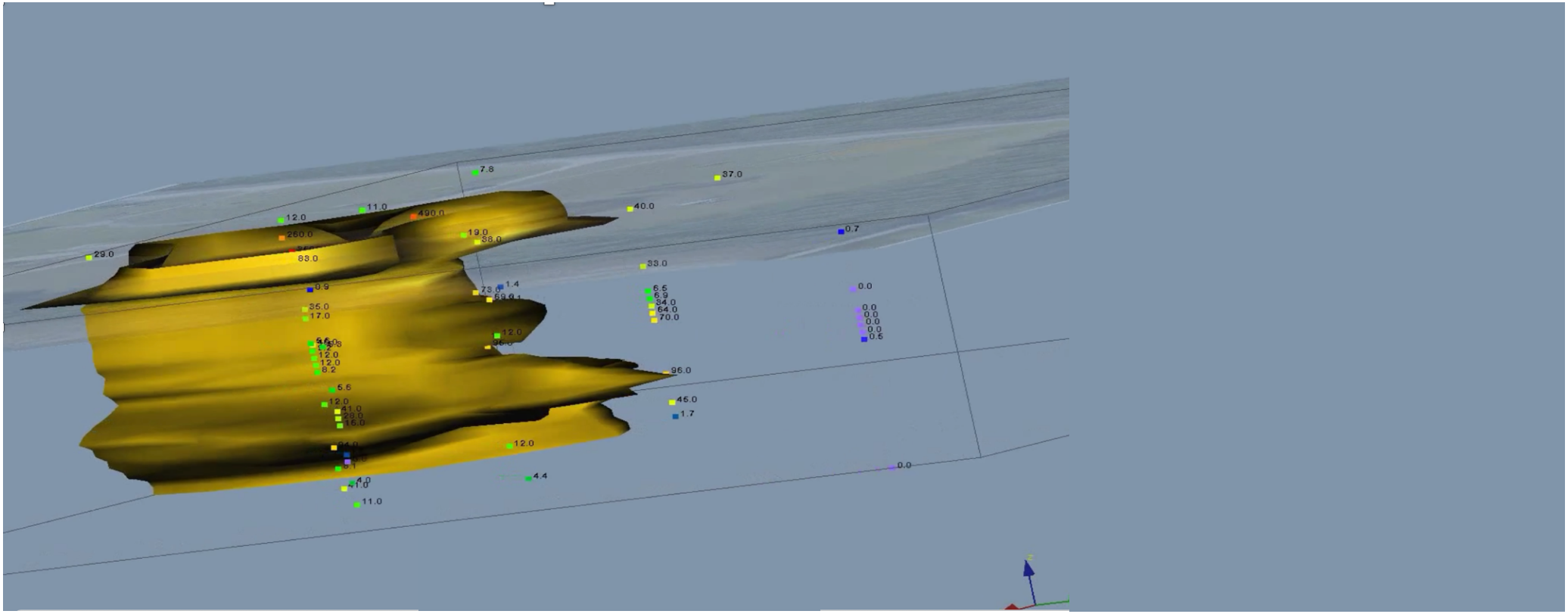


Comparing PFAS to Other Groundwater Contaminants: *Implications for Remediation*

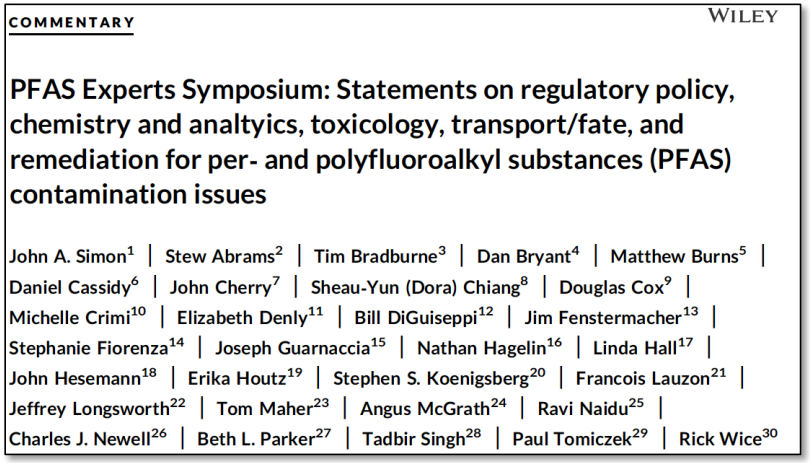
Charles Newell, David Adamson, Poonam Kulkarni, Blossom Nzeribe
(GSI Environmental Inc.)
Hans F. Stroo
(Stroo Consulting)

GSI ENVIRONMENTAL

Charles Newell
GSI Environmental
713 522 6300
cjnewell@gsi-net.com

PFAS IMPLICATIONS FOR REMEDIATION: KEY QUESTION

"The consensus message from the Symposium participants is that PFAS present far more complex challenges to the environmental community than prior contaminants."



