PFAS Overview

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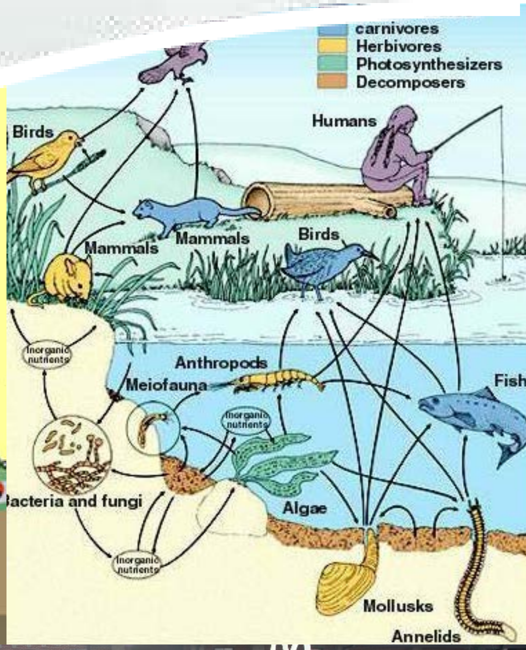


PFAS Overview

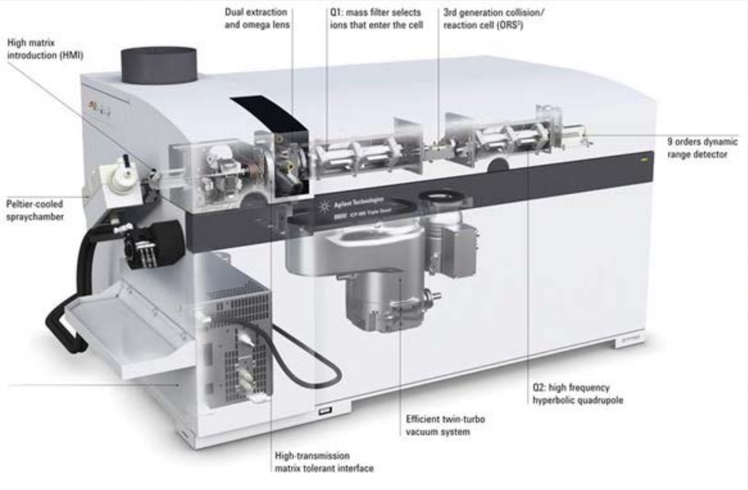
- Use of AFFF firefighting foams, DoD wide, since early 70's.
- Significant liability to DoD most recent estimate >$2B
- Army just issued guidance (September)
  - Investigation and inventory of sites (storage, training locations, hangar facilities, plating facilities, crash sites, landfills, wastewater treatment plants, etc.) focused on human health-based exposures.
  - Drinking water assessments at all installations
  - Preliminary Assessment (PA) – Site Inspection (SI) – Remedial Investigation (RI) (RIs focused where human drinking water exposure confirmed).
  - Prioritization "worst first" approach

PFAS Overview

- Currently,126 Army installations impacted with several reliant on alt water sources
- Corps providing technical support (Airforce and Army Installations) – primarily focused on remediation
- Unique Challenges
  - Highly stable, hydrophobic and lipophobic (unlike traditional ECOC’s)
  - 3000 compounds
  - Global distribution (including sources other than AFFF) (NHANES 2013-2014 detected PFOS, PFOA >99% of indiv.)
  - Extremely low health advisory levels (70ppt) potential to go lower (ATSDR, states)
  - Analytical methods currently only for water, other environmental media in development

PFAS Overview

- DoD in reactive/response mode
  - identification and remediation of drinking water and groundwater contamination with PFOS/PFOA focus;
  - R&D emphasis
    - analytical methods (Triple Quad MS, water)
    - remediation technology (GAC ⟹ single use resins; ex situ vs in situ)
  - additional PFASs under evaluation (PFHXs, and some of the shorter chain compounds);
  - just underway:
    - Pathways other than drinking water exposure (e.g., sediment, soil, food);
    - Eco (uptake, transfer, and effects)

