

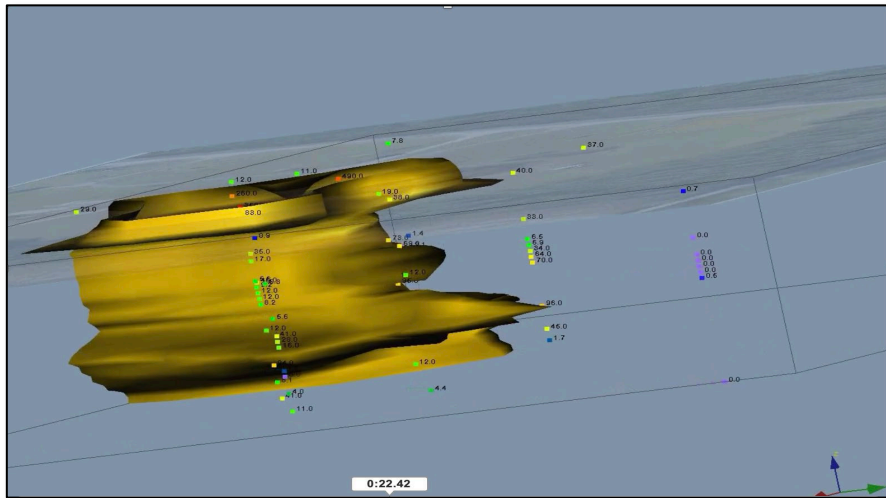
Monitored Natural Attenuation and Enhanced Retention Processes to Manage PFAS in Groundwater



NEWMOA: The Science of PFAS Conference

April 2022

Stephen D Richardson, PhD, PE
David T Adamson, PhD, PE
Charles J Newell, PhD, PE



AGENDA

- **PFAS = Bizzarro World?**
- **Potential Futures for PFAS MNA**
- **Retention-Based MNA for PFAS**
- **Key Retention Processes**
- **Wait – There’s More! Enhanced Attenuation (EA)**

What is the Philosophy Behind MNA?

**Nature
can help!**

It is harder and more expensive to clean these sites up than first thought.

Nature is amazing and seems to be degrading or sequestering some of these chemicals.

Let's let nature do the job.