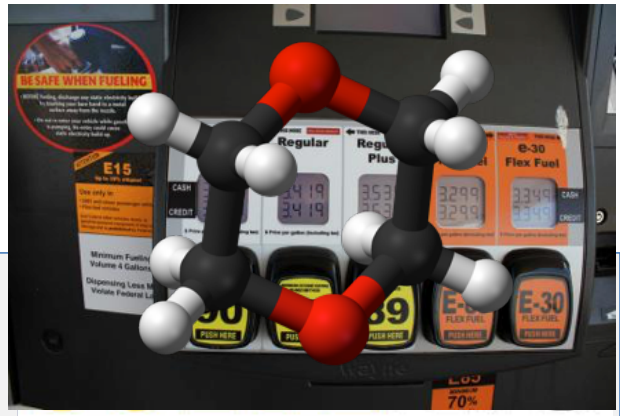
COMMENTARY

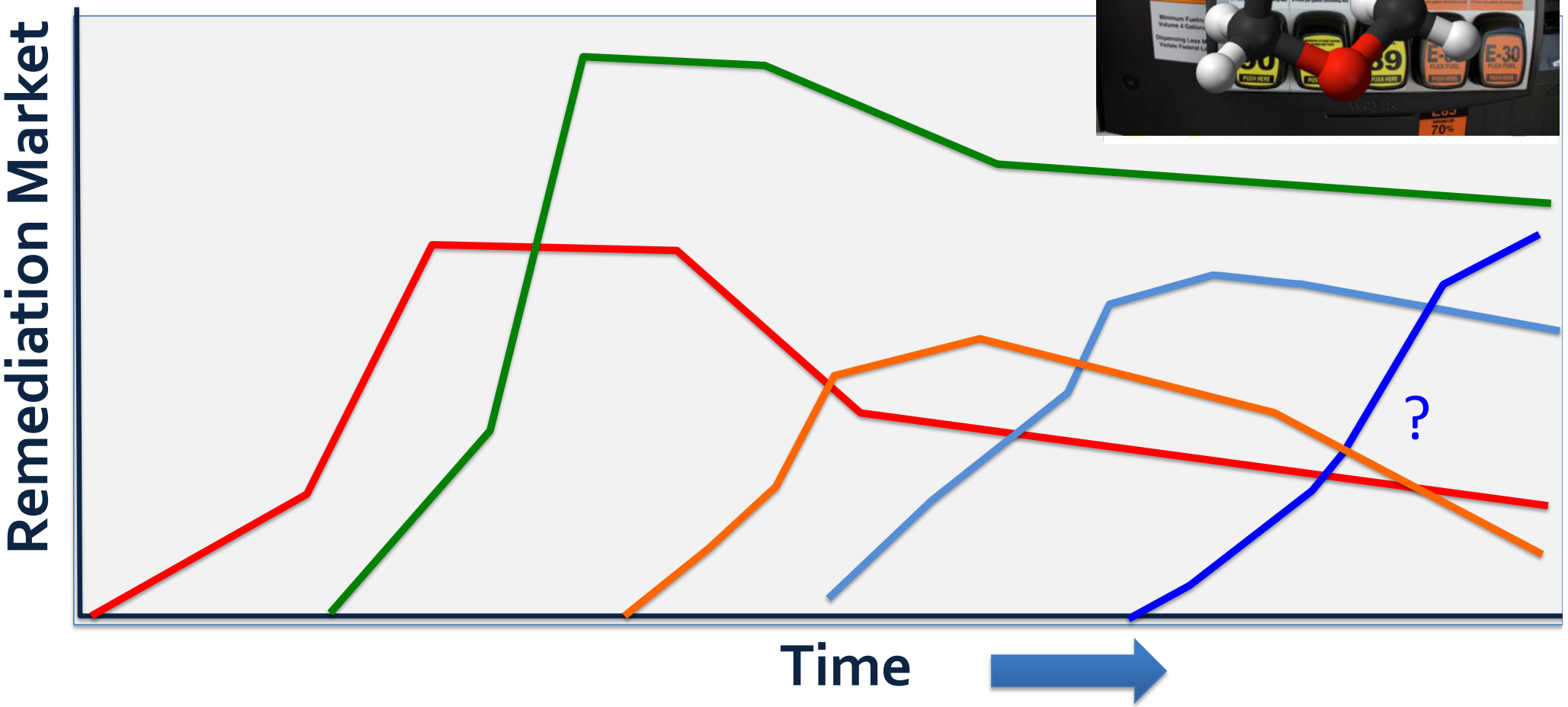
WILEY

PFAS Experts Symposium: Statements on regulatory policy, chemistry and analtyics, toxicology, transport/fate, and remediation for per- and polyfluoroalkyl substances (PFAS) contamination issues

John A. Simon[1] | Stew Abrams[2] | Tim Bradburne[3] | Dan Bryant[4] | Matthew Burns[5] | Daniel Cassidy[6] | John Cherry[7] | Sheau-Yun (Dora) Chiang[8] | Douglas Cox[9] | Michelle Crimi[10] | Elizabeth Denly[11] | Bill DiGuiseppi[12] | Jim Fenstermacher[13] | Stephanie Fiorenza[14] | Joseph Guarnaccia[15] | Nathan Hagelin[16] | Linda Hall[17] | John Hesemann[18] | Erika Houtz[19] | Stephen S. Koenigsberg[20] | Francois Lauzon[21] | Jeffrey Longsworth[22] | Tom Maher[23] | Angus McGrath[24] | Ravi Naidu[25] | Charles J. Newell[26] | Beth L. Parker[27] | Tadbir Singh[28] | Paul Tomiczek[29] | Rick Wice[30]

Successive Waves of Emerging Contaminants?