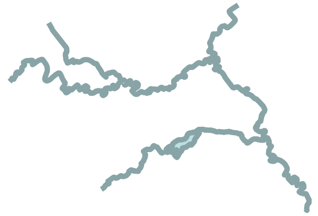


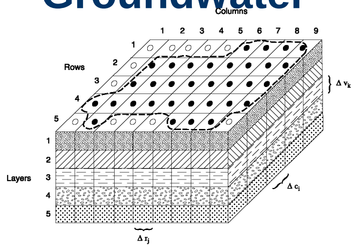
Knowledge Gaps - Analytical

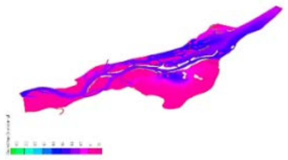
- Existing methods primarily for aqueous matrices
  - USEPA 537 is only approved for drinking water
  - Modifications to this method to complex water matrices yield unknown data quality and potential analytical shortfalls
- Relatively short list of target analytes monitored
  - USEPA 537 targets 14 compounds
  - Thousands of potential compounds of interest (e.g. precursors, degradation products, branched structures, etc.)
- Application to solid matrices is challenging
  - Soils, sediments, and tissues will each present extraction and analysis challenges
  - Method development, comparison, and validation studies are required

Knowledge Gaps- Fate & Transport

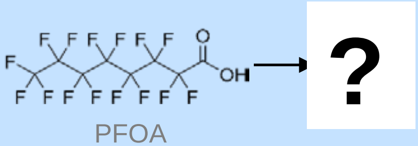
Surface Water + Groundwater + Hydrodynamics



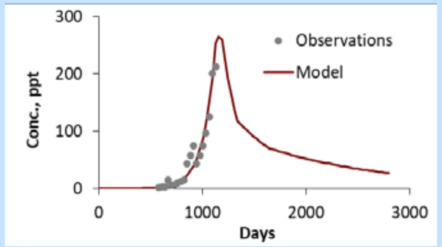




Fate mechanisms → Bench Scale → Parameterization



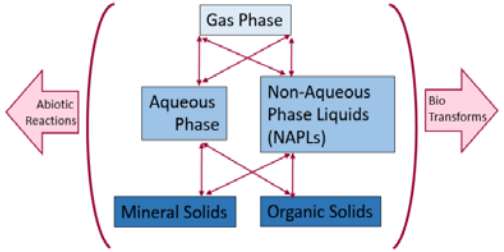
PFOA

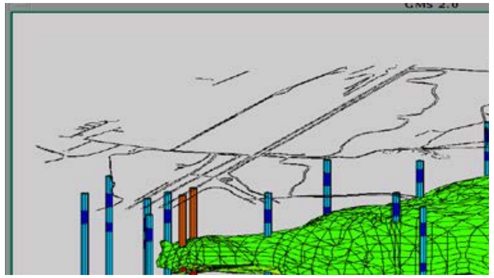


Multimedia Site concept →

Integrated Environmental Processes →

Fate and Transport Modeling





For the vast majority of PFAS compounds we do not know:

1) BioGeoChemical properties
- PFAS degradation pathways
- Degradation rates

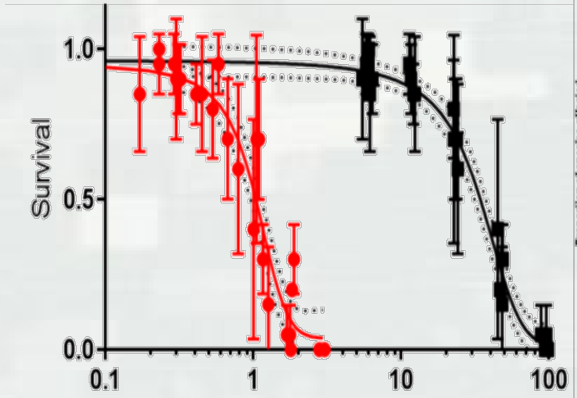
These properties are needed to determine how the PFAS waste mixtures evolve over time.

