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Perfluoroalkyl and Polyfluoroalkyl Substances –Treatment Challenges in High-Strength Wastewater Streams

Herwig Goldemund

Thursday, August 25, 2016

Georgia Environmental Conference, Jekyll Island, GA

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Treatment Challenges

- PFAS have many sources and uses
  - Southeastern US has history of manufacturing of these compounds (NE Alabama) and use in carpet industry (NW Georgia)
- PFAS have unique properties
  - Hydrophobic and oleophobic
  - Persistent, bioaccumulative and toxic
  - Moderate solubility – can be transported long distances
- Chemically and biologically stable
  - Resistant to typical environmental degradation processes
- Treatment approaches challenging and costly

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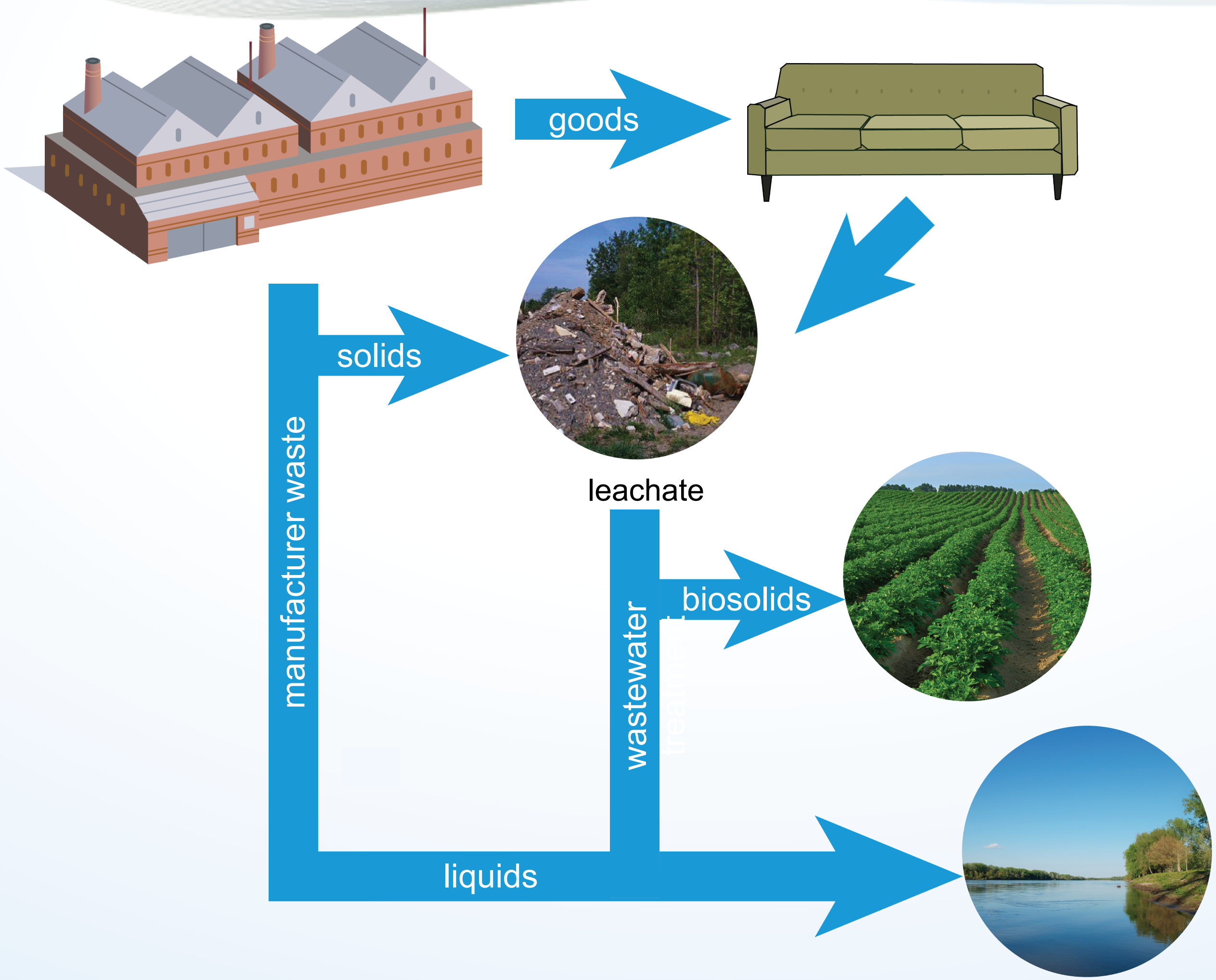
Environmental Inputs