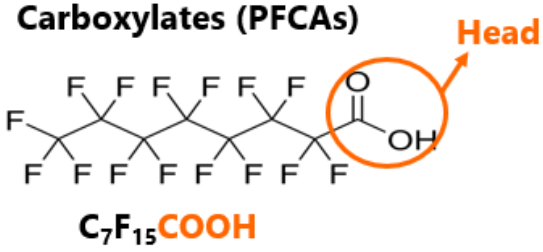




PFAS: PER- AND POLYFLUOROALKYL SUBSTANCES

Perfluoroalkyl substances

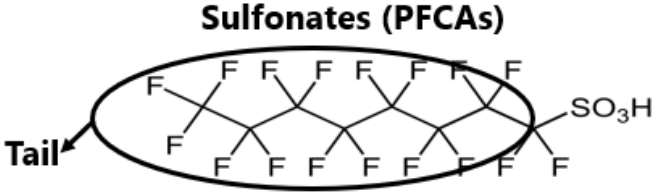
Carboxylates (PFCAs)



$C_7F_{15}COOH$

Perfluorooctanoic acid (PFOA)

Sulfonates (PFCAs)



$C_8F_{17}SO_3H$

Perfluorooctane sulfonic acid (PFOS)

What are remediation challenges?

- Recalcitrant: C-F
- Extremely stable
- Incomplete mineralization
- High mobility
- Complicated mixtures
- Potential for large dilute plumes
- Sampling/analysis difficult, costly

PFAS IMPLICATIONS FOR REMEDIATION: AUTHORS

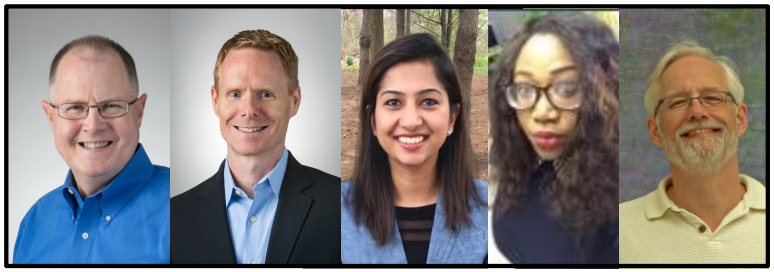
DOI: 10.1002/rem.21645

PRACTICE NOTE

WILEY

Comparing PFAS to other groundwater contaminants: Implications for remediation

Charles J. Newell[1] | David T. Adamson[1] | Poonam R. Kulkarni[1] | Blossom N. Nzeribe[1] | Hans Stroo[2]



Remediation. 2020;30:7–26.

Open Access. Google:
remediation PFAS implications comparing

GSI ENVIRONMENTAL

PFAS IMPLICATIONS FOR REMEDIATION: TWO-PRONGED APPROACH

- ***5 Qualitative* analogs with previous contaminants**

  - Sources Zones
  - Analytical
  - Attenuation
  - Mixtures
  - Plume lengths

- ***9 Quantitative* scale-of-remediation metrics in four categories:**

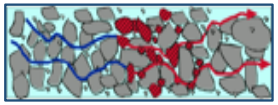
  - Prevalence Metrics
  - Fate/Transport Metrics
  - Remediation Metrics
  - Research Metrics

QUALITATIVE ANALOGS

Plume Length

Source Processes that Sustain Plumes

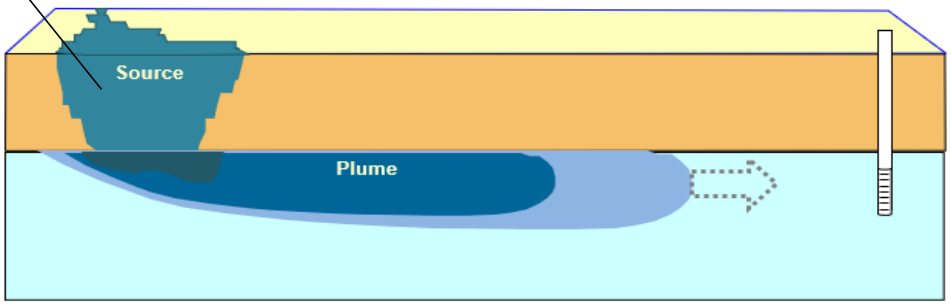
Fuels, chlorinated plumes sustained for decades/centuries by NAPLs, matrix diffusion



PFAA plumes sustained by 1) storage on air/water interfaces; 2) biodegradation of precursors; 3) matrix diffusion

Precursors

PFAAs



QUALITATIVE ANALOGS

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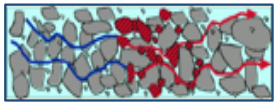
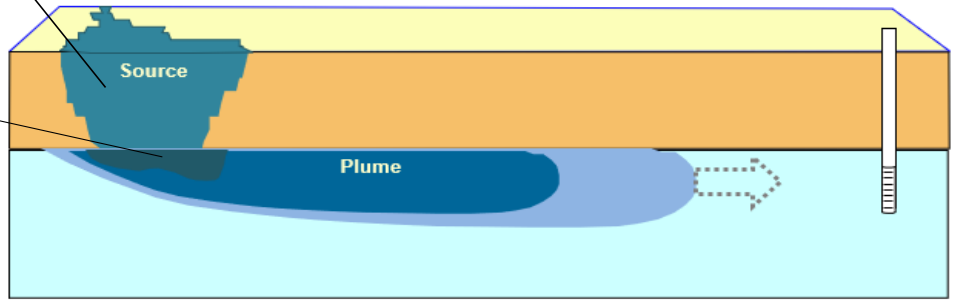
Source Processes that Sustain Plumes

Fuels, chlorinated plumes sustained for decades/centuries by NAPLs, matrix diffusion 	PFAA plumes sustained by 1) storage on air/water interfaces; 2) biodegradation of precursors; 3) matrix diffusion  *Precursors* *PFAAs*