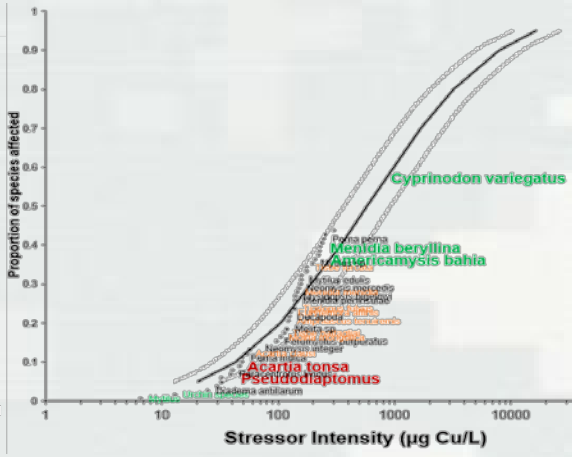
2) Fate determining properties for PFAS and degradation products
- Solubility
- Henry's constant
- Solid partitioning constants

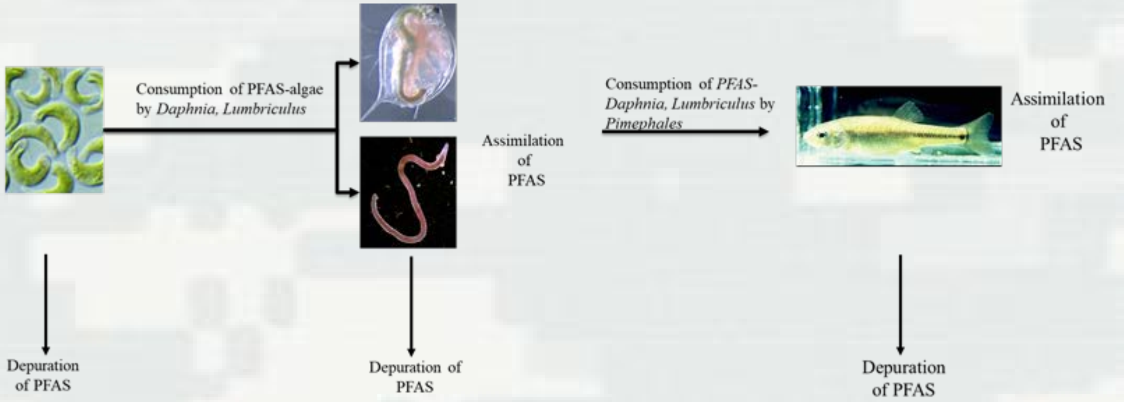
These properties are needed to asses interactions with soils, dissolved solids, and non-aqueous liquids as well as transformations between phases.

Knowledge Gaps – Uptake, Trophic Transfer, Effects

- Relative bioavailability of different PFAS compounds
- Data availability to determine more appropriate protective threshold levels
- Species sensitivity distributions
- Partitioning between different
  - Trophic levels
  - Organism tissue compartments
- Appropriate parameters to update predictive models for PFASs







ENVIRONMENTAL RESIDUE-EFFECTS DATABASE (ERED)

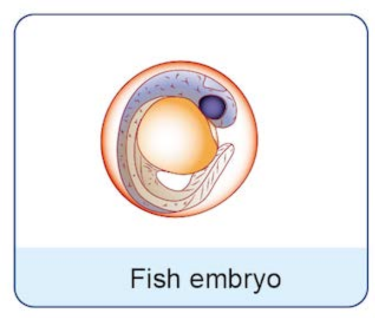
https://ered.el.erdc.dren.mil/

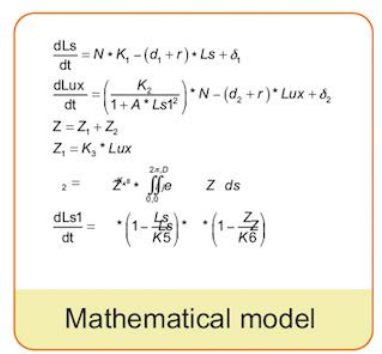
BIOTA-SEDIMENT ACCUMULATION FACTOR DATABASE

