2020 Paul L. Busch Award and Lecture

10/29/2020
## Agenda

<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
</tr>
</thead>
</table>
| 3:00p ET | **Welcome**  
Lola Olabode and Peter Grevatt – The Water Research Foundation |
| 3:03p | **Get to Know Paul L. Busch**  
Doug Owen, Glen Daigger, and Lisa Busch |
| 3:13p | **Testimonials from Past Paul L. Busch Awardees**  
David Sedlak *PLB 2003* and Paul Westerhoff *PLB 2006* |
| 3:18p | **2020 Paul L. Busch Awardee**  
Paul Westerhoff *PLB 2006* |
| 3:20p | **2020 Award Lecture**  
*Toward Selective Solute Separation (S³) for Sustainable Water and Wastewater Treatment*  
Dr. Shihong Lin |
| 3:45p | **Panel Discussion**  
Glen Daigger, David Sedlak and Paul Westerhoff |
| 3:55p | **Congratulations** |
| 3:58p 4:00p | **Adjourn** |
Get to Know
Paul L. Busch
Get to Know Paul L. Busch | Lisa Busch
Testimonials from Past Paul L. Busch Awardees

David Sedlak *PLB 2003* and Paul Westerhoff *PLB 2006*
Impact of 2003 Paul L. Busch Award

David Sedlak, Plato Malozemoff Professor– UC Berkeley

Topic: Trace Organic Contaminants in Municipal Wastewater Effluent

People + Ideas = Change

- Fono
- Mitch
- Kolodziej
- Lim

© 2020 The Water Research Foundation. ALL RIGHTS RESERVED.
Impact of 2006 Paul L. Busch Award
Paul Westerhoff, PhD, PE, BCEE – Arizona State University

Tools to Characterize and Understand the Risk of Biogenic and Commercial Nanomaterials in Wastewater Effluents

Implications

9 university EPA Center

Applications

NSF Nanosystems Engineering Research Center for Nanotechnology Enabled Water Treatment Systems (NEWT)

RICE, ASU, Yale, UTEP
Toward Selective Solute Separation ($S^3$) for Sustainable Water and Wastewater Treatment

Shihong Lin, Vanderbilt University

10/29/2020
The urgent need for engineered solutions to address water scarcity problem
The two types of things we do in water or wastewater (w/ww) treatment

- **Conversion**
  - chemical
  - electro-chem
  - photo-chem

- **Separation**
  - disinfection

**bio-chem**
Common separation processes in w/ww treatment

Drinking water treatment

Secondary clarifier

SWRO plant

(Image source: CDC.gov)

(Image source: Evoqua)

(Image source: Poseidon Water)
**Why separation in w/ww treatment?**

**Remove stuff**
- Bacteria, NOM
- Heavy metals
- Organics

**Retain stuff**
- MF/UF
- Bacteria
- Algae
- PAC

**Concentrate stuff**
- Trace organics
- PFASs
- NF
The rise of membrane separation

Smaller footprint  
Modular  
Reduced chemical use  
Energy efficient*

Focus on this talk
Improving solute separation membranes

- Increase water permeability
- Improve solute rejection

Elimelech and Philip., Science, 2011

Park et.al., Science, 2017
Selective solute separation ($S^3$) as the new frontier of membrane separation

The old art of sieving

but at molecular level

Epsztein et al., Nature Nanotech., 2020
Zooming in on the separation spectrum

Size | 1 Å | 1 nm | 10 | 100 | 1 μm | 10 | 100 | 1 mm
---|---|---|---|---|---|---|---|---
Ro | | | | | | | | |
Uf | | | | | | | | |
Mf | | | | | | | | |
particle filtration | | | | | | | | |

EOPs | NOM | viruses | bacteria | protozoa
---|---|---|---|---
salts | | proteins | |

Emerging Organic pollutants (PFAS, Pharms, ED...)

Monovalent ions

Di/multi-valent ions (Hardness, heavy metals...)

Stokes diameter (Å)
Why precise $S^3$?

Water softening

\[ \text{Na}^+, \text{K}^+ \quad \text{Mg}^{2+}, \text{Ca}^{2+} \]

\[ \text{Na}^+ \quad \text{K}^+ \quad \text{Mg}^{2+} \quad \text{Ca}^{2+} \]

Wastewater reuse

\[ \text{N}, \text{P} \quad \text{M}^{x+}, \text{EOPs} \]

\[ \text{N} \quad \text{P} \]

Process intensification

salt

PFAS

\[ \text{S}^3 \]

\[ \text{salt} \]

\[ \text{PFAS} \]

Resource mining

\[ \text{Li}^+ \]

\[ \text{Li}^+ \]

\[ \text{Mg}^{2+} \]

and more…
Precise $S^3$ and its challenges

- Has been achieved in MF membranes via track-etching.
- But track-etching cannot create sub-nanometer pores for NF.
Interfacial polymerization: the industrial state-of-the-art
Polyamide membrane with sub-1Å precision for S³

Trimesoyl chloride (TMC)

Piperazine (PIP)

Sodium dodecylsulfate (SDS)

Liang et al., Nature Comm., 2020
Can we make $S^3$ more adaptable?

- applicable in multiple scenarios
- accommodate temporal variations in feedwater quality
- control product water quality on demand

*Unlikely with conventional NF process*
Electro-regulated nanofiltration (e-NF)

- Positive vs. negative
- Multivalent vs. monovalent
- Charged vs. neutral

Cheng et al., Nature Nanotech, 2018, 13, 685
Electro-regulated nanofiltration (e-NF)

Conductive mesh

Perforated graphene

Polycarbonate support

Conductive mesh

Carbonized cross-linked PVDF

Carbonized porous PVDF

Cheng et al., Nano Lett., 2020

Koh et al., Science, 2016
Summary

• Selective solute separation (S$^3$) is the new frontier of membrane-based water separation

• Electro-regulated NF (e-NF) can potentially make S$^3$ more adaptable.

• The Paul L. Busch Award will support the development of e-NF and advancing the fundamental understanding of S$^3$. 
Many thanks to

• Paul L. Busch Award Sponsors
• Water Research Foundation

• Mentors (Meny and Mark)

• Lin Research Group

• Yanting, Shiloh, and Charlotte
Panel Discussion

Glen Daigger, David Sedlak and Paul Westerhoff
Congratulations!