Analytical Developments Identified Problem

VOC analytical developments in the 1960s and 1950s such as GC/MS allowed VOC plumes to be identified and scale of problem to be revealed	PFAS analytical developments in the 2000s allowed quantification down to the ppt level and showed PFAS were present in the environment on a global scale



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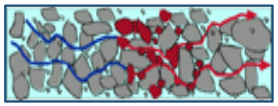

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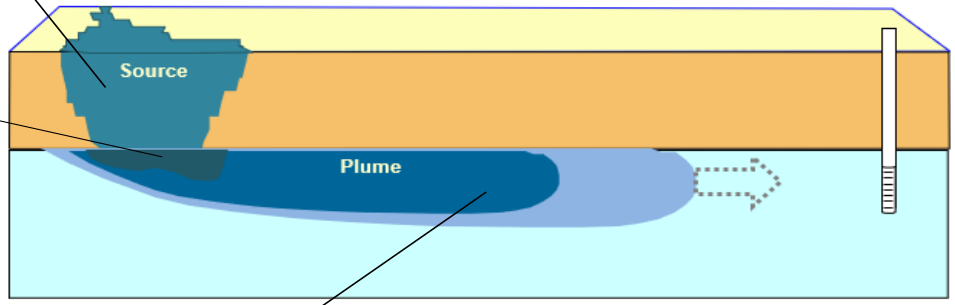
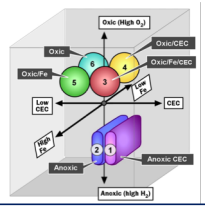


Viability of MNA



Metals and radionuclide plumes can be managed by Monitored Natural Attenuation (MNA) via sequestration under the right geochemical conditions

Some PFAS plumes may be amenable to MNA via air/water partitioning, matrix diffusion, and sorption sequestration processes

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Plume Length

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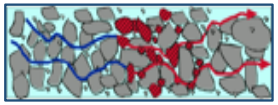

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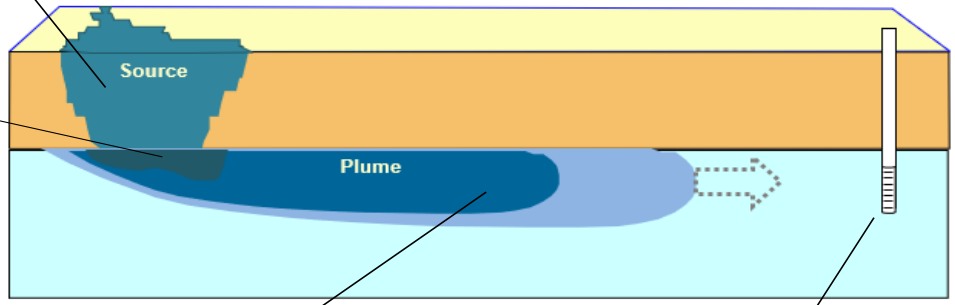

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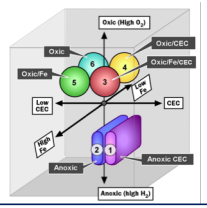

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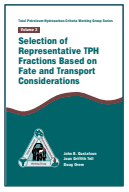
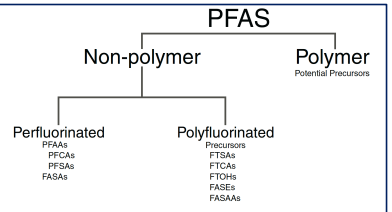
Assessing Risk from Mixtures



Fuels: TPH Criteria Working Group methodology based on 7 aliphatic fractions and 6 aromatic fractions with surrogate compounds

PFAS mixtures classified by functional group, manufacturing process, chain length, charge, isomer (e.g., linear vs branched)



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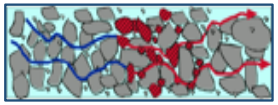
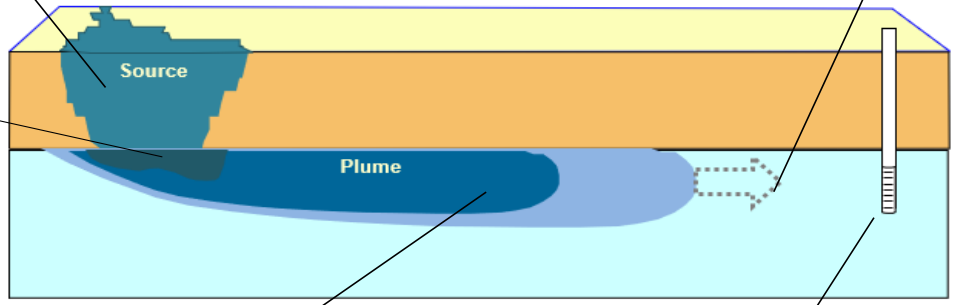


PFAA plumes sustained by 1) storage on air/water interfaces; 2) biodegradation of precursors; 3) matrix diffusion

Early Forecasts of Maximum Plume Length

Hydrocarbon, chloroethene, MTBE, 1,4-Dioxane plumes were all found to degrade more rapidly in groundwater than first thought, limiting plume length

Terminal PFAAs do not appear to biodegrade in subsurface, leading to speculation that these plumes can become very long



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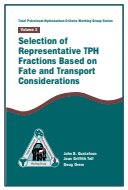

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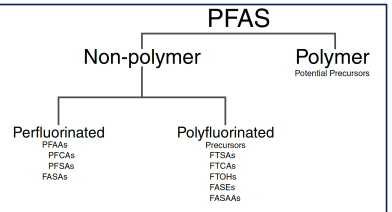