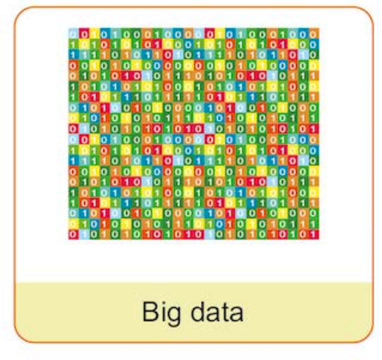
https://bsaf.el.erdc.dren.mil/

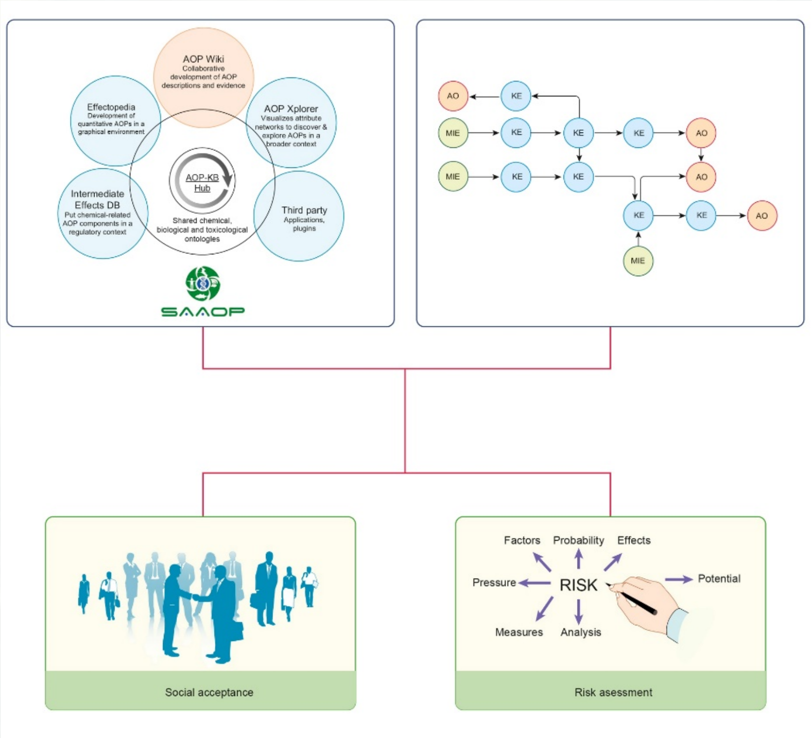
Knowledge Gaps – Mode of Action / Adverse Outcome

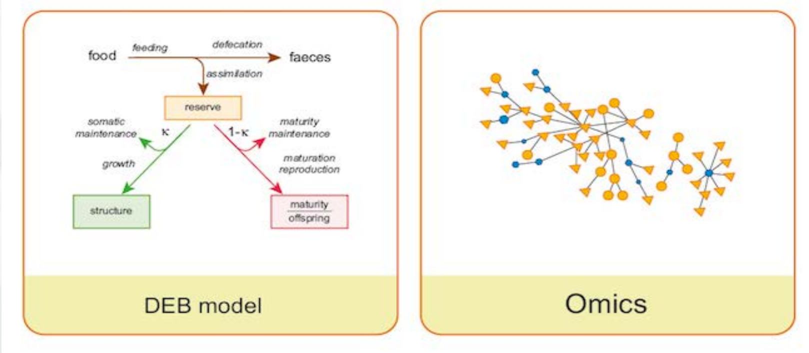
- Mechanism(s) of action
- Adverse Outcome Pathways (Networks)
- Species sensitivity
- Life stage sensitivity
- Data to inform predictive computational models
- Accurate docking/binding models to predict toxicity

