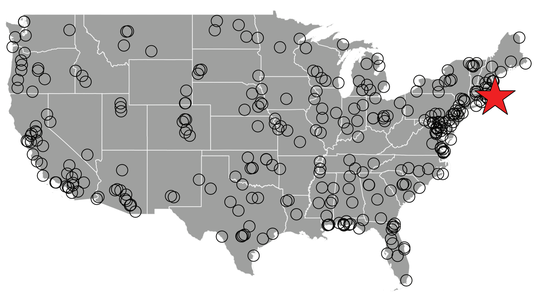
Centurial Persistence of Forever Chemicals at Military Fire Training Sites Without Remediation

Biogeochemistry of Global Contaminants HARVARD

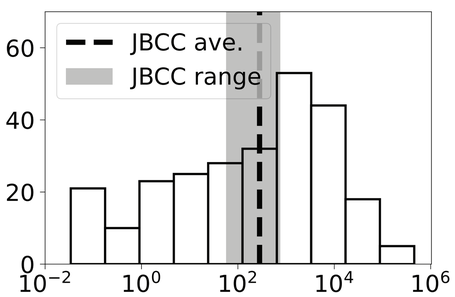
Bridger J Ruyle,[1] Colin P Thackray,[1] Craig M Butt,[2] Chad D Vecitis,[1] Elsie M Sunderland[1]
[1]Harvard John A Paulson School of Engineering and Applied Sciences, [2]SCIEX

under review

PFAS contamination from 3M AFFF widespread at hundreds of military sites



★ Joint Base Cape Cod (JBCC)



PFOS at military sites [nM F]

Aims:

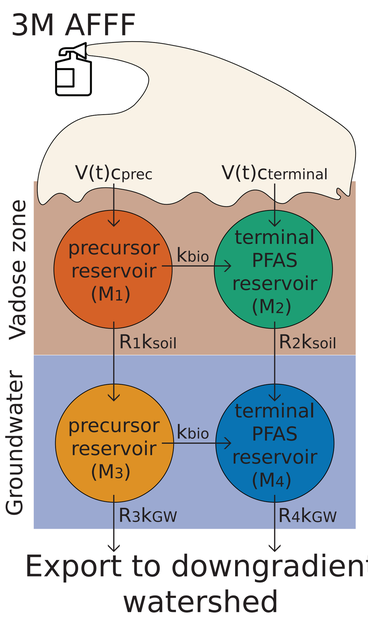
1. Characterize the distribution of PFAS over time in the vadose zone and groundwater
2. Evaluate importance of retention at the air-water interface and on solids
3. Quantify impact of precursor biodegradation into terminal compounds of concern

JBCC represets a rapid endmember for decontamination due to its hydrogeology (fast water transport times, high precipitation, low soil organic carbon)

Site history and PFAS biogeochemistry inferred from four-box geochemical model

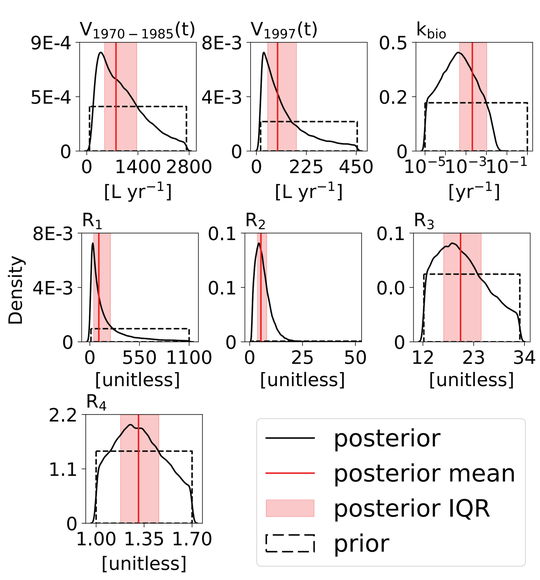
Posterior **Modeled likelihood** **Prior**

$$\mathbf{P}(V(t),K_{bio},R_{1,2,3,4}|M_{1,2,3,4}) \propto \mathbf{P}(M_{1,2,3,4}|V(t),K_{bio},R_{1,2,3,4}) * \mathbf{P}(V(t),K_{bio},R_{1,2,3,4})$$



Known: c_{prec}, $c_{terminal}$, k_{soil}, k_{GW}, $M_{1,2,3,4}$

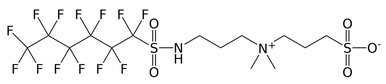
Inferred: V(t), $R_{1,2,3,4}$, k_{bio}



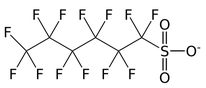
Range of retardation coefficients derived from field + site-specific experimental data and captures spatial and temporal variability in hydrology and sorbate properties

An analytical and statistical toolbox quantifies all PFAS in first decadal record in groundwater

Precursors
- *quant.*: TOP assay + Bayesian inference
- *ident.*: suspect screening