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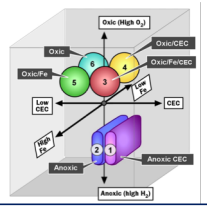

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PFAS IMPLICATIONS FOR REMEDIATION: TWO-PRONGED APPROACH

- ***9 Quantitative** scale-of-remediation metrics in four categories:*

Prevalence Metrics

Fate/Transport Metrics

Remediation Metrics

Research Metrics

QUANTITATIVE METRICS:

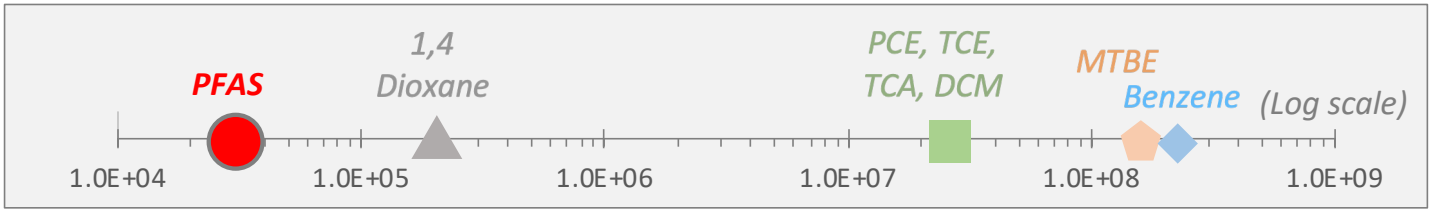
Total Production During Periods with Higher Release Potential

Prevalence Metrics

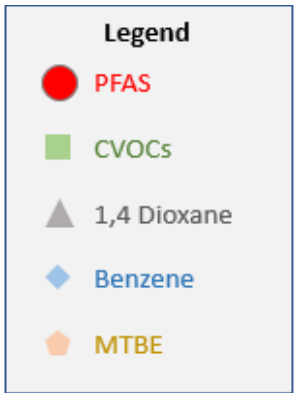
1.1 Total Production During Periods with Higher Release Potential

Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide



(tonnes)



QUANTITATIVE METRICS:

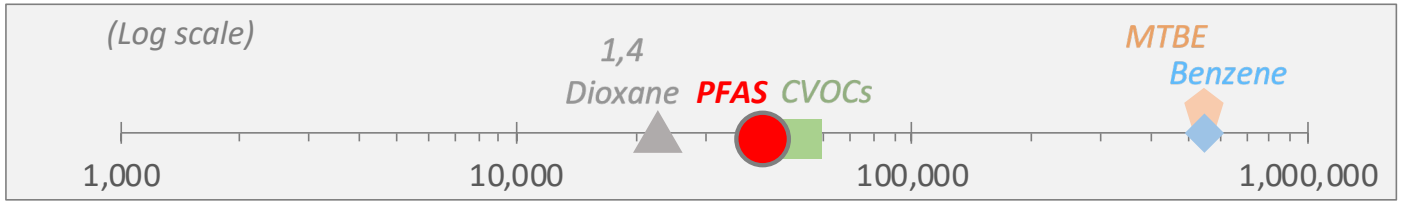
Total Production During Periods with Higher Release Potential

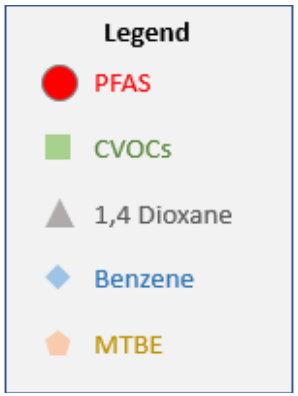
Prevalence Metrics

Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide

1.2 Estimated Number of Groundwater Sites





QUANTITATIVE METRICS:

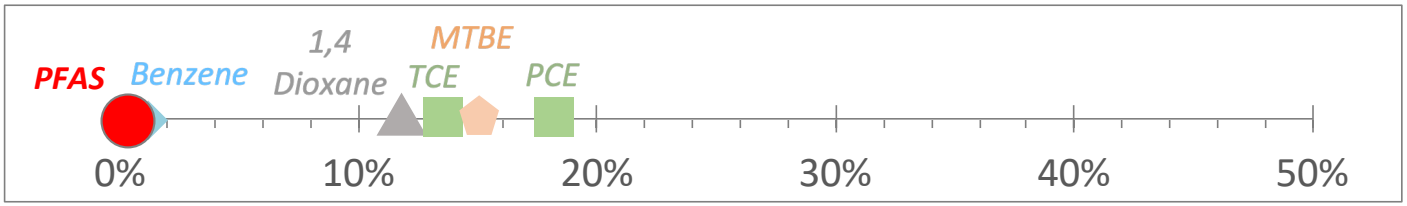
Total Production During Periods with Higher Release Potential

Prevalence Metrics

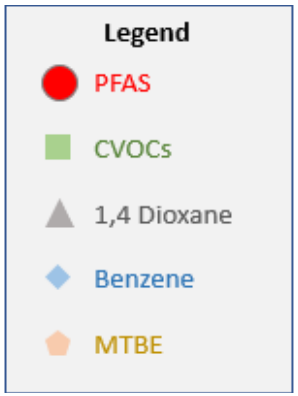
Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide

1.3 Frequency Detected in Public Groundwater Water Supply Systems



(% of water systems with detects)



QUANTITATIVE METRICS:

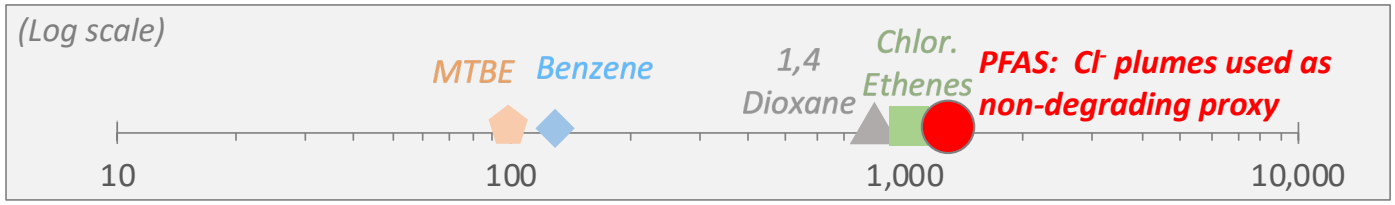
Total Production During Periods with Higher Release Potential

Fate /Transport Metrics

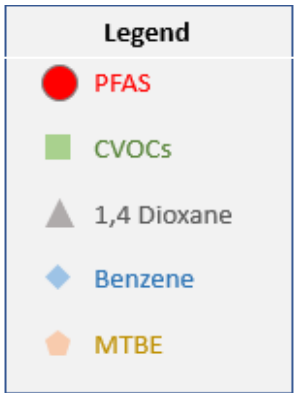
Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide

2.1 Attenuation Indicator: Median Plume Length from Multiple Site Studies



(feet)



QUANTITATIVE METRICS:

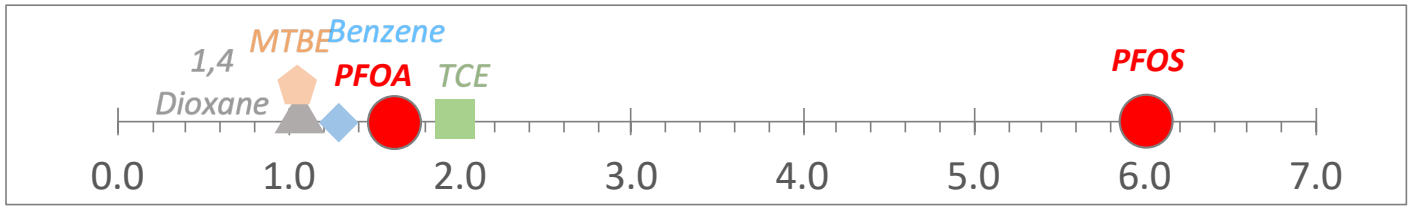
Total Production During Periods with Higher Release Potential

Fate /Transport Metrics

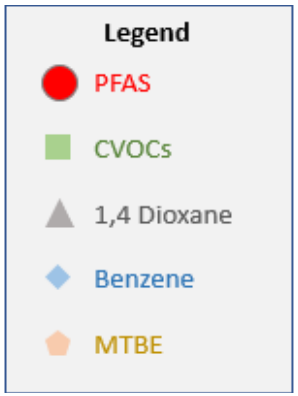
Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide

2.2 Hydrophobic Sorption



Retardation factor (-)



QUANTITATIVE METRICS:

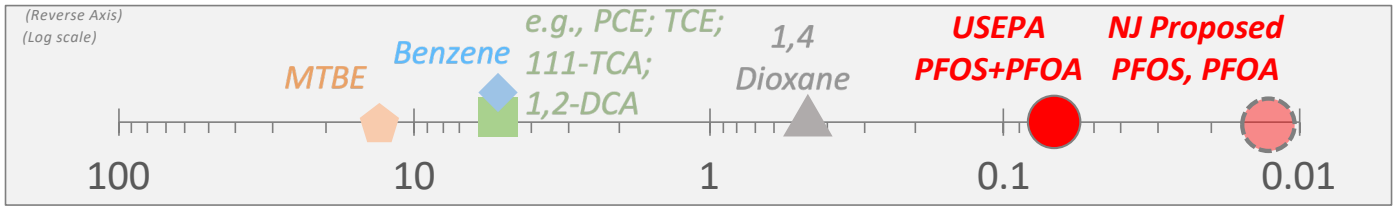
Total Production During Periods with Higher Release Potential

Remediation Metrics

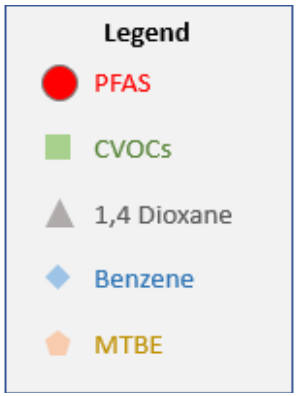
Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide

3.1 Regulatory Criteria



(ug/L)



QUANTITATIVE METRICS:

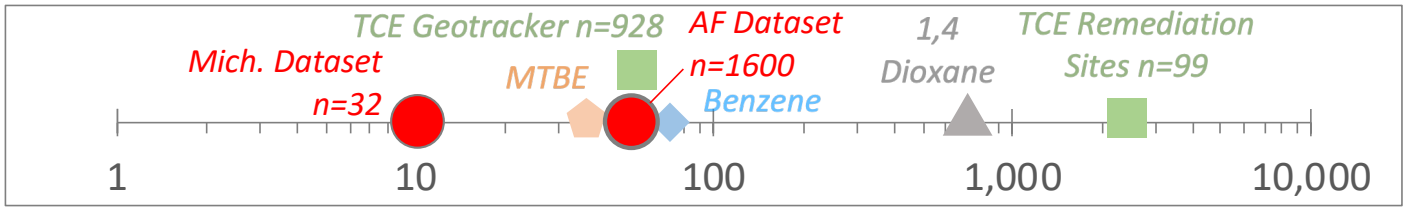
Total Production During Periods with Higher Release Potential