Modified from Oliaei et al.; Environ Sci Pollut Res (2013) 20:1977-1992

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Treatment Approaches

- Soils and sediments
  - Typically soils are excavated (and treated/stabilized if needed) followed by off-site disposal or reuse
  - Other technologies are incineration, soil washing
- Groundwater (ex situ)
  - Full-scale PFAS treatment systems use granulated activated carbon (GAC) or ion exchange
    - GAC not effective in removing short-chain (C2, C3 compounds)
  - Membrane treatment (e.g., nanofiltration [NF] or reverse osmosis [RO]) also effective but expensive
    - Still leaves reject (concentrate) that needs to be dealt with

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Treatment Approaches

- Other
  - Sonochemical degradation, sub- or super-critical treatment, microwave-hydrothermal treatment, and non-thermal plasma treatment
- Ongoing research to develop effective in situ groundwater remediation technologies
  - PFAS sequestration with alternative sorbents (low-cost long-term treatment barrier, polyaluminum chloride, cationic polymers)
  - Proof-of-concept studies for microbial treatment
    - Limited degradation by fungi but difficult to implement and maintain in situ
  - In situ chemical reduction
    - Zero-valent metals/bimetals (Pd /Fe, Mg, Pd/Mg) with clay interlayers and co-solvent assisted Vitamin B12 defluorination

Example Waste Stream - Leachate

TABLE 1 POLLUTANTS IN LEACHATE

Group of Pollutants In Leachate		Components
1	Organic matters	Acids, alcohols, aldehydres and others usually quantified as COD (Chemical Oxygen Demand), BOD (Biochemical Oxyegn Demand), DOC (Dissolved Organic Carbon), Other Volatile fatty acid and refractory compound include fulvic-like and humic like compounds
2	Inorganic matters	Sulfate, chloride, ammonium, calcium, magnesium, sodium, potassium , hydrogen carbonate, iron and manganese and heavy metal like lead, nickel, copper, cadmium, chromium and zinc
3	Xenobiotic organic compounds	Aromatic hydrocarbon, phenols, chlorinated aliphatics, pesticides and plastizers include PCB, Dioxin, PAH, etc

Adapted from Lee et al., 2010. International Journal of Environmental Science and Development 1:347-350

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Leachate Treatment Challenges and Approaches

- Thousands of mg/L (ppm) of constituents other than PFAS (BOD, COD, ammonia, salts)
  - "Regular" MSW leachates contain PFAS concentrations in the single digit µg/L (ppb) levels at max
- Proven technologies such as GAC or RO not feasible
  - Would require full-scale wastewater treatment system upfront with potential polishing approaches using GAC or RO

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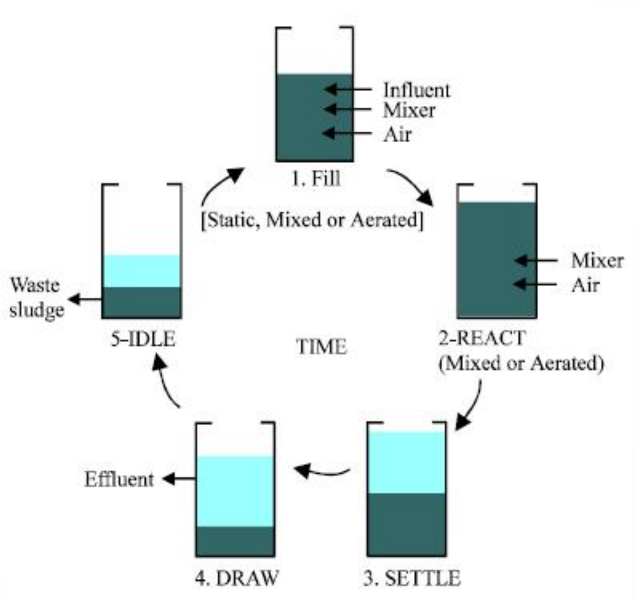
Solids Settling

- Solids settling may remove substantial quantities of PFAS
  - PFAS sorb to solids that can be removed
  - Solids still need to be treated or stabilized
  - Decanted water relatively cleaner
  - Consistent with a sequencing batch reactor (SBR) approach
  - Will not achieve parts per trillion (ppt) levels



Picture source: www.packageplants.com

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Leachate Pilot Testing

- Leachate contained PFAS at elevated levels (~100 µg/L for each of the C5 to C8 compounds) due to local sources
- Evaluated conceptual treatment trains using:
  - GAC, RO, and settling
  - GAC and RO not feasible due to leachate matrix
- Selected settlement for pilot testing
  - Tanks and aeration equipment already present at site