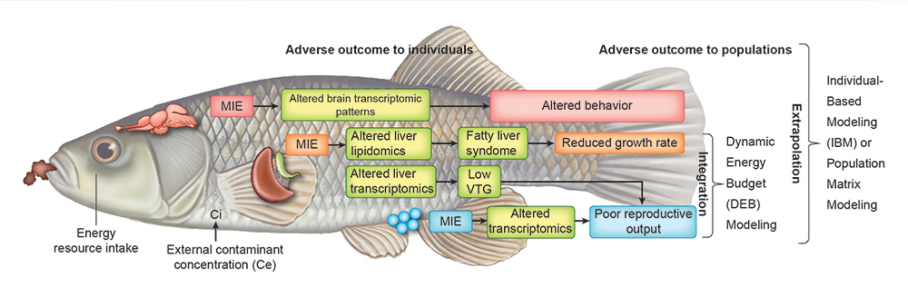




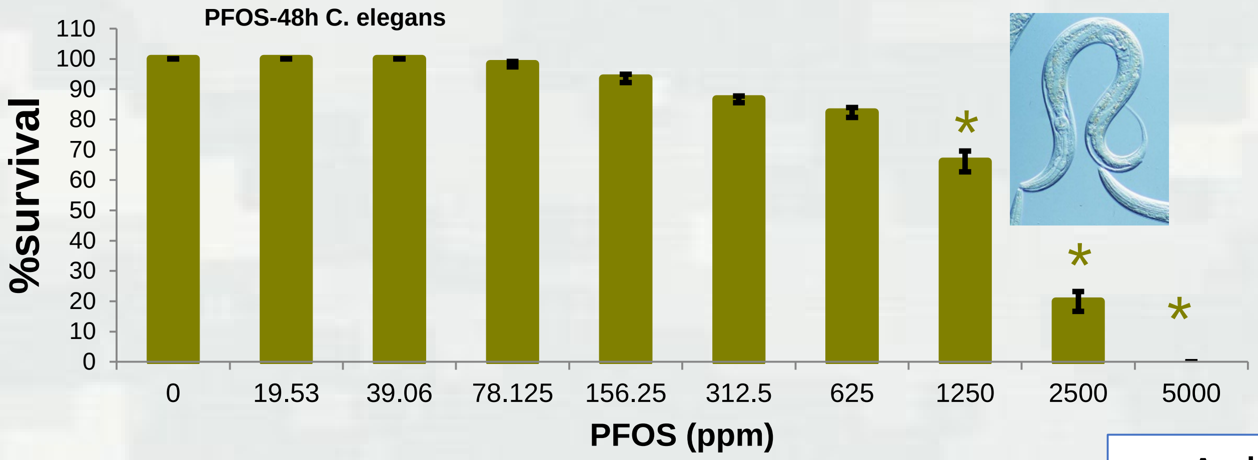




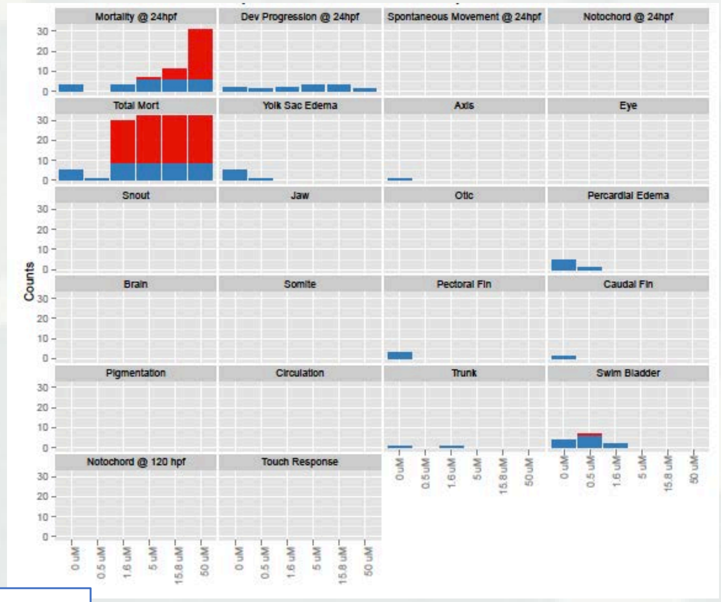




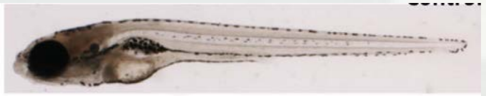
Ongoing Work – Mode of Action / Adverse Outcome

