Update on research activities at WEST center

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WEST center
Water Treatment + (Chem & Bio) Analysis
Contaminants in water

- Chemical origins:
  - Pharmaceuticals
  - Pesticides
  - Industrial chemicals
  - Natural chemicals
  - Personal care products
  - Household chemicals
  - Transformation products

- Microbial origins:
  - Anions
  - Cations
  - Metals
  - Viruses
  - Bacteria
  - Protozoa
  - Helminths
PFASs were detected at or above the MRLs in 4% of public water supplies, serving 16.5 million residents in 33 different states.

<table>
<thead>
<tr>
<th>Agency</th>
<th>Matrix</th>
<th>Contaminant</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. EPA</td>
<td>Drinking water</td>
<td>PFOA &amp; PFOS (Combined or individually) 70 ng/L*</td>
</tr>
</tbody>
</table>

*Lifetime Health Advisory level

**Agency Matrix Contaminant**

- **State**           | **Matrix**                  | **Contaminant**                           |
- Illinois            | Groundwater                 | PFOA – 0.4 µg/L, PFOS – 0.2 µg/L          |
- Maine               | Groundwater                 | PFOA – 0.05 µg/L, PFOS – 0.1 µg/L         |
- Michigan            | Surface Water               | PFOA – 0.42 µg/L, PFOS – 0.012 µg/L       |
- Minnesota           | Drinking Water + Fish Consumption | PFOA – 0.61 µg/L (Lake), PFOA – 0.72 µg/L (River), PFOS – 0.012 µg/L (Lake), PFOS – 0.006 µg/L (River) |
- New Jersey          | Drinking Water              | PFOA – 0.04 µg/L                           |
- North Carolina      | Groundwater                 | PFOA – 2 µg/L                              |

A drop of a compound

10 μL
Density: 1g/mL = 1mg/μL
Mass: 10 mg

How much water do we have to make it 1 ng/L?

10,000,000 L > Volume of water in an Olympic pool (50 m x 25 m x 2 m)

Analytical instruments

Agilent Technologies
Magnetic ion exchange resin (MIEX®) is efficacious to attenuate perfluorinated alkylsubstances (PFASs) such as perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) in groundwater.

- **PFOA**
  - Carboxylic acid group
- **PFOS**
  - Sulfonic acid group

Increase in the chain length of PFASs leads to greater attenuation by MIEX®.
## Treatment technologies for PFAS

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost</th>
<th>Removal Effectiveness</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Activated carbon</td>
<td>$$</td>
<td>PFOA&gt;90%, PFOS&gt;90%</td>
<td>(+) Good removal, (-) Regeneration</td>
<td></td>
</tr>
<tr>
<td>Anion exchange</td>
<td>$$</td>
<td>PFOA = 10-90%, PFOS&gt;90%</td>
<td>(+) Effective for PFOS, (-) Less effective for shorter chain PFCs</td>
<td></td>
</tr>
<tr>
<td>Membrane filtration (RO/NF)</td>
<td>$$$</td>
<td>PFOA&gt;90%, PFOS&gt;90%</td>
<td>(+) Excellent removal, (-) Costly, Brine treatment</td>
<td></td>
</tr>
<tr>
<td>AOP (UV/H₂O₂, UV/S₂O₈²⁻)</td>
<td>$$$</td>
<td>PFOA &lt; 10%, PFOS = 10-50%</td>
<td>(+) can oxidize a multitude of contaminants, (-) Less effective, costly</td>
<td></td>
</tr>
</tbody>
</table>
Evaluation of treatment technologies for PFAS abatement

< Fig. 1 > Rapid small-scale column testing (RSSCT)

< Fig. 2 > Breakthrough of PFASs in a RSSCT testing.
Research proposals

• **WRF 4913 (Drs. Snyder and Park as co-PIs)**, Investigation of Treatment Alternatives for Short-Chain Poly and Perfluoroalkyl Substances, **($300,000)**

• **EPA-G2018-STAR-B1 (Drs. Snyder and Park as co-PIs)**, Practical Methods to Analyze and Treat Emerging Contaminants (PFAS) in Solid Waste, Landfills, Wastewater/Leachates, Soils, and Groundwater to Protect Human Health and the Environment **($900,000)**
The application of MIEX resin to remove organic carbon in water reuse

**8 mL/L resin dose**

**DOC**

**WWTP2**

(6.3 mg/L)