*But you have to do **three things**:*

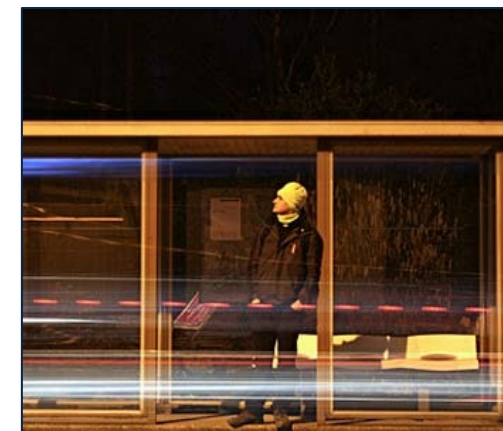
Protect



Understand



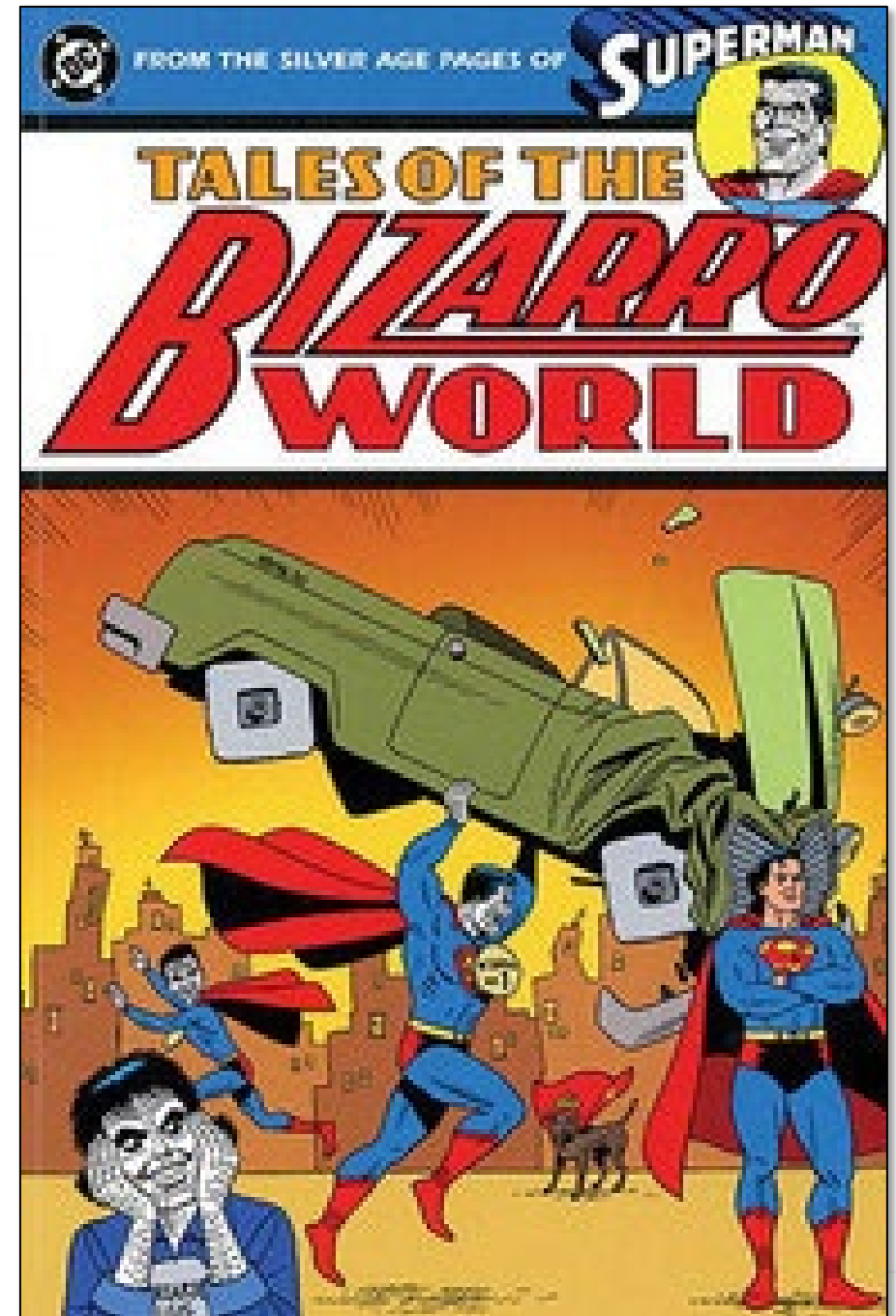
Watch



PFAS = Bizarro World

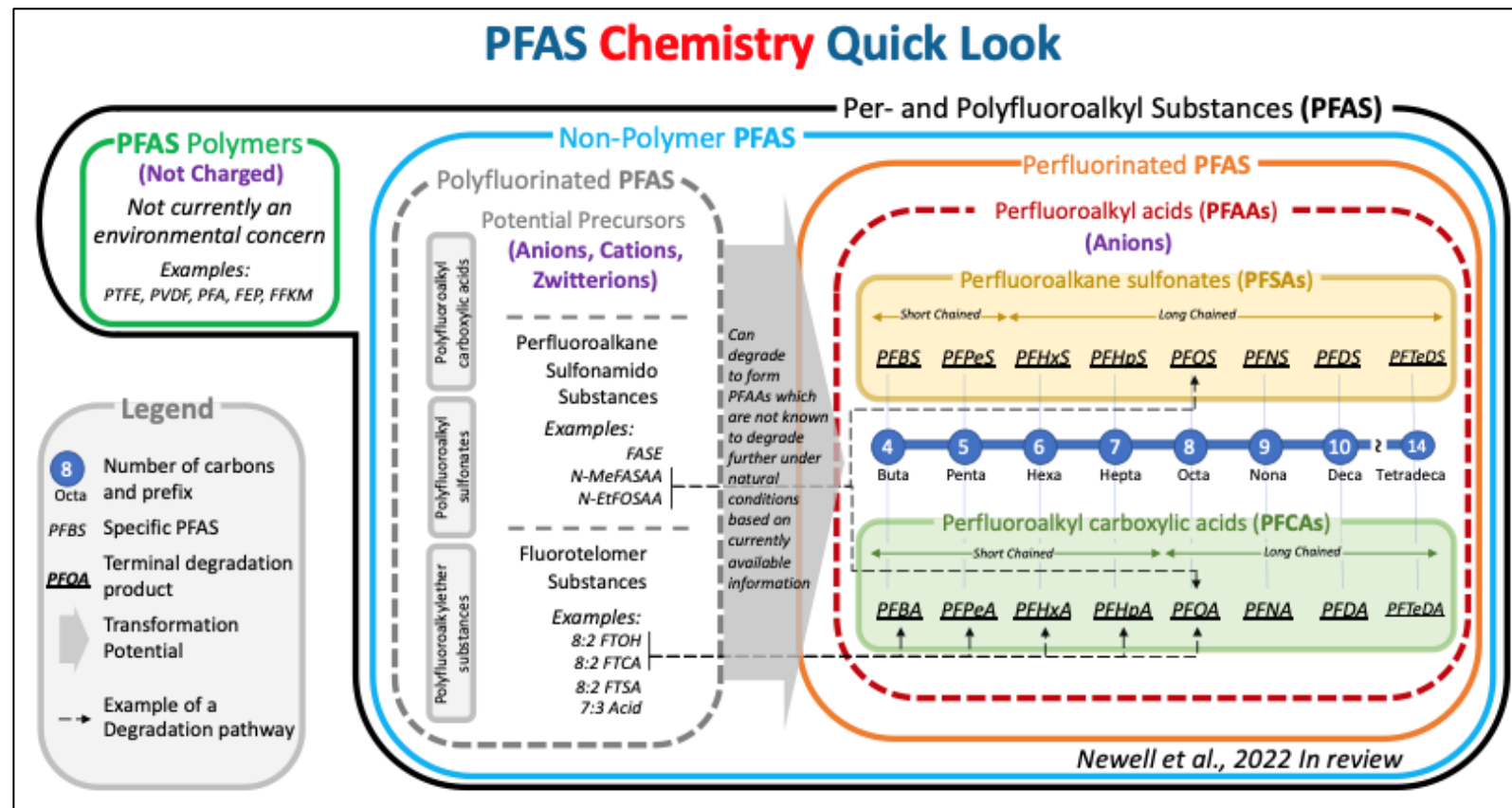
- › “The Bizarro World (also known as *Htrae*, which is “Earth” spelled backwards) is a fictional planet appearing in American DC comic books.
- › *Htrae* is a **cube-shaped** planet, home to Bizarro and companions, all of whom were initially Bizarro versions of Superman, Lois Lane, others
- › In popular culture, **“Bizarro World” has come to mean a situation or setting which is weirdly inverted or opposite to expectations.**”

Wikipedia, 2022



PFAS = Bizarro World for Groundwater People?

- › Little or no in-situ degradation of regulated PFAAs!
- › Biodegradation doesn't help, it hurts!
- › Front-line technology is Pump and Treat? Are we back in the 1980s?
- › Concentrations: single digit Nanogram per liters?
- › Thousands of individual PFAS!
- › 40,000+ sites? (EBJ, 2019)



Key Point: “Business as Usual” won’t work for PFAS Groundwater Cleanup

Potential Futures for PFAS Management?

- › **Scenario 1:** Pump & Treat is the predominant approach for PFAS plumes (with some injected sorbents)?
- › **Scenario 2:** Researchers deliver a “silver bullet” that destroys PFAS in-situ, it is rapidly adopted.
- › **Scenario 3:** Risk / Triage strategy used with variety approaches, including retention-based MNA at some sites.



40,000 Pump & Treats Too Many?



Nothing Yet





**PFAS Experts:
Most likely**

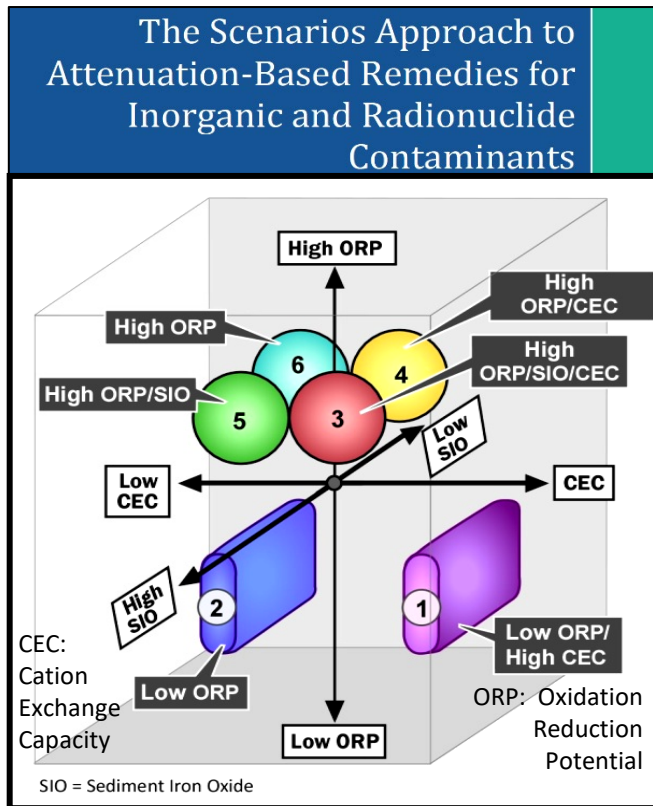
COMMENTARY

WILEY

PFAS Experts Symposium 2: PFAS Remediation research – Evolution from past to present, current efforts, and potential futures

Charles J. Newell¹  | William H. DiGiuseppi² | Daniel P. Cassidy³ |
 Craig E. Divine⁴ | James M. Fenstermacher⁵ | Nathan W. Hagelin⁶ |
 Ryan A. Thomas⁷ | Paul Tomiczek III⁸ | Scott D. Warner⁹ | Zhong John Xiong¹⁰ |
 Paul B. Hatzinger¹¹ 

EPA's Guidance MNA for Metals and Rads Lead to DOE's "Scenarios" Guidance



Contaminant	Scenarios					
	Scenario 1 <i>low ORP high CEC</i>	Scenario 2 <i>low ORP low CEC</i>	Scenario 3 <i>high ORP high CEC high SIO¹</i>	Scenario 4 <i>high ORP high CEC low SIO¹</i>	Scenario 5 <i>high ORP low CEC high SIO¹</i>	Scenario 6 <i>high ORP low CEC low SIO¹</i>
Cr(III)						
Cr(VI)	reduced to Cr(III)	reduced to Cr(III)				
⁹⁹ Tc(IV)			Likely oxidized to Tc(VII)	Likely oxidized to Tc(VII)	Likely oxidized to Tc(VII)	Likely oxidized to Tc(VII)
⁹⁹ Tc(VII)	reduced to Tc(IV)	reduced to Tc(IV)				
Pu						
U						
Cd, Cu, Pb, Zn						
Ni						
As						
Se						
⁹⁰ Sr, Cs ² , Ra ³	↑TDS		↑TDS			
NO ₃ ⁻ , ClO ₄ ⁻	<i>can degrade</i>	<i>can degrade</i>				
¹²⁹ I						

HIGH Mobility
MEDIUM Mobility
LOW Mobility

Six geochemical scenarios (based on ORP, CEC, SIO) for 19 Inorganic / radionuclide contaminants determine **Mobility** for MNA purposes