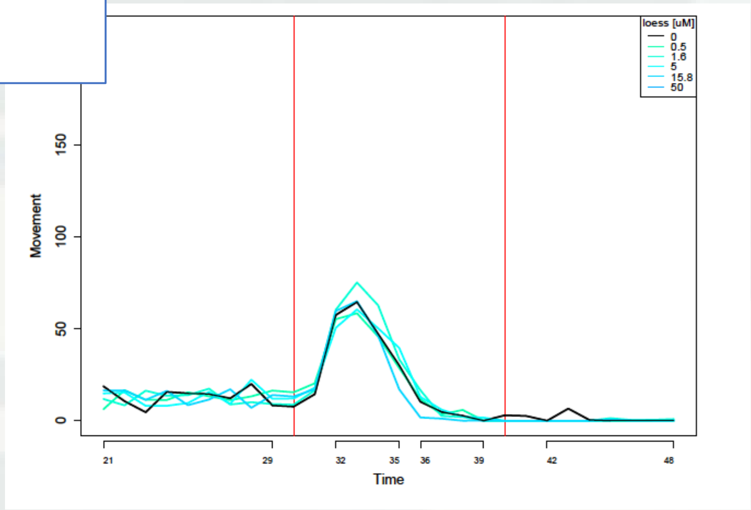


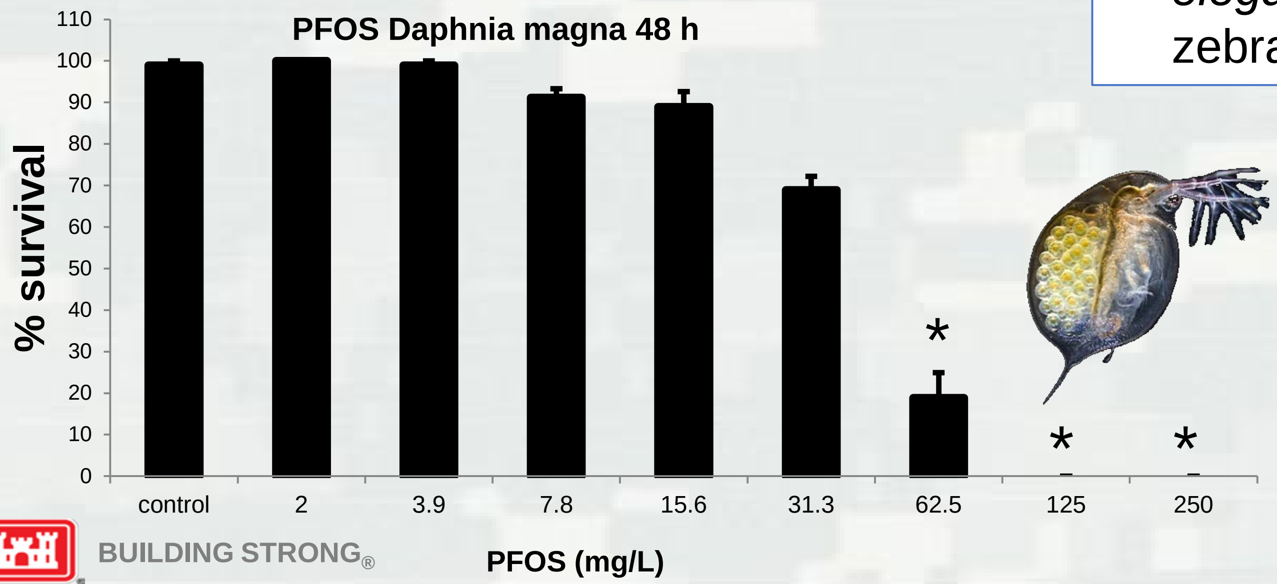
Genomic samples: 78.125, 39.06, 19.53, 9.765, 4.88 mg/L



- Apical endpoints, (*C. elegans*, *Daphnia magna*, zebrafish embryo)



