PFAS Investigations: A Site Investigation Framework Based on Lessons Learned

Authors: Stefano Marconetto, Andrew Holloway, Ross Bennett, Ian Hers

Sites Screening/Prioritization

Portfolio-level assessment to prioritize sites for investigation

Consider screening criteria:

- Historic records on PFAS use, sources, hydraulic/ hydrogeologic settings and associated contaminant transport.
- Presence, type and distance of receptors
- Stakeholders involvement
- Site type (manufacture, firefighting training area, landfill, etc.)

Example for Landfill Site:

Primary Factors

- Hazardous vs. non-hazardous (Municipal Solid Waste vs. Construction and Demolition)
- Lined vs. unlined
- History of releases

Operational Considerations

- Leachate recirculation
- On-site leachate treatment
- On-site biosolids management, handling
- On-site use of firefighting/AFFF

Waste Types

- Disposal or beneficial use of biosolids, paper sludge, auto fluff, etc.
- Wastes from industries with high PFAS usage
- Wastes from remediation sites

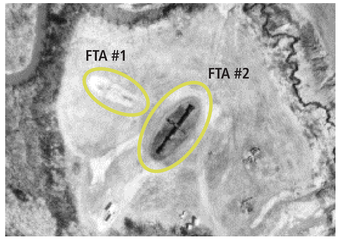
Site Settings & Stakeholders

- Hydraulic/hydrogeologic settings
- Local residential groundwater use
- Local public groundwater or surface water supply
- Re-circulation and/or irrigation of waters
- Regulatory involvement
- Other relevant stakeholders

Desktop Review

Review of historic and current site information

Lesson Learned 1 - Prioritize Safety Data Sheets, product inventories/purchase records, process data, aerial photographs, spill records, land use inventories.



Lesson Learned 2 - Take note of dates: persistent contaminants with varied product composition over time.

- Electrochemical fluorination (mainly C6-C10 from 1947 to 2002 and C2-C4 post 2002): PFSAs and PFCAs, mix of straight and branched isomers, impurities including precursors.
- Telomerization (since 1970s): PFCAs, FTSs and FTOHs (no PFSAs), typically linear isomers.

Occurrence/distribution of isomers in the environmental media can be different from source composition based on different physicochemical properties of individual isomers.

Lesson Learned 3 - Interview knowledgeable personnel about site/plant operations. Especially useful for identification of secondary sources.

Lesson Learned 4 - Review previous remediations for other contaminants (pump&treat, ISCO, enhanced biodegradation, biopiles and landfarming): potential effect on PFAS composition and distribution.

Preliminary CSM

Development of preliminary CSM including potential sources, fate and transport (F&T), receptors and stakeholders based on data gathered in previous steps

Lesson Learned 1 - Consider these CSM components based on site type:

Fire-fighting areas: Primarily C6-C8 PFSAs and FTSs, rapid decrease of concentrations in soil with depth, potential for NAPL or dissolved phase hydrocarbons/solvents, anaerobic source zone, extent of source area affected by foam spraying and runoff, secondary sources from historic on-site treatment of hydrocarbon impacted soil.

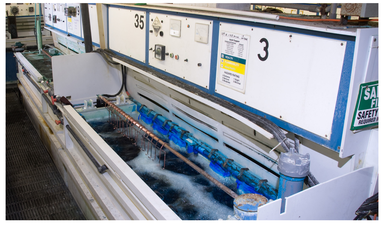
Landfills: Leachate as main PFAS source, mixture of PFAS, higher concentrations of short-chain PFAAs and some precursors (5:3 FTCA), likely release of other contaminants, anaerobic source zone, secondary sources from biosolids/sludge management/use and landfill gas, potentially higher PFAAs concentrations in leachate treatment effluent.

Electroplating facilities: Typically PFOS dominated with C4-C6 PFSAs and 6:2 FTS, generally lower concentrations of PFCAs, primarily impacts from wastewater discharge and sludge disposal. Air emission as potential secondary source.

Surface coating facilities: Wastewater, air emissions and waste disposal as primary sources, PFCAs dominant, potential for hydrocarbon/solvent impacts, wastewater treatment may increase PFAAs concentrations being discharged, PFAS sorbed on materials/equipment can act as long term source.