Remediation Metrics

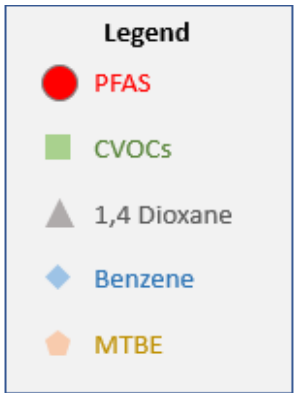
3.2 Required Destruction/Removal Efficiency

Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide



(Median source concentration from multiple sites divided by regulatory criteria)



QUANTITATIVE METRICS:

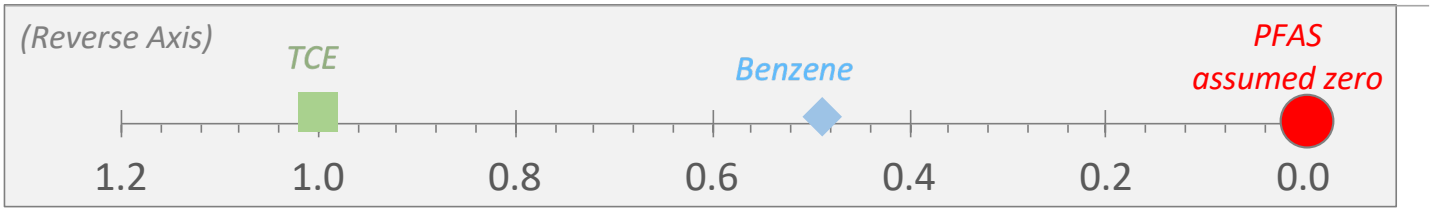
Total Production During Periods with Higher Release Potential

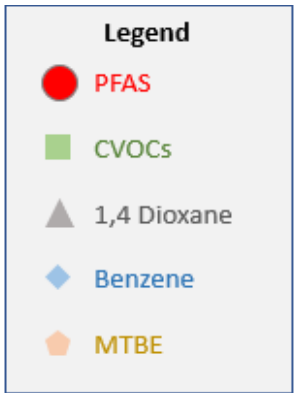
Remediation Metrics

3.3 Relative In-Situ Remediation Capability

Potential for **smaller** scale of groundwater remediation nationwide

Potential for **larger** scale of groundwater remediation nationwide





(Order of Magnitude difference between median source concentrations before and after in-situ treatment from multiple site database (OoMs))

QUANTITATIVE METRICS:

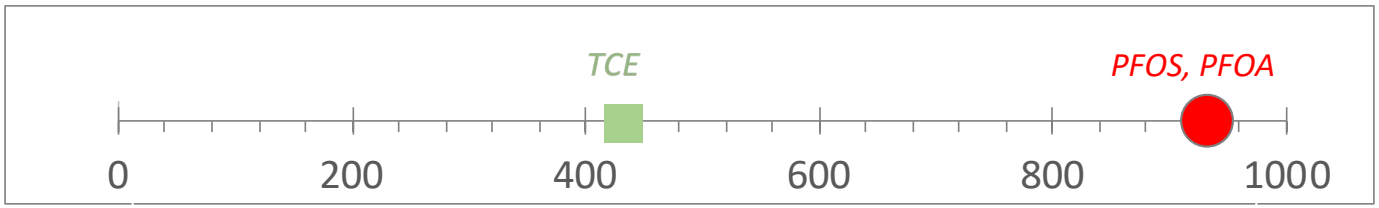
Total Production During Periods with Higher Release Potential

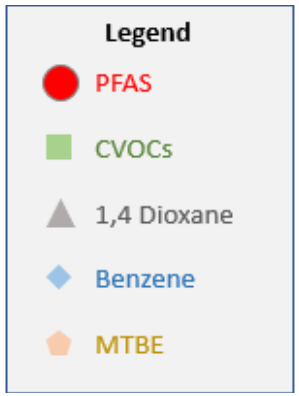
Research Metrics

Potential for **smaller** scale of groundwater remediation nationwide

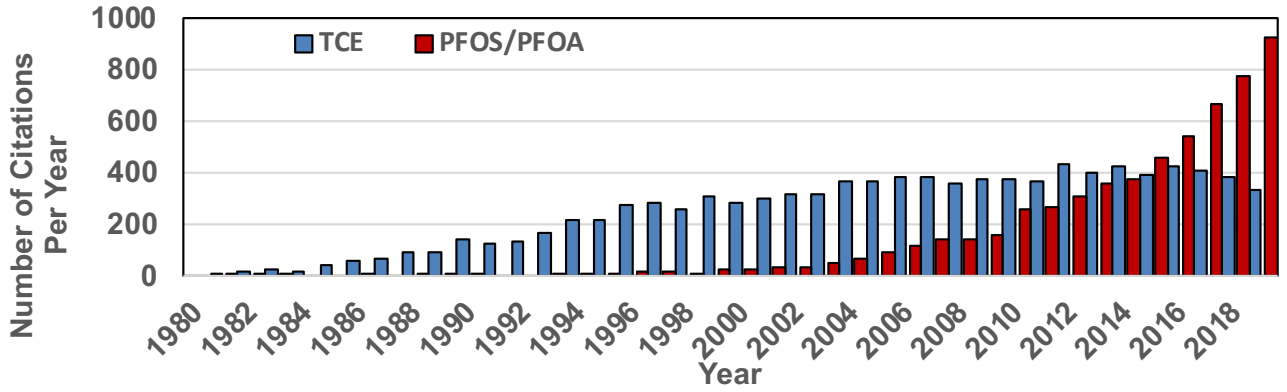
Potential for **larger** scale of groundwater remediation nationwide

