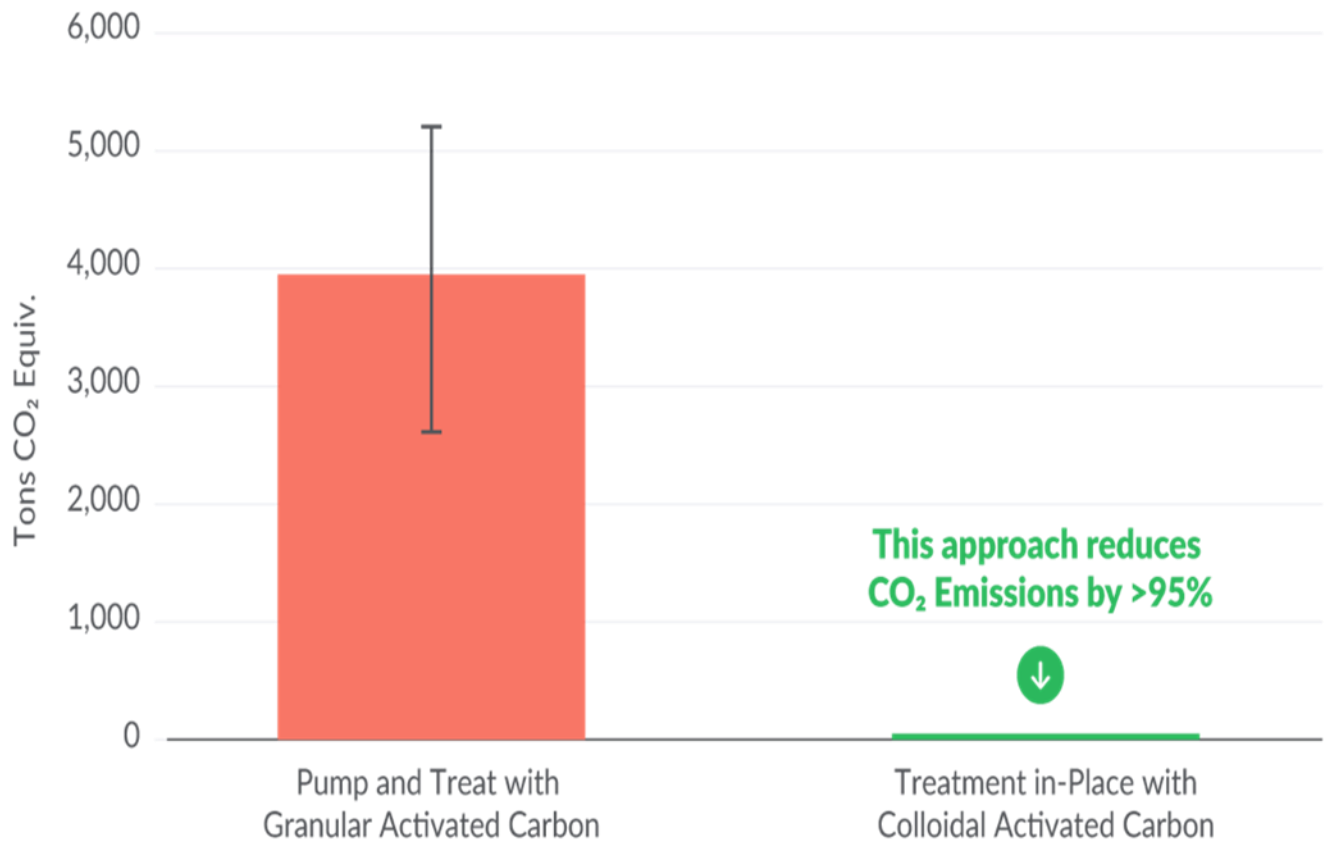
Pump & Treat with
GAC filtration

- Continuous operation: 15 years, 95% uptime
- 8 extraction wells, 8 meters deep
- Groundwater pumping rate: 100 liters/min
- GAC usage rate: 24,000 kg/yr
- Adsorption capacity: 100 mg/kg
- Electricity consumption: 960 MWh/yr
- O&M inspection: 4 times/yr
- Fuel used for installation: 2,300 liters
- 3 monitoring wells, 10 meters deep
- Environmental monitoring: 2 times/yr