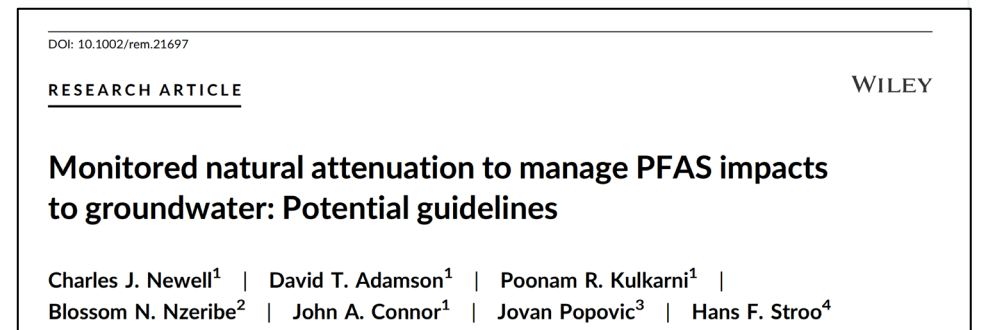
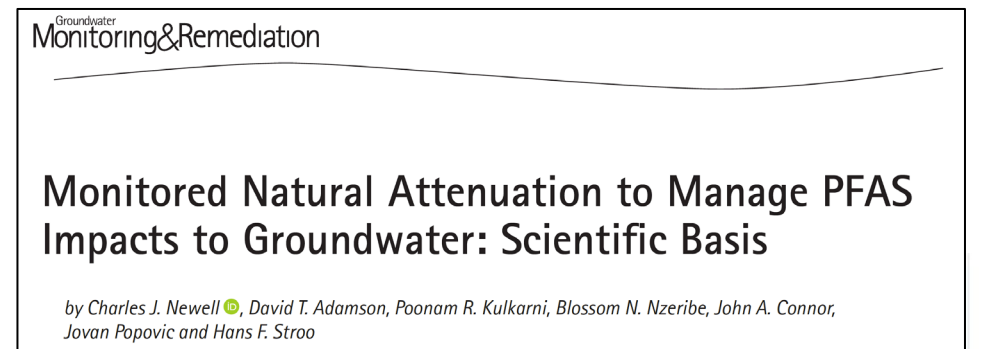
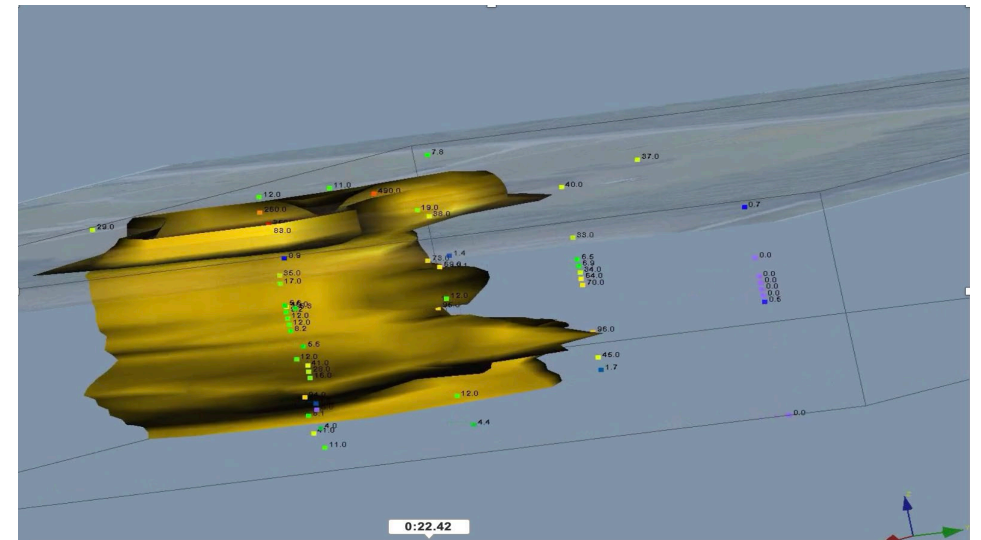
Monitored Natural Attenuation for PFAS?

Key Inspiration: High-resolution sampling, matrix diffusion modeling for ESTCP project ER-201633, NAVFAC PFAS Project.

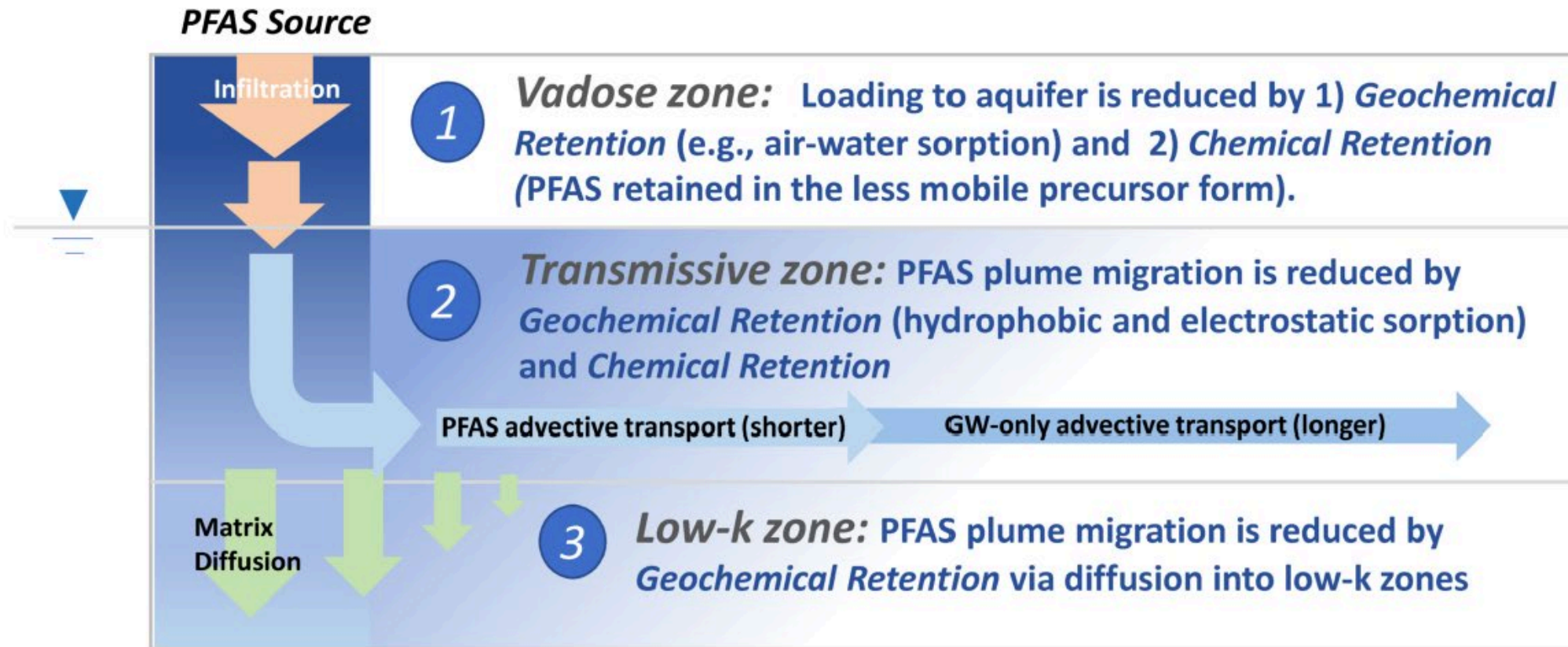
Key Result: Over 75% of PFAS mass in saturated zone is retained in low-permeability units.