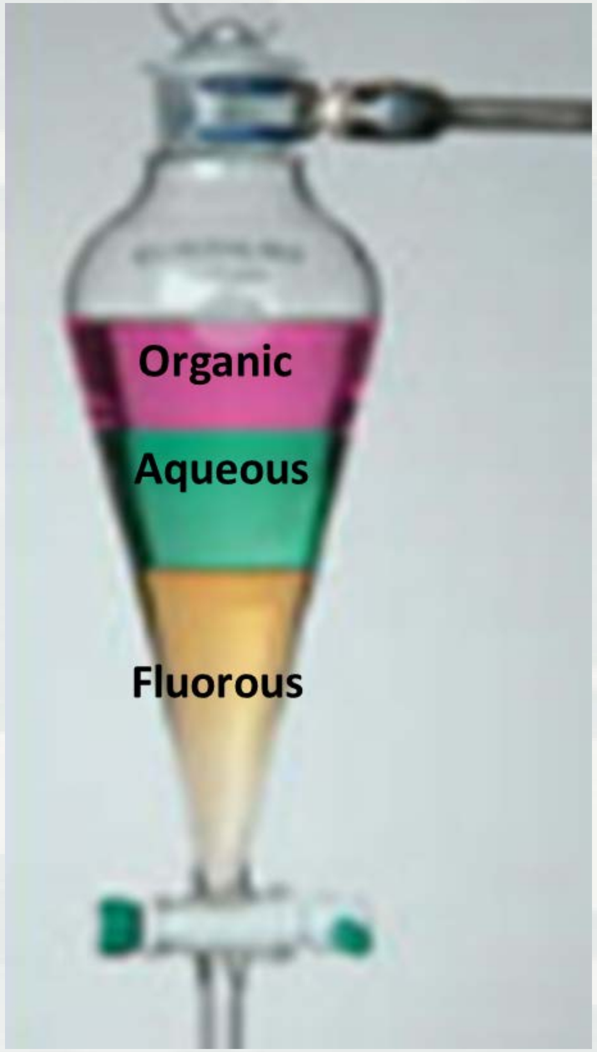


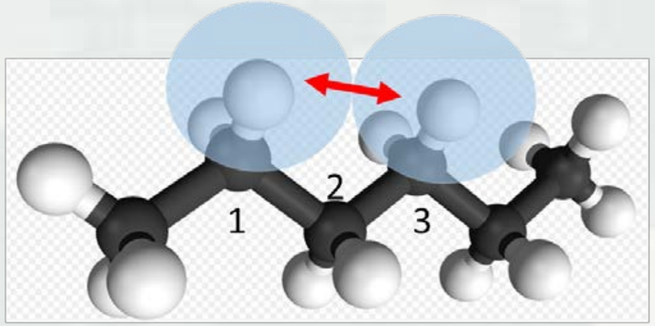


Knowledge Gaps – Remediation / Treatment

Wide range of PFAS chain lengths, configurations, and precursors

- Myriad of chemical configurations
- Diverse interactions with environment
- (GAC) filtration for short-chain PFAS
- (RO) membranes for short-chain PFAS
- Ion exchange exchange resins show promise but require a good deal of further study
- Electrocatalytic Degradation possible but scalability and deleterious by-products are a concern
- Physically hydrophobic, oleophobic, and lipophobic - tends to associate with proteins





1,3 repulsions force the F atoms out of linearity

Implications

- Issues are already being raised in Great Lakes Region (Michigan)

Re: beneficial use and in lake disposal

- If you have airports, military installations, refineries, or fire training areas – could be coming to a theater near you.
- Papers have been published showing presence in SF Bay seds
- Some indication that PFAS associates with sediments in marine estuarine environments more so than in FW systems.

Next Steps

- Development and validation of analytical methodologies for range of environmental media other than drinking water
- Better understanding of mode of action and potential human health risks.
- Improved understanding of fate, transport, uptake, and transfer/biomag. mechanisms
- Rationale/approach for addressing mixtures (exposure, uptake, and toxicity)
- Cost effective remedial strategies, regenerative resins and cost effective destructive technologies, *in situ* as opposed to *ex situ* methods (especially for soils/sediments)
- Framework for proactively identifying and addressing ECOCs (avoid reactive science and policy decisions)