Carbon Footprint – CAC vs. GAC

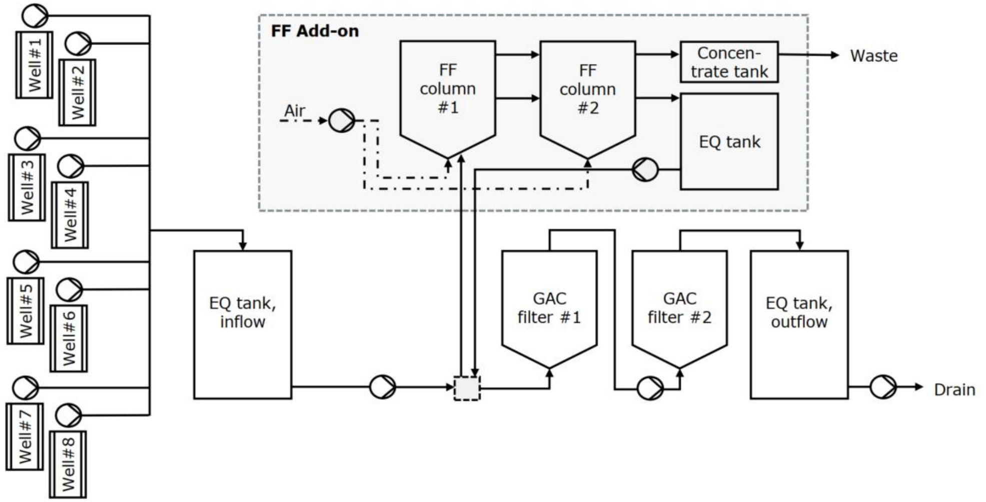


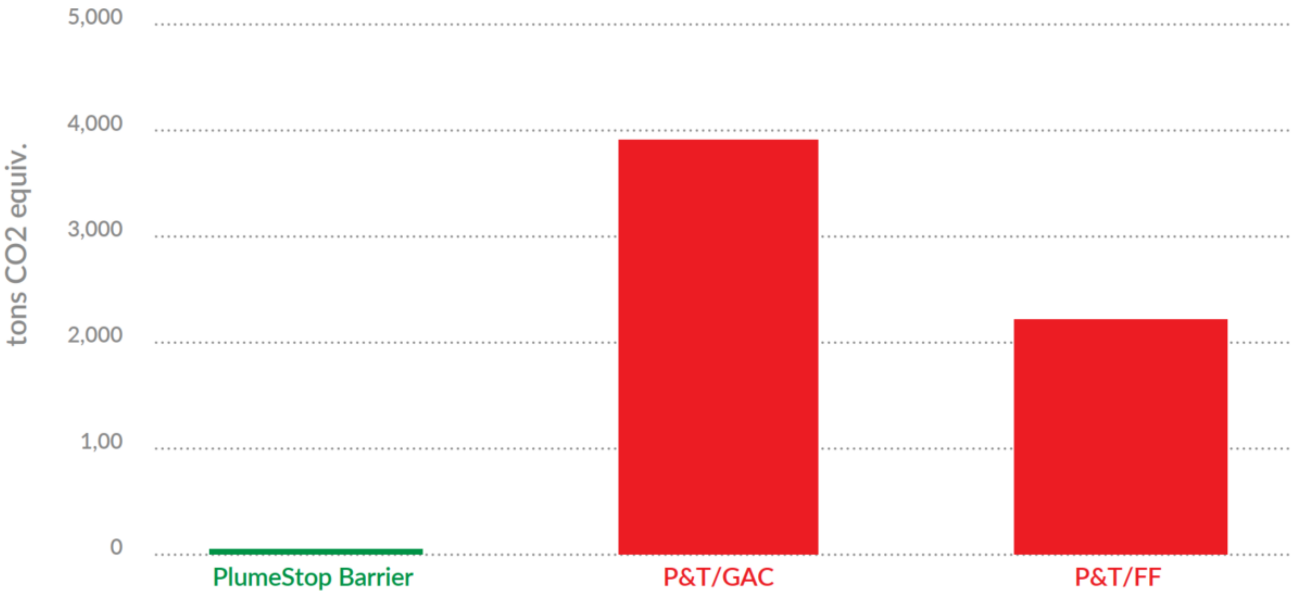
Metric tonnes (kt) CO2-eq. / 15 years operation

	PlumeStop	P&T w/ GAC
Remediation equipment		15,2
Civil works		
Fixed installations	0,05	0,9
Machinery	1,0	1,3
Remediation and operations		
PlumeStop / GAC	50,5	2 860
Electricity		281
Maintenance		3,6
Monitoring	4,0	4,0
Waste management		
Hazardous waste		112
Wastewater treatment		644
Total carbon footprint	**55,5**	**3 922**

Carbon Footprint – CAC vs. Foam fractionation

We also modelled Foam Fractionation (FF):
- Bubble/skim off PFAS
- Swapping GAC for equipment/electricity





In-situ retention still 97.5% lower carbon footprint (98.5% lower for P&T with GAC)