4.0 Research Intensity





(Peak annual citations in any one year between 1985 and 2019)

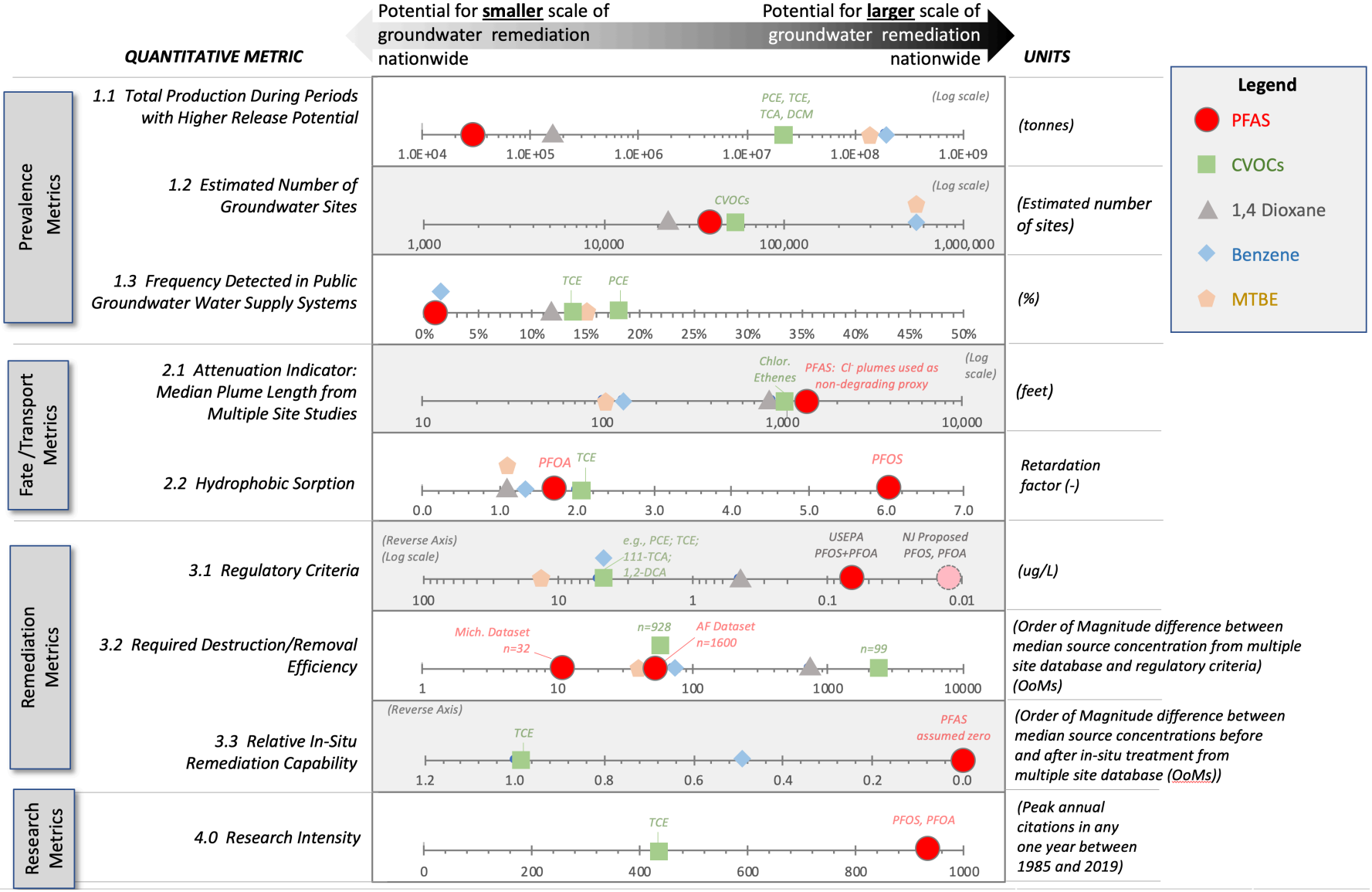


Number of Google scholar "hits" on "Groundwater+TCE" and "Groundwater PFOA or PFOS" from 1985 to 2019

Comparing PFAS to Other Groundwater Contaminants

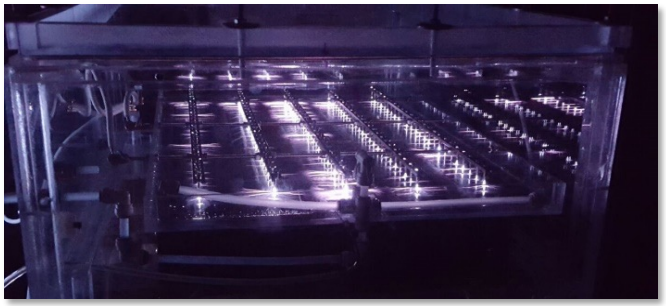
Implications for Remediation:

Mixed results when comparing overall scale of groundwater remediation to other contaminants



PFAS IMPLICATIONS FOR REMEDIATION:

"Although the problem of PFAS in groundwater appears to be a daunting one, we feel confident that a similar level of ingenuity (invented for previous contaminants) will lead to surprising technical developments in remediating PFAS sites in the future as well"



Source: Clarkson University