Key Points:

- Significant PFAS mass is retained in saturated zone
- Other PFAS researchers show significant retention on air/water, NAPL/water interfaces
- PFAS will sorb
- We can integrate these together to understand MNA

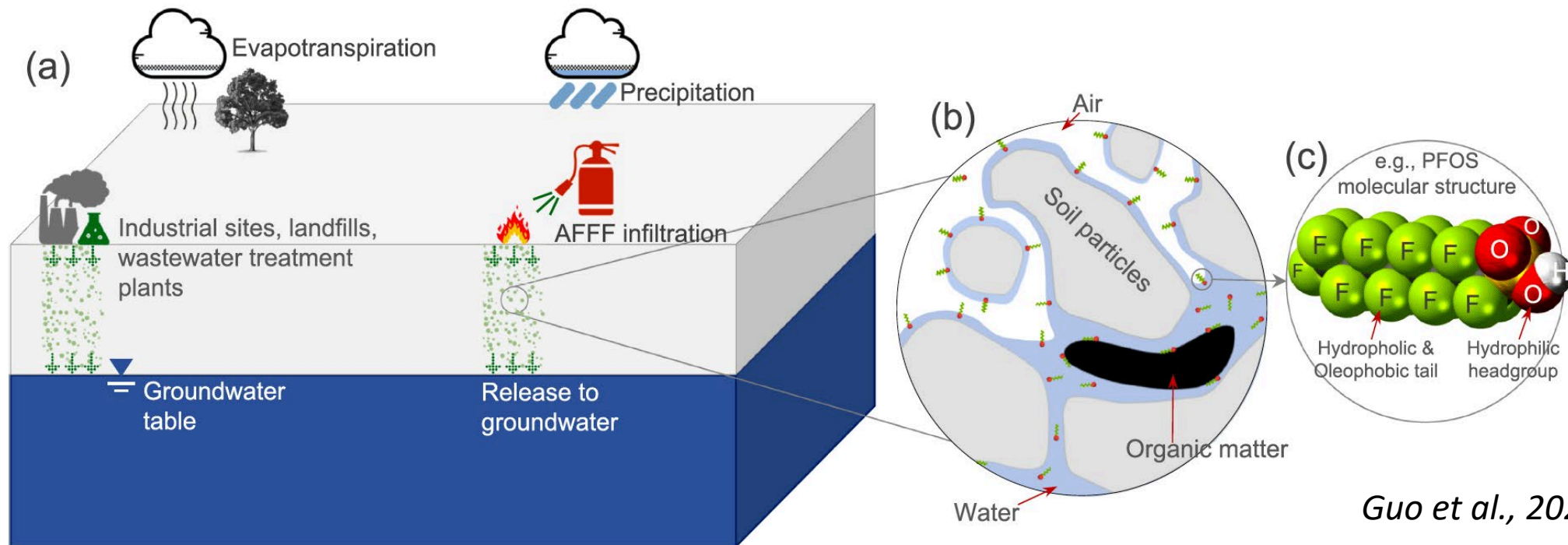


Key PFAS MNA Processes



Key Vadose Zone Retention Processes – *Air/Water Partitioning*

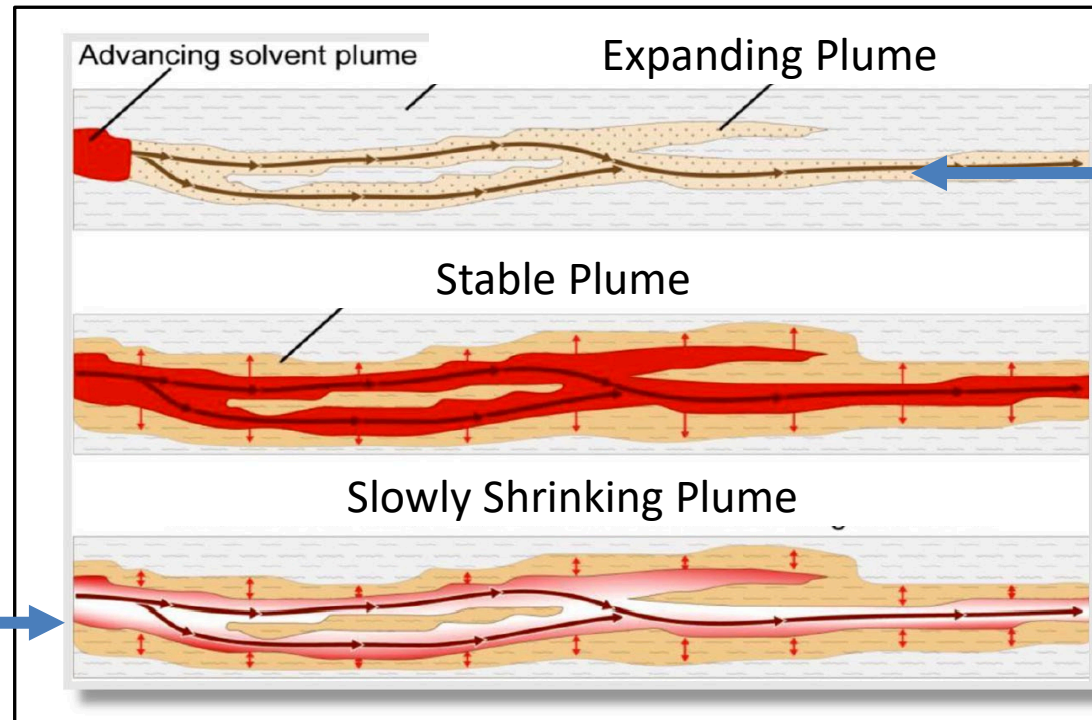
- PFAS are surfactants
- They like to accumulate at air/water interfaces
- This can retain some PFAS in the unsaturated zone for a long time
- Depends on site, but *“can take several decades or longer for PFOS to reach groundwater.”*



Key Saturated Zone Retention Processes – *Sorption and Matrix Diffusion*

- PFAS sorb to organic carbon on soils (more carbons = generally more sorption)
- For PFAAs, similar sorption as chlorinated solvents (Retardation Factor in single digits)
- Like CVOCs, PFAS diffuse in low-permeability geologic media
- But this matrix diffusion has different implications:

Most **chlorinated sites** down here: Matrix diffusion makes it harder to remediate

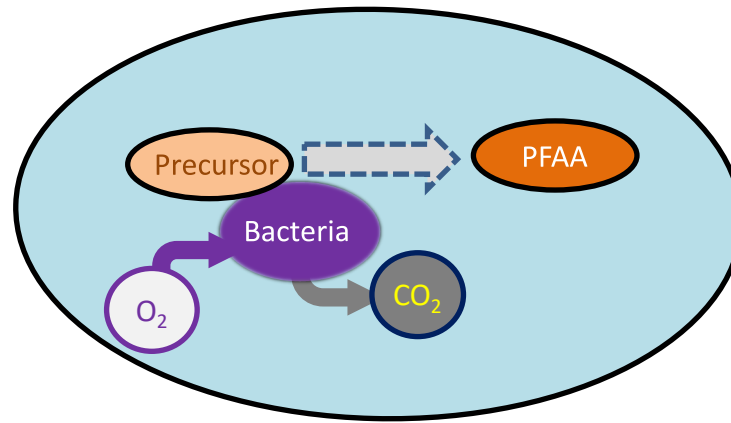


PFAAs don't readily degrade, so there may be more **expanding PFAS plumes**. But matrix diffusion is retaining PFAS, therefore slowing plume expansion

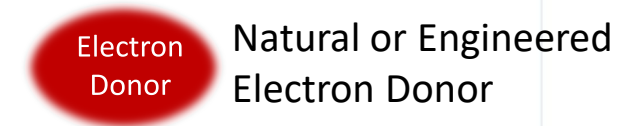
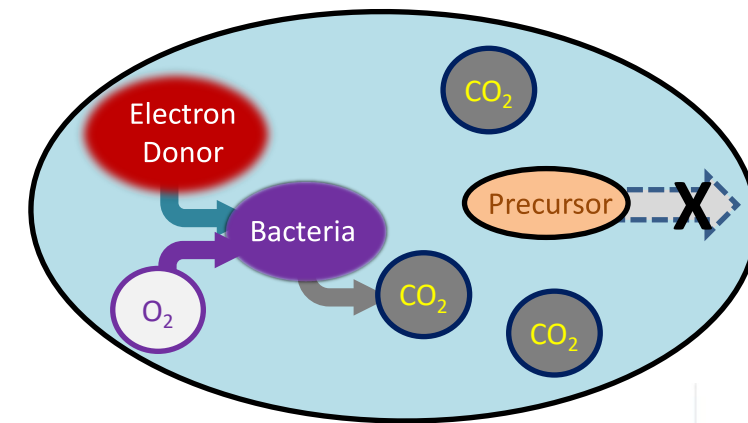
Key PFAS Retention Processes – *Chemical Retention*

- Most regulated PFAS are Per-fluoroalkyl Acids (PFAAs)
- Examples: PFOS, PFOA, PFHxS
- The biodegradation of precursors can form PFAAs, the terminal compound in the degradation pathway
- PFAAs are often more mobile than precursors
- **“Chemical retention”** is a general term for when PFAAs are left in the more environmental benign precursor state