< Removal of trace organic compounds >
• Aromatic humic substances were effectively removed by MIEX®.
• Low molecular weight neutral or acids were attenuated slightly whereas little removal of macromolecules were observed.
PACl-Ceramic membrane application in water

: Ceramic membrane with in-line polyaluminium chloride (PACl) coagulation in water reuse

1. Fouling reduction by PACl

2. Virus reduction

: PACI-Ceramic membrane system is effective for the reduction of MS2 coliphage (>7 LRV)
Chemically enhanced backwashing (CEB): H₂SO₄ + HOCl

TMP after mechanical backwashing

LRV of MS2 phage

PACl-Ceramic membrane application in water reuse
PACi-Ceramic membrane application in water reuse

Univ. of Arizona (Dr. Ikner and Dr. Park)
Various phage Field tests

Dr. Luisa Ikner

Univ. of Tokyo (Dr. Torrey)

Dr. Jason Torrey

Coagulation System Operation
Analysis/Evaluation with indigenous virus

METAWARE
(Yonetani)

Pepper Mild Mottle Virus (PMMoV) consistently occurred in the tertiary effluents over the course of sampling campaigns.

PMMoV was successfully attenuated by META-Hybrid CERA system (>3.44 – 4.78 LRV).
The objective of this project is to evaluate whether commercially available on-line sensor can capture anomaly of reuse treatment processes.

- Ozone-biological activated carbon (BAC) system is in operation.
- Various water qualities such as total organic carbon (TOC), UV absorbance at 254nm, humic substance-like fluorescence, NH$_3$, NH$_2$Cl and turbidity are being monitored.
- Little total organic carbon (TOC) was observed for ozone (6.4 mg O$_3$/L).
- About 30% of TOC reduction was achieved by BAC.
Attenuation of trace organic compounds

Ozone

BAC

Attenuation (%)

Université de Lorraine
Laboratory of Chemistry and Materials (LCM)

GARVER

TRICLOSAN

DICLOFENAC

CARBAMAZEPINE

TRIMETHOPRIM

DITIAZEM

PROPANOLOL

GEMFIBROZIL

TRICLOCARBAN

FLUOXETINE

HYDROCHLOROTHIAZIDE

ATENOLOL

LOPAMIDOL

DEET

BENZOPHENONE

PRIMIDONE

ACESULFAME

PFPA

SIMAZINE

IHOXOL

MEPROBAMATE

LORZEPAM

SUCRALOSE

TCP

PRHVA

PFPE

ACESULFAME
The surrogate model with the on-line fluorescence data was applied to predict TOrC attenuation. Overall, good agreement between the observed and predicted data was achieved except for gemfibrozil.

\[
\ln \left( \frac{[C]}{[C]_0} \right) = \frac{k_{OH}}{k_{OH,S}} \left( 1 + \alpha \right) \ln \left( \frac{[S]}{[S]_0} \right) = \frac{k_{OH}}{K_S} \ln \left( \frac{[S]}{[S]_0} \right)
\]

\[
K_S = \beta \ln \left( 1 + k_{OH} / (k_{OH,R} \cdot R_{CT}) \right)
\]

\( R^2 = 0.82 \) (n=63)

Gemfibrozil excluded

On-line sensor monitoring in water reuse (WRRF 14-01)
Failure testing

5 mg/L NO₂-N spiked

- Ozone influent (OI Analytical 9210)
- Ozone effluent (OI Analytical 9210)
- BAC effluent (OI Analytical 9210)

TOC (mg/L)

12:00 AM 12:00 PM 12:00 AM 12:00 PM
7/7/2018 7/8/2018

E. coli spiked

AWQS

500-700 nm
700-1000 nm
1000-2500 nm
>2500 nm

1:00 AM 6:00 AM 12:00 PM 6:00 PM 12:00 AM
7/18/2018 7/19/2018

Hach PCX

>2 μm
>3 μm
>5 μm

12:00 AM 6:00 AM 12:00 AM 6:00 AM 12:00 AM
7/18/2018 7/19/2018

fDOM signal (gSU)

12:00 AM 6:00 AM 12:00 PM 6:00 PM 12:00 AM
7/7/2018 7/8/2018

PDX count (x10^3)

12:00 AM 6:00 AM 12:00 AM 6:00 AM 12:00 AM
7/18/2018 7/19/2018
Thank you for your attention!