GROUP 1

FACTORS INFLUENCING FATE & TRANSPORT OF PERFLUOROALKYL ACIDS IN GROUNDWATER: AN EMPIRICAL DEMONSTRATION

by **Jeffrey R. Hale** - Kleinfelder, **Damien Skinner** - Kleinfelder, **Brendan Grant** - Kleinfelder, **Shona Gelsthorpe** - Kleinfelder

1. FOAM APPLICATION & CHARACTERISTICS 1

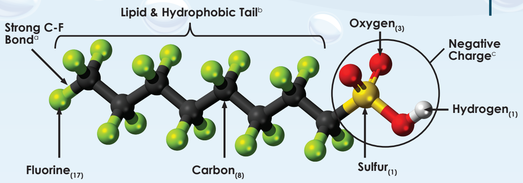
- Low volume spills of foam concentrate during storage or transfer
- One-time, high-volume, broadcast application of foam solution for firefighting
- Occasional, low to moderate volume, local application of foam solution for vapor suppression
- Periodic, low to moderate volume, broadcast application of foam solution for apparatus testing
- Periodic, high volume, broadcast application of foam solution for fire training

2. SORPTION CHARACTERISTICS

- Key property of PFAAs limiting migration
- Diagnostic of release and migration characteristics
- Can be exploited for remediation and treatment
- PFAAs sorb to organic carbon, positively charged mineral surfaces, and oil by hydrophobic and electrostatic interactions
- Low pH and high Ca2+ result in greater sorption
- Ionic strength of solution affects sorption

3. PFOS ($C_8F_{17}SO_3H$) PROPERTIES

- Soluble
- Non-Volitile
- Sorptive
- Recalcitrant

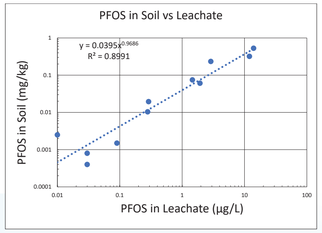


a) Strong C-F bond = persistent & recalcitrant (not degradable).
b) Water and lipid repellent characteristic.
c) Bonds to positive surfaces through electrostatic attraction.

By Manuel Almagro Rivas (Own work using: Avogadro, Discovery Studio, GIMP) [CC BY-SA 4.0 (http://creativecommons.org/licenses/by-sa/4.0)], via Wikimedia Commons

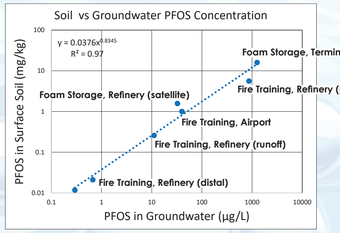
4. SOIL VERSUS LEACHATE CONCENTRATION 4

- Soil concentration versus leachate concentration results.



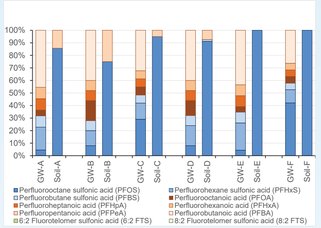
5. VADOSE ZONE SORPTION & INFILTRATION 5

- Residual footprint of PFOS in surface soil where foam was applied or spilled compared to co-located shallow groundwater concentrations.



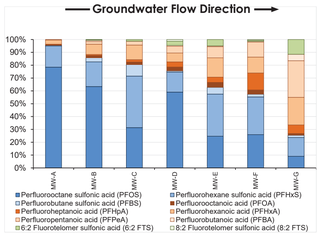
6. VADOSE ZONE SORPTION & INFILTRATION (FRACTIONATION) 6

- Fractionation of PFAS due to vertical infiltration from ground surface through vadose zone to groundwater.