Aerobic Conditions

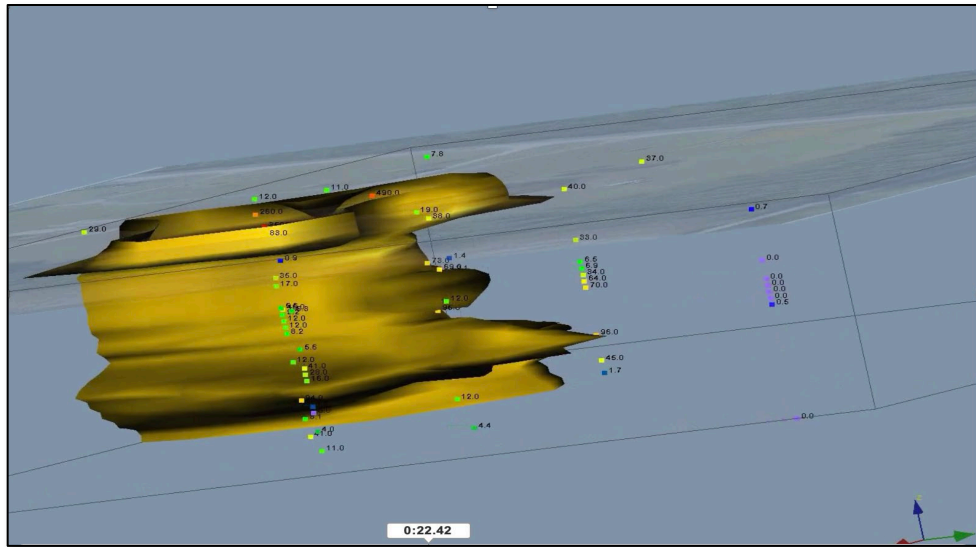


Anaerobic Conditions



How Might Retention-Based PFAS MNA affect Plumes?

- Apply matrix diffusion model to extremely well characterized PFAS sites
- **Key Point: attenuation affect of matrix diffusion on plume migration seen at this site**



Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Journal of Contaminant Hydrology

ELSEVIER journal homepage: www.elsevier.com/locate/jconhyd

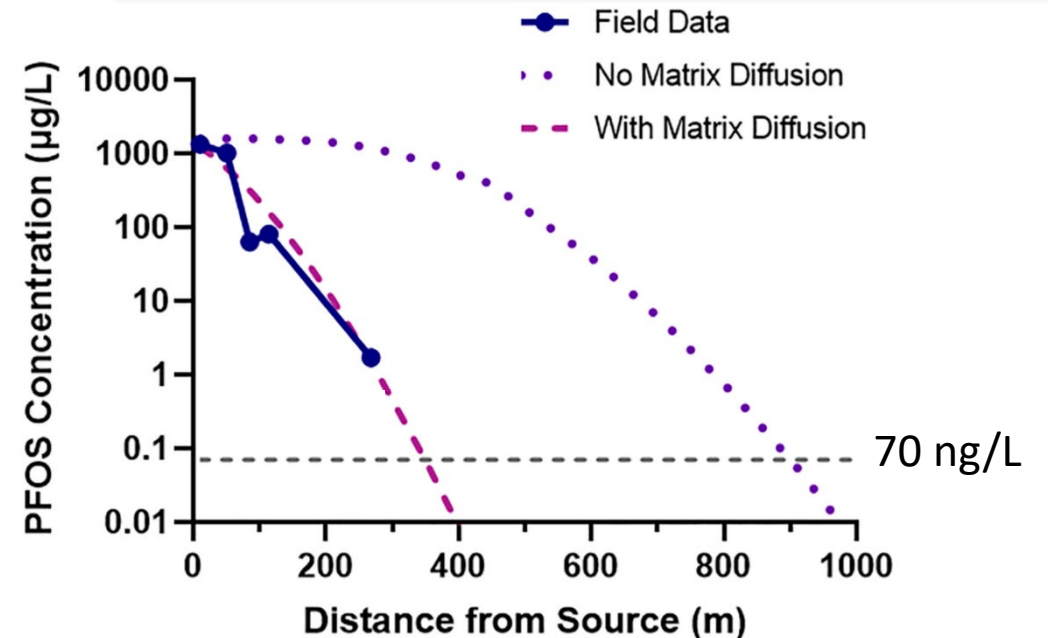
Modeling a well-characterized perfluorooctane sulfonate (PFOS) source and plume using the REMChlor-MD model to account for matrix diffusion

Poonam R. Kulkarni^{a,*}, David T. Adamson^a, Jovan Popovic^b, Charles J. Newell^a

[Check for updates](#)

Mass-Based, Field-Scale Demonstration of PFAS Retention within AFFF-Associated Source Areas

David T. Adamson,* Anastasia Nickerson, Poonam R. Kulkarni, Christopher P. Higgins, Jovan Popovic, Jennifer Field, Alix Rodowa, Charles Newell, Phil DeBlanc, and John J. Kornuc



How Might Retention-Based PFAS MNA Affect Plumes?

- Modeling Studies to Explore Retention-Based PFAS MNA

Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Journal of Contaminant Hydrology

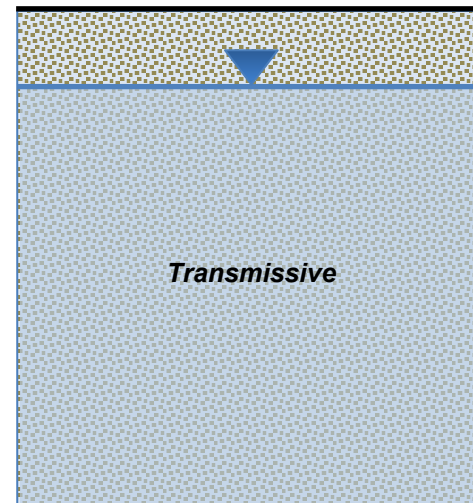
journal homepage: www.elsevier.com/locate/jconhyd

Impact of matrix diffusion on the migration of groundwater plumes for Perfluoroalkyl acids (PFAAs) and other non-degradable compounds

Shahla K. Farhat^{a,*}, Charles J. Newell^a, Sophia A. Lee^b, Brian B. Looney^c, Ronald W. Falta^d

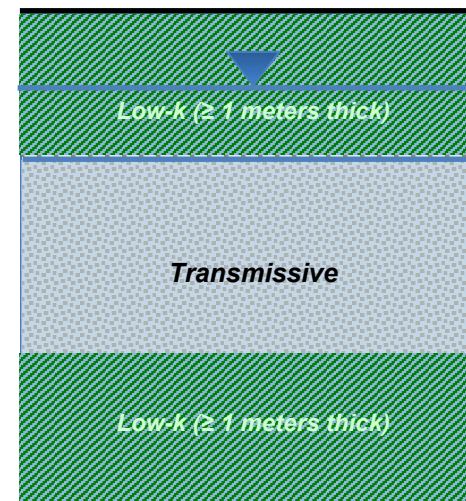


Homogeneous Aquifer



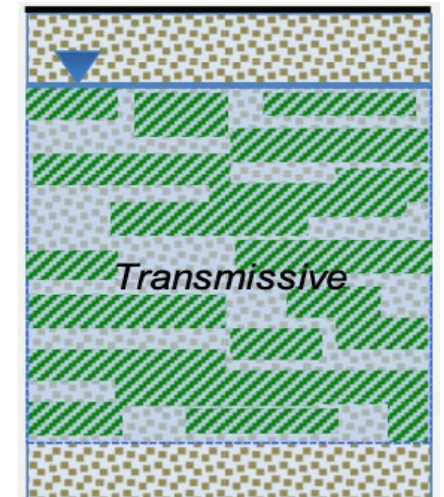
1310 meters

Transmissive With Aquitards



1040 meters

Transmissive With 80% Lenses



250 meters

PFOS Plume Length after 100 years:



Wait – There's More!

GINSU
ESSENTIALS

10-PIECE GOURMET CUTLERY SET

LIFETIME WARRANTY
THE GINSU EDGE NEVER NEEDS SHARPENING

www.ginsu.com

The advertisement features a collection of ten kitchen knives with black handles and stainless steel blades, arranged on a dark surface. The GINSU logo is visible on the blades.