Bench-scale settling test

Tank aeration and solids settling

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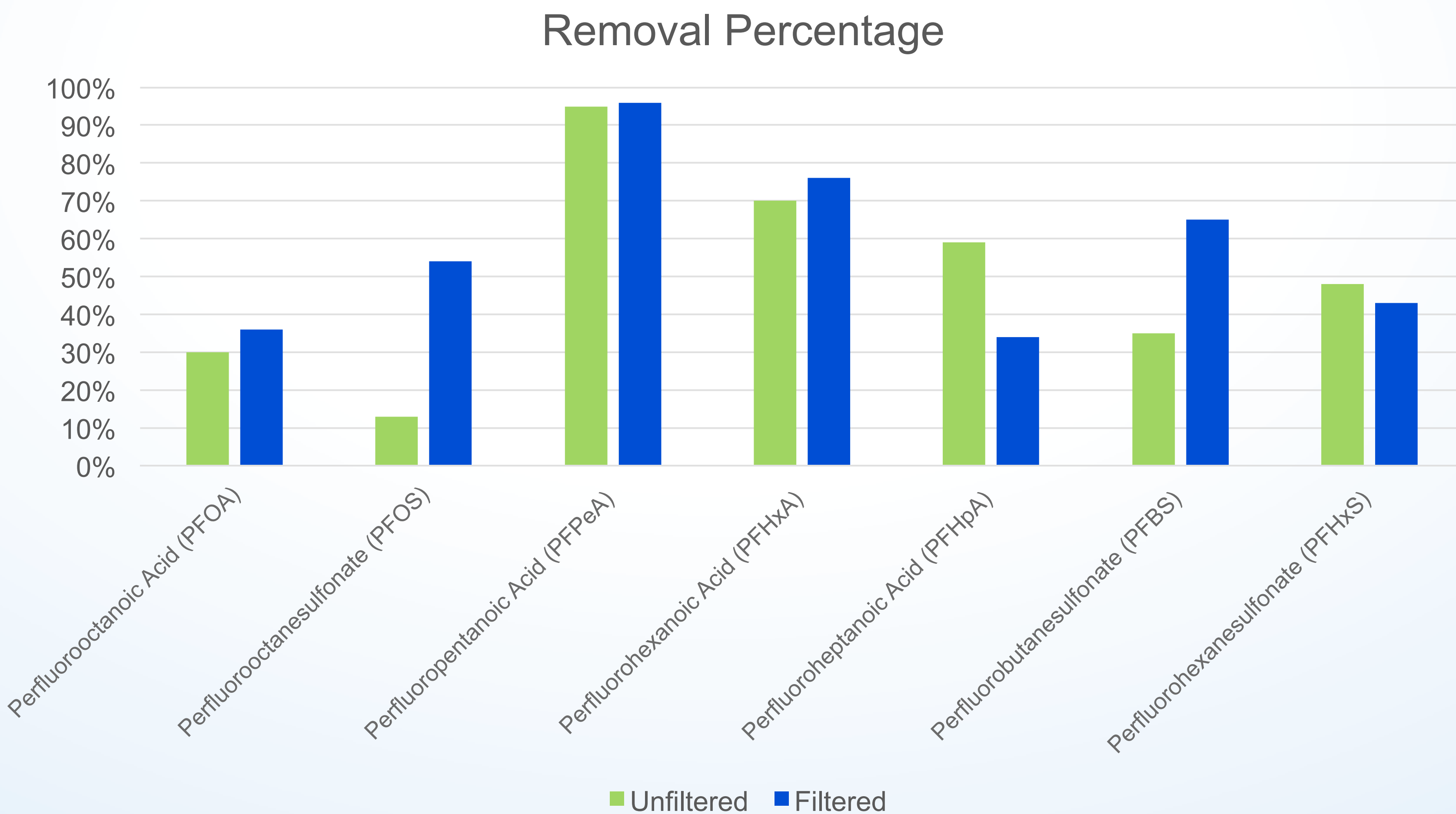
Solids Settling Pilot Study



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Treatability Results

- Leachate had poor settleability
- Filtration improved % removal for most compounds
- Certain waste streams may require addition of polymers and a separate clarification step
- Filtration step at the back end may also help

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Conclusions

- Removal of PFAS from aqueous waste streams is challenging and costly
- Proven technologies at full scale are limited to GAC, ion exchange, and membrane technology
- High-strength wastewater even more challenging
  - Proven technologies may only be applicable as a polishing step

Conclusions (cont.)

- No current guidance on effluent limits or required removal efficiencies
  - Creates uncertainty for treatment designs
- Solids settling (coupled with SBR-like treatment approach) appears promising for pretreatment
- Future effluent limits likely to be very low
  - Will likely require costly polishing steps

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