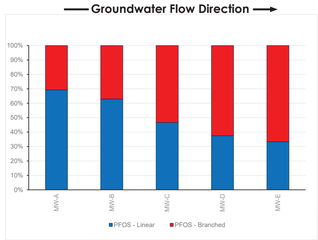
7. ADVECTION IN GROUNDWATER (FRACTIONATION) 7

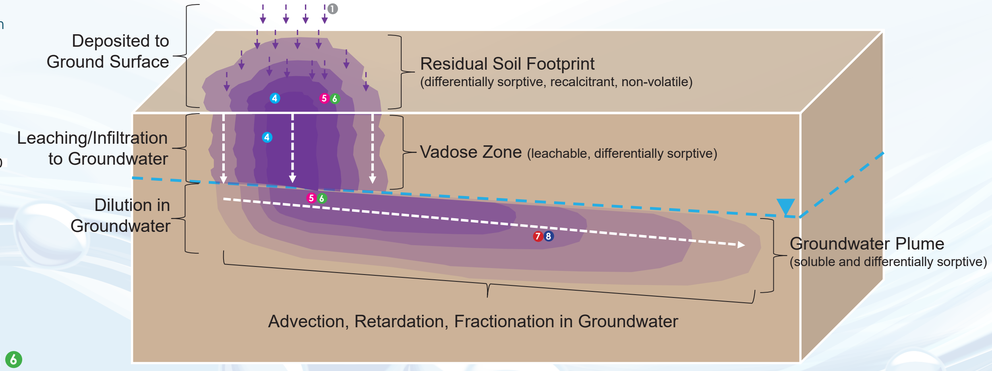
- Fractionation of PFAS along advective migration pathway in groundwater.



8. ADVECTION IN GROUNDWATER (FRACTIONATION) 8

- Fractionation of linear and branched chain PFOS along advective migration pathway in groundwater.



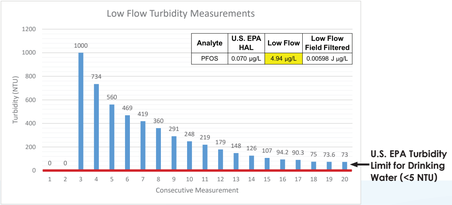


12. CONCLUSIONS

- 'Long' PFAS plumes attributable to release mechanism (foam application), runoff, and infiltration
- Soil footprint diagnostic of source and extent of groundwater plume
- PFAA migration in vadose zone and groundwater limited by retardation
- Enhanced sorption (↓concentration) approaching coastal water
- Fractionation patterns differentiate advection, infiltration, other sources
- PFAAs can readily sorb and desorb from soil and concrete due to weak electrostatic attraction and/or change in geochemical conditions
- Turbidity adds positive bias to results (not representative of drinking water)
- Bench-scale testing affirms preferential sorption of longer-chain PFAS
- Sorptive media have in-situ and ex-situ applications (GAC may not be best)

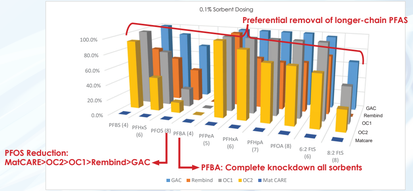
9. TURBIDITY – POSITIVE BIAS IN SAMPLE RESULTS

- Apparent effect and signficance of turbidity on PFOS concentrations in groundwater samples comparing filtered vs unfiltered results and turbidity measurements



10. BENCH SCALE SORBENT TESTING

- Preferential sorption of PFAS and relative effectiveness of treatment media for filtration.



11. BENCH SCALE SORBENT TESTING

- Preferential removal of longer chain PFAS:
  - PFOS (8) > PFHxS (6) > PFBS (4)
  - PFOA (8) > PFHpA (7) > PFHxA (6) > PFPeA (5) > PFBA (4)
- 8:2 FtS (8) > 6:2 FtS (6)
- Preferential removal of PFOS by sorbent at 0.1% dosing
  - MatCARE > Organoclay 2 > Organoclay 1> Rembind > GAC
- Initial knockdown by MatCARE at 0.01% dosing
- Ex-Situ and in-situ applicability

KLEINFELDER
Bright People. Right Solutions.