Lesson Learned 2 - Map current and historical potential sources on- and off-site including secondary sources such as:

- Materials, equipment, gaskets that contacted PFAS
- Car washes, junkyards
- Carpet cleaning facilities, automotive detailing
- Granite/stone cutting/sealing facilities
- Paper mills
- Septic systems
- Agricultural fields, nurseries, sport fields, etc. from biosolids application



Preliminary Investigation

Planning and execution of investigation followed by data validation and interpretation

Lesson Learned 1 - Many field protocols are overly conservative. Include scientifically based and practical list of precautions to reduce potential sources for cross-contamination. For example:

- Rinse equipment using pre-tested tap or tanker water (plan ahead – analyze these water sources before mobilization)
- Use polyethylene, vinyl or PVC rain gear
- Use sunscreens made with natural ingredients
- Use DEET or insect repellents made with natural ingredients

Lesson Learned 2 - Implement rigorous QA/QC program. Equipment, field and trip blanks are vital for determining false positives.

Lesson Learned 3 - Consider total PFAS mass screening (TOP, AOF or PIGE) to assess source magnitude

Lesson Learned 4 - Prioritize sampling locations that provide information of potential migration to surface water or potable groundwater.

Acronym Legend

PFSAs: Perfluoroalkyl Sulfonic Acids
PFCAs: Perfluoroalkyl Carboxylic Acids
PFAAs: Perfluoroalkyl Acids
FTSs: Fluorotelomer Sulfonates
FTOHs: Fluorotelomer Alcohols
TOP: Total Oxidisable Precursor
AOF: Adsorbable OrganoFluorine
PIGE: Particle-Induced Gamma Emission
AFFF: Aqueous Film Forming Foam

Updated CSM

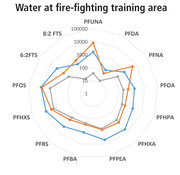
Identification and preliminary composition of primary sources, issue magnitude, update of F&T and receptors potential exposure

Lesson Learned 1 - Compare PFAAs concentrations with total PFAS mass for quantification of potential precursors mass.

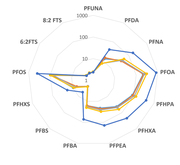
Lesson Learned 2 - Assess PFAAs relative concentrations within same medium and between media to aid with preliminary source/plume differentiation and F&T assessment.

Radial plots can be a simple tool for this assessment:

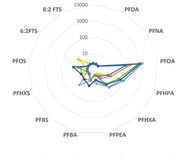
Water at fire-fighting training area



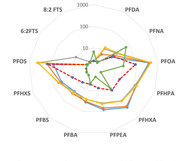
Surface water near a landfill



Groundwater near a former high-performance films manufacturing facility



Wastewater lagoons and groundwater at filters manufacturing facility



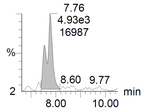
Lesson Learned 3 - Evaluate need for off-site investigation and stakeholder/community engagement

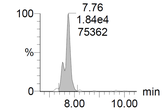
Detailed Investigation

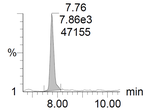
In-depth understanding of sources, F&T, current and future exposure scenarios, and liability assessment

Lesson Learned 1 – Assess composition of primary and secondary sources and plumes (fingerprinting) and concentration changes along flowpaths:

- Total PFAS mass
- Quantitative analysis of selected precursors
- PFAA ratios
- Branched vs. linear isomers
- Geochemistry and other non-PFAS analytes







Lesson Learned 2 - Evaluate long-term source contribution:

- Leachability of soil and sediment (SPLP tests)
- Leachability of secondary sources such as concrete structures, equipment, gaskets, etc.

Lesson Learned 3 - Complete biota sampling and toxicity assessment for site specific risk assessments

Lesson Learned 4 - Be prepared to initiate a risk assessment in parallel with the Detailed Investigation if a source–pathway-receptor connection is considered likely

Lesson Learned 5 - Estimate environmental liabilities based on:

- Current risks: Complete pathways
- Future risks: F&T, evolving regulations, stakeholders

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