Opportunities for enhanced attenuation of trace organics during infiltration

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Feb 22, 2024
**Nature-based solutions for water treatment and storage**

**Goal:** Purify water while increasing supply in water stressed regions

**Approach:** Develop, study, and optimize nature-based systems with multifaceted treatment (biological and abiotic).

**Opportunities:**
1) Water resource applications
2) Reliable & clean water supply
3) Sustainable: People, planet, & profit
INfiltration

Water Quality Challenges

- TDS/turbidity
- Shifts in redox/pH
- Precipitation (e.g. Fe, Mn)
- Mobilization (e.g. As, U)

Introduction
(e.g. DBPs, Pharma, PFAS)

Attenuation Mechanisms
- physical
- chemical
- biological
Water Quality Challenges

TDS/turbidity

Shifts in redox/pH
Precipitation (e.g. Fe, Mn)
Mobilization (e.g. As, U)

Introduction
Nitrosamines, Pharma, PFAS

Attenuation Mechanisms
physical
chemical
biological
Pharmaceuticals are a ubiquitous class of trace organics associated with water reuse
Disinfection can form carcinogenic (and recalcitrant) byproducts

“It’s tasteless, odorless, and dissolves instantly in water...."

Acute Exposure = Toxin (Homicide ≤ 1.5 grams)

Chronic Exposure = Carcinogen (EPA safe exposure = 0.7 ng/L)
Nature based-solutions offer a sustainable treatment alternative
Can we manage infiltration (and other nature-based systems) to increase biotransformation capabilities?

Image of Orange Country Groundwater Basin: Courtesy of OCWD
The challenge of trace organics and biodegradation

1ppt = ng/L = 1 x 10^{-12}
There are 5 x 10^{10} drops of water in an Olympic size swimming pool

Growth is supported by mg/L or more: How can we select for desirable attributes?
Environmental stress can promote nitrosamine biodegradation

↓ environmental stress = ↑ oxygenases = ↑ biodegradation

Food
Oxygen
Desiccation
Toxicity

Apply this toward antibiotics during simulated infiltration

Spatial profiles reveal increased biodegradation potential

Wet/dry cycles can further influence biodegradation potential

A looming threat for subsurface banked water

- **PFAS = Per- and Polyfluoroalkyl Substances**
  - "Forever chemicals"
  - PFOA = Perfluorooctanoic Acid (C$_8$H$_{15}$O$_2$)
  - PFOS = Perfluorooctane Sulfonate (C$_8$H$_{17}$O$_3$S)

- **Man-made compounds, no natural occurrence**

- **Used since the 1950s in many industrial and municipal applications**
  - Heat resistant/ flame retardant, oil resistant, water resistant

- **Properties which make these compounds useful also result in their persistence in the environment**

- **Varying (and moving target) approaches to regulation of concentration in drinking water at the State and Federal Level**

<table>
<thead>
<tr>
<th>Compound</th>
<th>Proposed MCL</th>
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<tbody>
<tr>
<td>PFOA</td>
<td>4 ppt (ng/L)</td>
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<tr>
<td>PFOS</td>
<td>4 ppt (ng/L)</td>
</tr>
<tr>
<td>PFNA</td>
<td></td>
</tr>
<tr>
<td>PFHxS</td>
<td>1.0 (Hazard Index)</td>
</tr>
<tr>
<td>PFBS</td>
<td></td>
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<tr>
<td>HFPO-DA(GenX0)</td>
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\[
\text{Hazard Index (unitless)} = \frac{\text{PFHxS: } 0 \text{ ppt}}{9.0 \text{ ppt}} + \frac{\text{PFNA: } 0 \text{ ppt}}{10.0 \text{ ppt}} + \frac{\text{HFPO-DA (Gen-X): } 0 \text{ ppt}}{10.0 \text{ ppt}} + \frac{\text{PFBS: } 0 \text{ ppt}}{2000.0 \text{ ppt}}
\]
The good: PFAS can undergo biodegradation

The bad: long time, the more fluorinated (per vs. poly) the more difficult

The ugly: often incomplete, precursors and reformation
Engineer infiltration layers with targeted functions

Deploy a thin layer of activated zeolite (fluorosorb) or analogous sorbent with a lifespan of decades+
Collaborative study underway to explore this for percolation basins

- Upper sediment layers remove: TSS, OM, nuts. & trace organics
- Engineered geomedia is then more effective for targeted sorption of PFAS

MAR w/ media layer

1.) Surface water w/ PFAS
2.) PFAS adsorbed by media
3.) Recharged water w/o PFAS

Native soil
Actively manage and operate these "passive" systems

Acknowledgements and Questions