30 Day Trial Only \$1495

FREE SHIPPING
NY, NJ & CA residents add sales tax
Please send check or money order to:
AB Rocket
P.O. Box 3012
Wallingford, CT 06492

www.tryABrocket.com

30 Day Money Back Guarantee! (less S&H)
Allow 2 Weeks For Delivery - ©2007 AB Rocket

1-800-232-0400

The advertisement shows a television screen displaying a scene of people in a gymnasium. The text is overlaid on the right side of the screen.

EggGenie

AS SEEN ON TV

The advertisement shows a white EggGenie egg cooker with three eggs inside. Below the main image are four small circular icons showing different stages of cooking.

VIDEO: Infomercials

The Amazing New WonderSpud!
You'll never cook potatoes the old way ever again!

Order Now and we'll send you a second WonderSpud absolutely FREE!
(just pay extra S&H)

ONLY \$19.95
(what \$56.95 S&H)

Se Habla Español!

1-800-44SPUDS
(1-800-447-7837)

The advertisement features a red starburst graphic with a yellow potato in the center. The background is blue with white text.

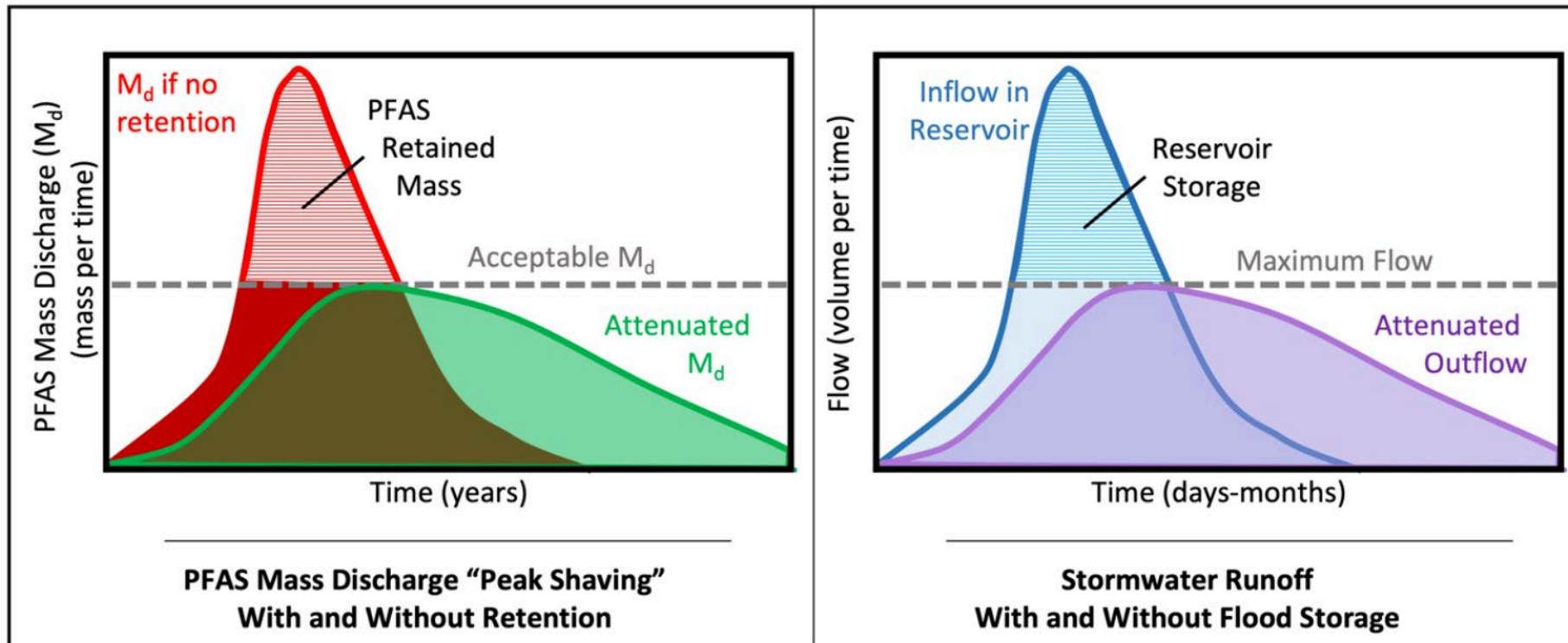


Enhanced Attenuation (EA)

Enhanced Attenuation (EA) Processes to Manage PFAS Plumes in Groundwater:
Current, Emerging, and Speculative Approaches

Charles J. Newell, Hassan Javed, Yue Li, Nicolas W. Johnson, Stephen D. Richardson,
John. A. Connor, and David T. Adamson

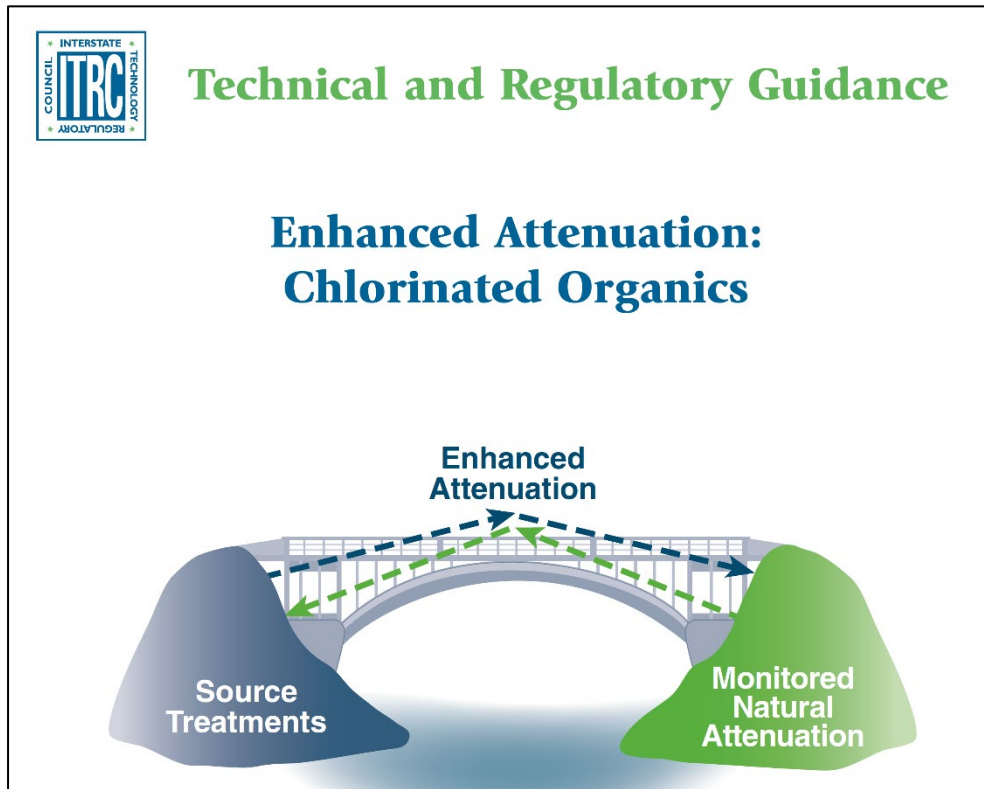
- Many PFAS retention processes produce mass flux “Peak Shaving”
- Similar to flood control reservoirs