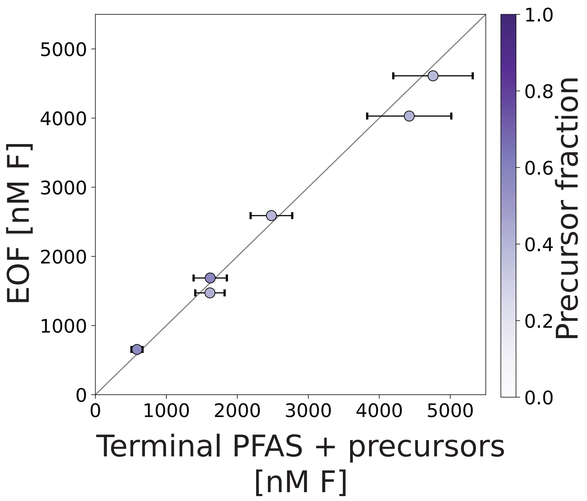


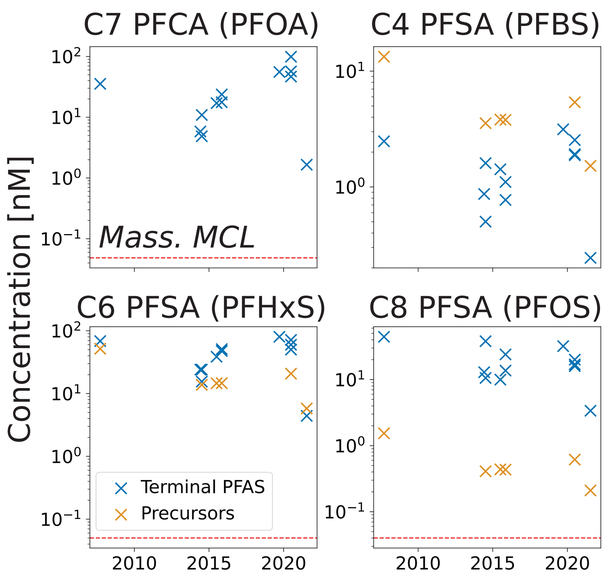
example C6 sulfonate (PFSA) precursor



C6 PFSA (PFHxS)

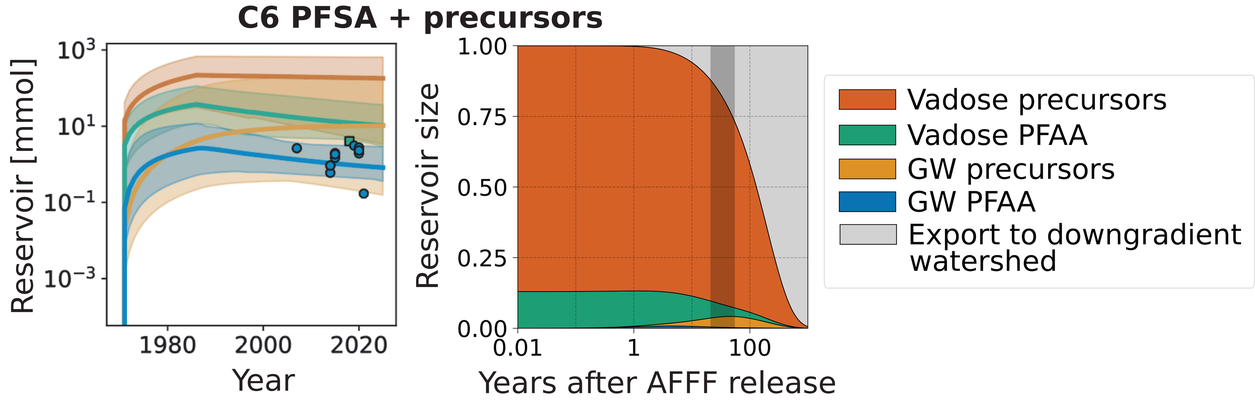
Terminal PFAS
- targeted analysis



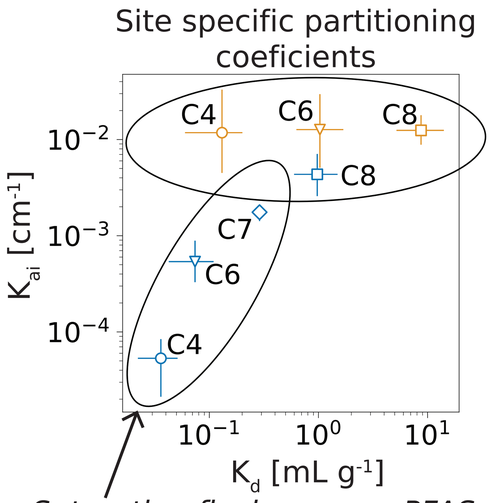


Large fluctuations in concentrations but no consistent temporal decline

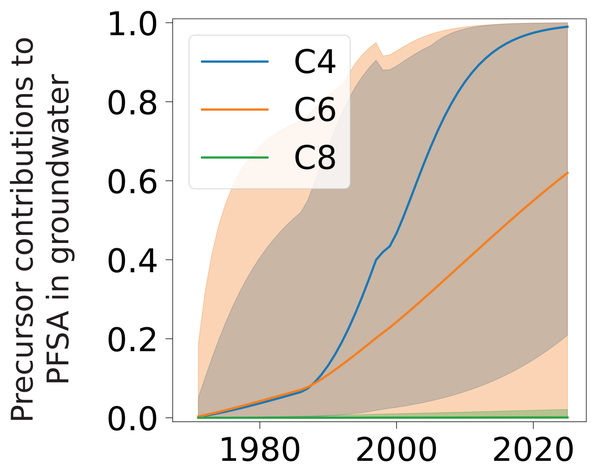
Retention at air-water interface and slow precursor biodegradation will sustain PFAS fluxes from vadose zone into groundwater (GW) for centuries



Majority of PFAS remains in vadose zone >50 years after first release
Vadose zoone reservoir 4-97 times greater than groundwater reservoir
Remediation should target vadose zone



Saturation flushes some PFAS into groundwater



Detection of C4 and C6 PFSA primarily reflect precursor degradation