Changing treatment ≠ significant reduction

Pumping alone = 1-2 Orders Of Magnitude increase in Carbon Footprint compared to in-situ retention

ANY filtration or destructive treatment technique only adds to this

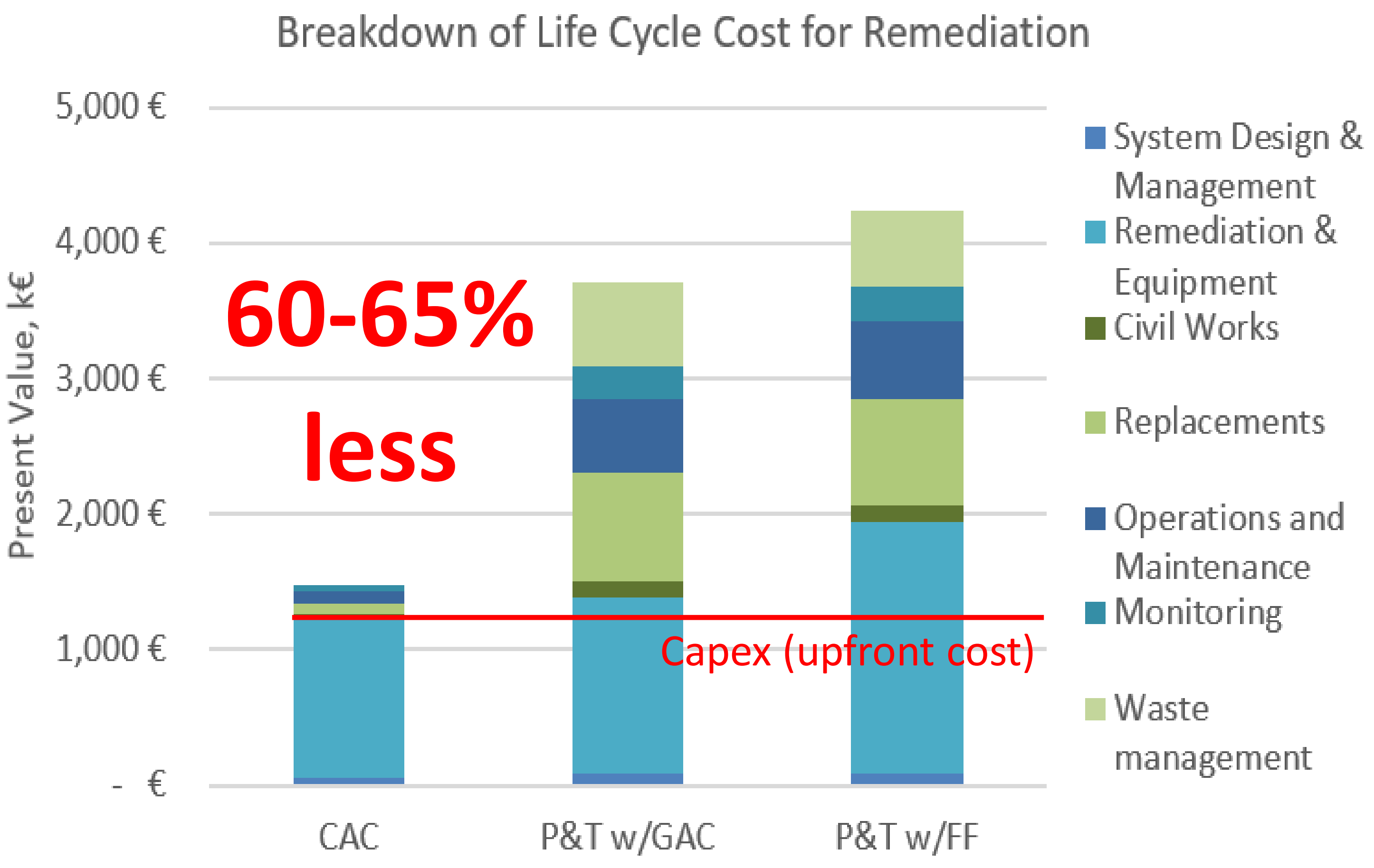
Life Cycle Cost Analysis (LCCA)

- Pricing analysis for 15-year treatment
- Net Present Value:

  CAC barrier = **€1.5m**

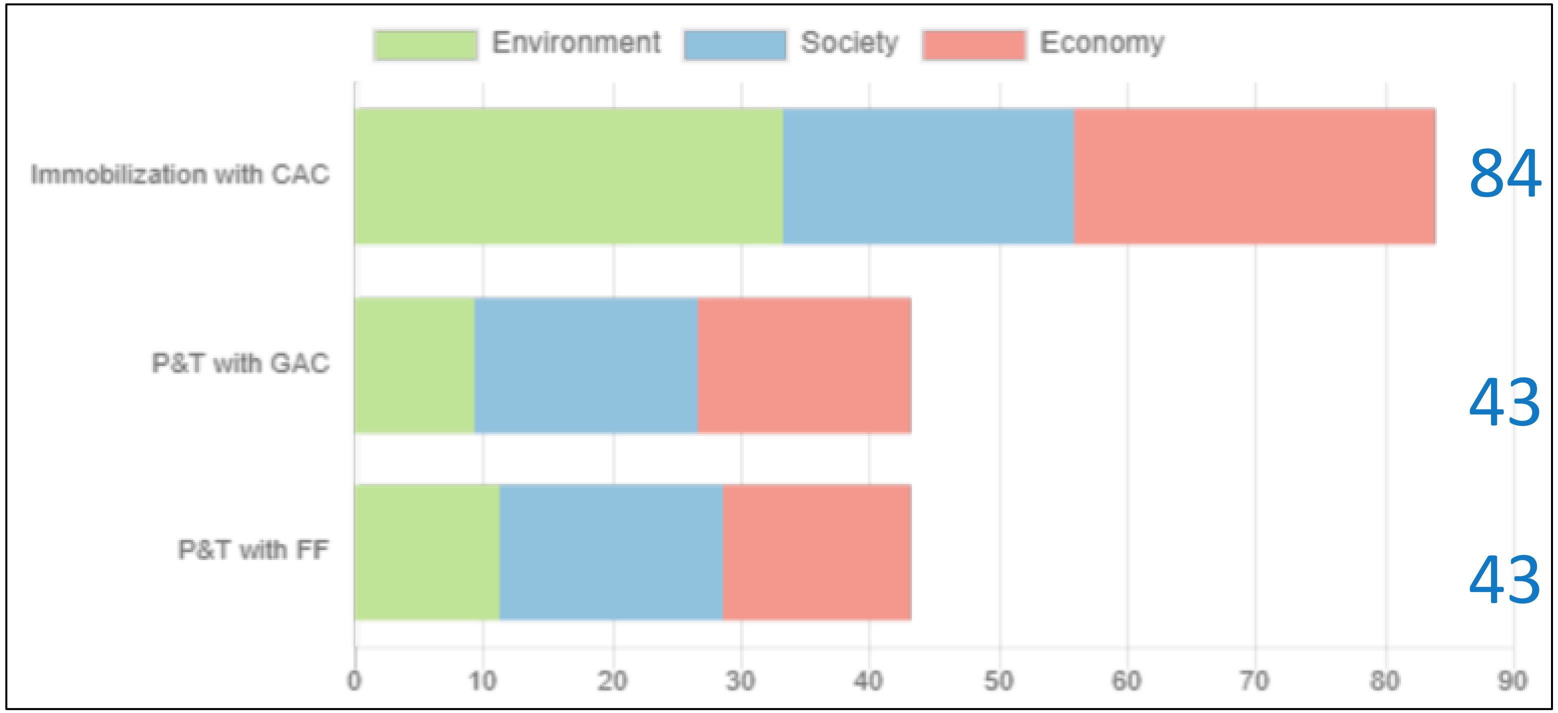
  P&T with GAC = €3.8m

  P&T with FF = €4.4m
- CAC solution costs 60-65% less than P&T (GAC or FF)
- Note: Regulatory or property owner requirements to recover and dispose the treatment media not considered



Sustainability score

- Completed using Ramboll SURE tool (On-line tool for sustainable remediation assessment, communication, and reporting, relying on a multi-criteria analysis)
- In line with:
  - ✓ ISO18507:2017 definition of sustainable remediation
  - ✓ SuRF-UK framework for assessing the sustainability of soil and groundwater remediation
- Brings together summary of other impact factors (qualitative and quantitative)
  - ✓ Creates a semi-quantitative score (out of 100)



Conclusions – LCA / LCCA / Sustainability assessment

- **Based on the LCA and LCCA for this specific case study, immobilization with CAC was more ecological and economic than P&T-based alternatives, having:**
  - ✓ 95+ % smaller carbon footprint
  - ✓ 60 to 65 % smaller total life cycle costs
- **The SURE by Ramboll semi-quantitative sustainability assessment aligned with the findings from the LCA and LCAA** => Immobilization with CAC had 100 % higher Sustainability Assessment Score, compared to the P&T based remediation alternatives.

https://regenesis.com/wp-content/uploads/2019/12/Sustainability-Case-study-PlumeStop-vs-PT-Final.pdf

Questions?