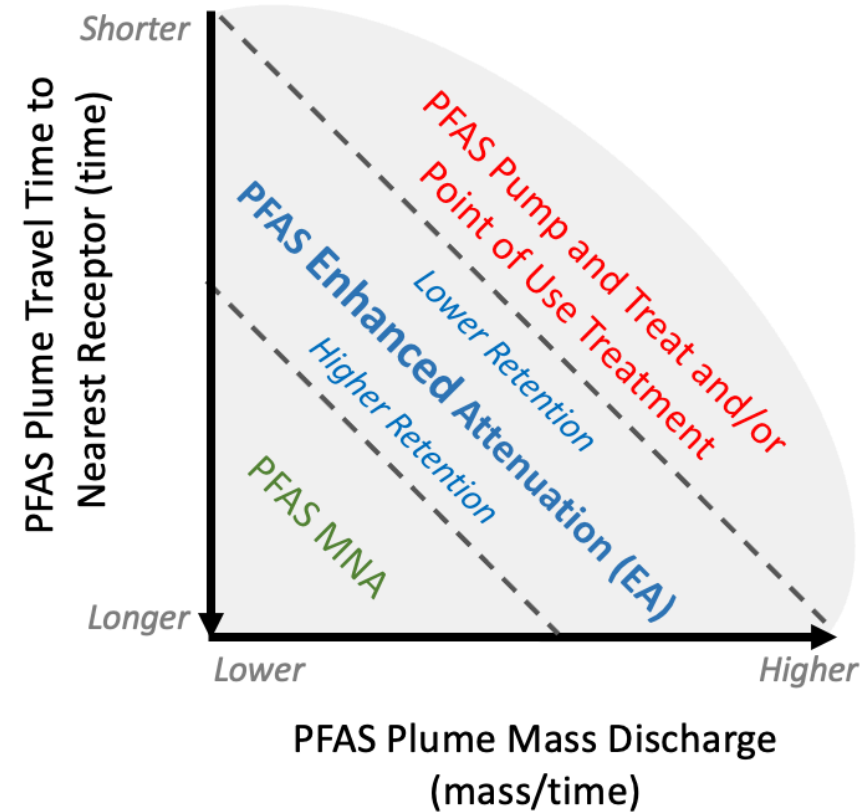
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Enhanced Attenuation guidance
(ITRC, 2008)

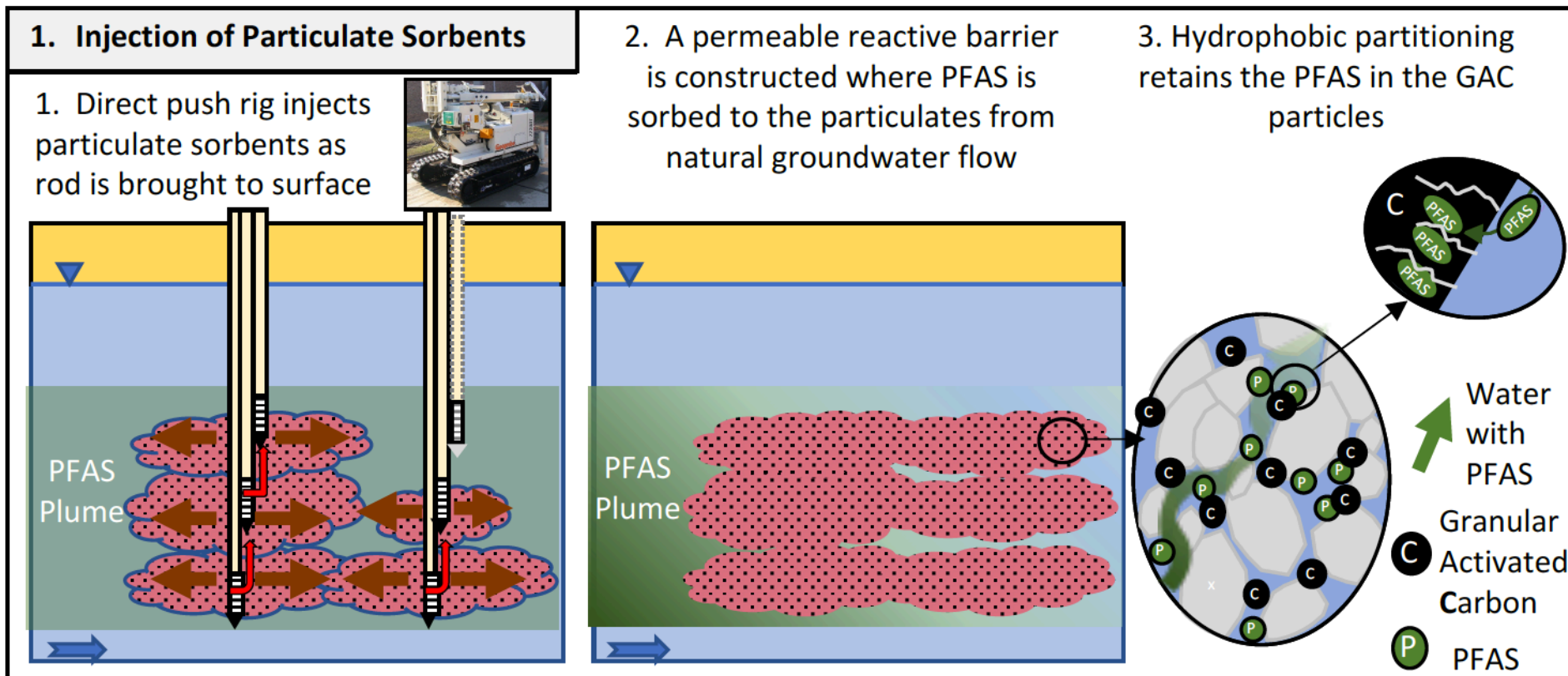


Enhanced Attenuation Framework for PFAS
(Newell et al., in review)

Enhanced Attenuation (EA) – Examples for PFAS

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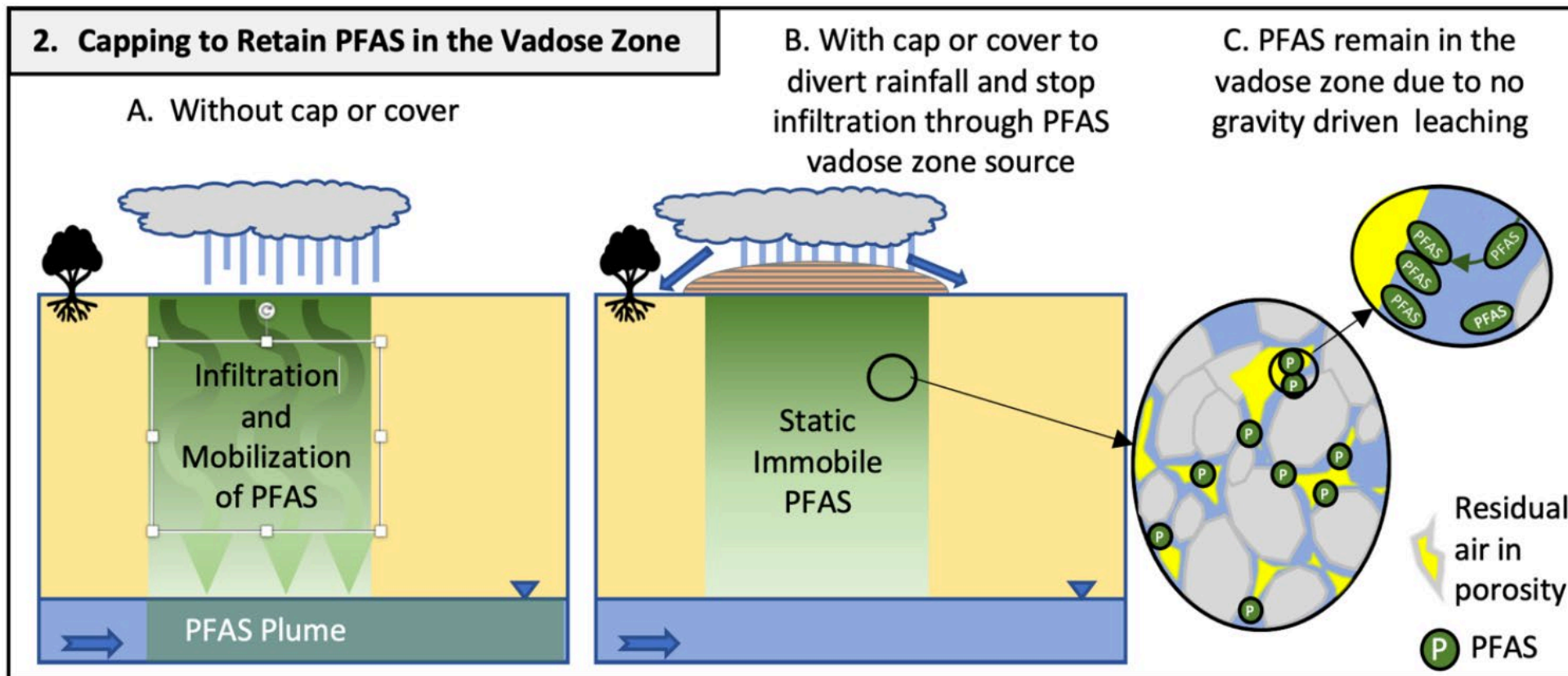


Injection of Particulate Sorbents. **Status: Being Done Now**

Enhanced Attenuation (EA) – Examples for PFAS

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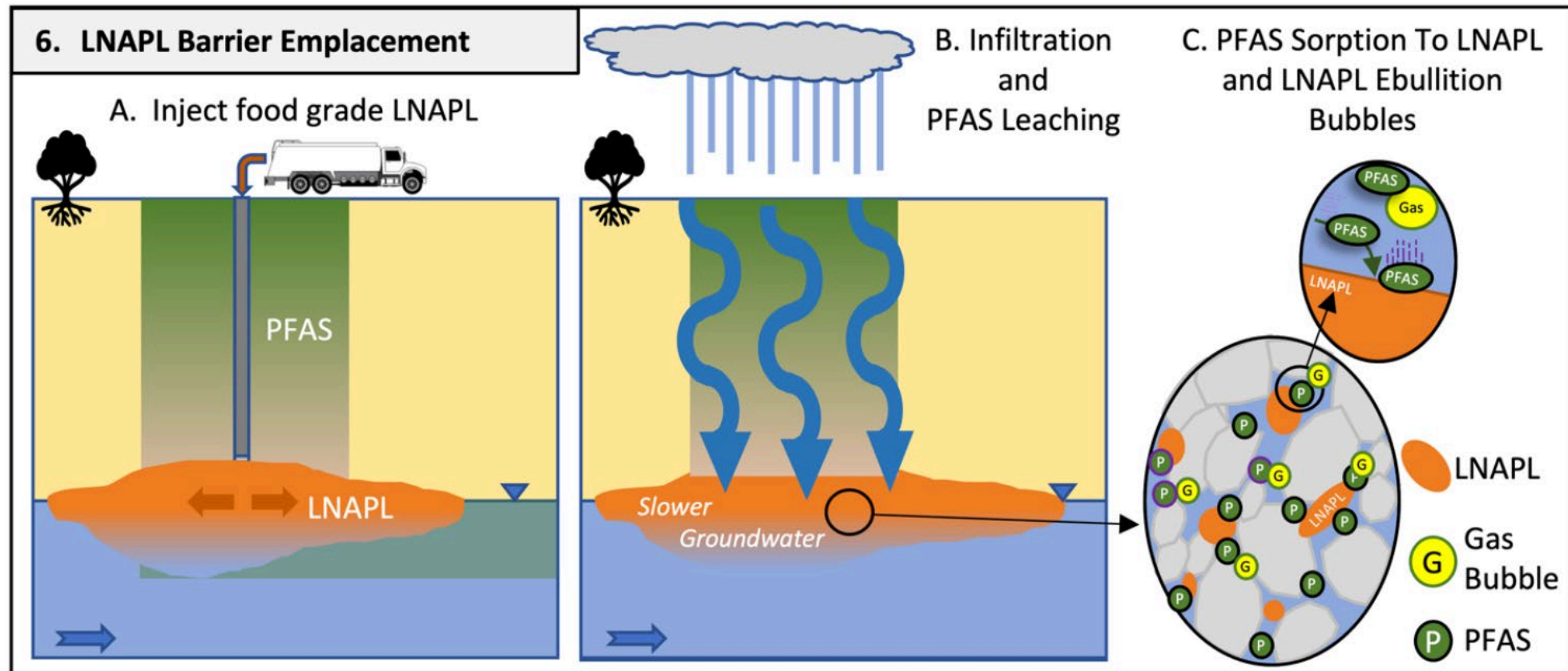


Capping to Increase Retention in the Vadose Zone. **Status: Being Done Now**

Enhanced Attenuation (EA) – Examples for PFAS

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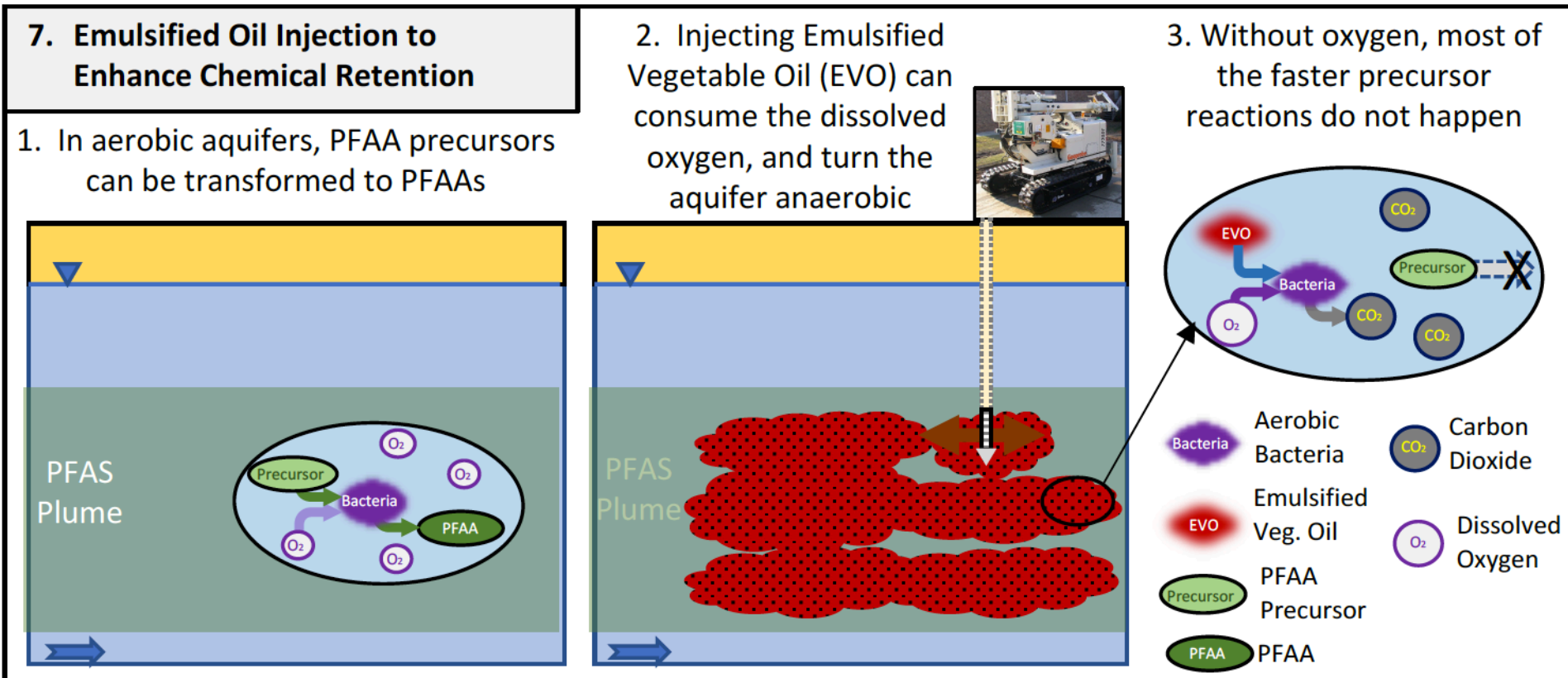


Emplacement of LNAPL Sorption Barrier. **Status: Proposed for Research Project**

Enhanced Attenuation (EA) – Examples for PFAS

Enhanced Attenuation (EA) Processes to Manage PFAS Plumes in Groundwater: Current, Emerging, and Speculative Approaches

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Injection of Emulsified Oil to Enhance Chemical Retention. **Status: Proposed for Research Project**

WRAP UP

- **PFAS in groundwater is a daunting challenge**
- **No proven in-situ PFAS destructive technologies means “not business as usual”**
- **Retention-Based PFAS MNA may be useful for some sites**
 - Sites with long travel time to receptors/compliance point
 - Sites with relatively lower mass flux
- **Data requirements for evaluate MNA and gather lines of evidence are likely to be significant**
- **At other sites, Enhanced Attenuation (EA) approaches may be useful**
- **But time will tell!**

QUESTIONS



