ESTRONE AND TEMPERATURE: EFFECTS ON THE PREDATOR-PREY RELATIONSHIP IN FRESHWATER FISH

Victoria Korn
Aquatic Toxicology Laboratory
St. Cloud State University
INTRODUCTION

- Exposure to multiple forms of anthropogenic stress
- Adverse effects: molecular, physiological, behavioral
- Estrogenic pollutants are ubiquitous
- Potential impacts on population dynamics
- Varied susceptibility between species
- Variation in ambient environment
• Estrogenic exposure and temperature will independently or interactively decrease survival rate of larval fathead minnows following predation through an impairment in the predator avoidance response.
EXPOSURE SYSTEMS

Larval static renewal exposure system

Adult flow through exposure system
PREDATOR AVOIDANCE RESPONSE

- High speed camera (1000 frames/s)
- Analyze video for length (mm), latency (ms), velocity (BL/s), angle (degrees), and total escape response (BL/s)
CALCEIN STAINING

Bath treatment: 250 mg/L from 1% stock solution
Duration: 6 hours

Calcein stained larva: 30 days exposure
Caudal fin stained with calcein
Acclimation Period
1.5 hours

Predation Trial
1 hour
Percent survival of larval fathead minnows in competitive predation trials.
Predation success of predatory sunfish (% of total larvae in the trial consumed).
Predator avoidance responses of larvae at 21 days exposure.
Average body length (mm) of larval fathead minnows at 21 days exposure.
RESULTS RECAP

• E1 independently affected larval survival following predation as well as predator success
• Temperature independently affected the predator avoidance response
• No interactive effects or trends to suggest temperature modulation
• Individuals at the larval stage are more susceptible to effects from exposure and temperature fluctuation
DISCUSSION

• Alteration of predator-prey relationships and aquatic food webs
• Survival: Control: 74.2%, E1LOW: 49.2%, E1HIGH: 52.9%
• Similar to past study using estradiol
• Multi-generation population modeling: projected decline
• Mitigation of effects on larvae through reduced predator success
SIGNIFICANCE

- Risk assessment
- Ecological management plans
- Identification of vulnerable populations
- Prediction of population dynamics in real world settings
ACKNOWLEDGEMENTS

Jessica Ward and Heiko Schoenfuss: experimental design and data analysis

Members of the SCSU aquatic toxicology laboratory

Funding by the Minnesota Environment and Natural Resources Trust Fund (Grant M.L. 2014, Chp. 226, Sec. 2, Subd. 03d)
QUESTIONS??
Micropollutants in Groundwater and Soil at Wastewater Land Application Sites

Sarah M. Elliott, Melinda L. Erickson, and Aliesha L. Krall

U.S. Geological Survey

Byron A. Adams

MN Pollution Control Agency
Some Definitions

- **Land Application Site Types**
  - Large subsurface treatment systems (LSTS)
    - Small communities
  - Rapid infiltration basins (RIB)
    - Municipalities
    - Allow rapid infiltration of wastewaters into soils & groundwater

- **Micropollutants**
  - Contaminants of emerging concern (pharmaceuticals, personal care products, etc.)
Problem & Significance

- Micropollutants detected in surface waters upstream of point sources
  - What are other important sources?

- Many micropollutants can move through septic treatment untreated
  - Source to surface waters?
  - Contamination of downgradient drinking wells?

Carrera et al., 2008
Problem & Significance

In Minnesota:

- **LSTS**
  - ~125 large (1 MGY)
  - 1,000’s more mid-size & smaller systems

- **RIB**
  - 30 large
  - 20 other

USGS
Objectives

Objective - Determine occurrence of micropollutants in:

(a) shallow groundwater near 7 on-site treatment facilities (LSTS/RIB)

(b) soil at one land application site irrigating with domestic septage
Objective (a):

Determine the occurrence of micropollutants in shallow groundwater near 7 LSTS/RIB facilities
Objective (a) - Methods

- 5 LSTS and 2 RIB facilities
  - One downgradient well per site
  - Three sample events

- Chemical analyses
  - Physical water quality parameters
  - Nutrients – MDH
  - Ions – MDH
  - Pharmaceuticals (109) – USGS NWQL
  - Other wastewater indicators (67) – USGS NWQL
  - Sterols & hormones (20) – USGS NWQL
  - Antibiotics & Pharmaceuticals (33) – USGS KS OGRL
Facility Locations

Generalized On-Site Wastewater Treatment System Layout

- **LSTS**
- **RIB**
- **community wastewater**
- **municipal wastewater**
- **septic tank**
- **drainfield**
- **infiltration basin**
- **pretreatment pond**
- **groundwater flow direction**
- **sampled downgradient monitoring well**

**Static water level 2 - 40 ft**

**FIGURE NOT TO SCALE**
LSTS/RIB Results

- 34 micropollutants detected at least once
  - Pharmaceuticals (19), flame retardants, pesticides, industrial chemicals
- Mixtures of 2 – 26 micropollutants in all samples
- Sulfamethoxazole was detected in ALL samples (7 – 965 ng/L)
LSTS/RIB Results

LSTS - A

LSTS - B

LSTS - C

LSTS - D

LSTS - E

RIB - F

RIB - G

Number of detections

Number of detections

Number of detections

Number of detections

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 May-15 Aug-15

0
5
10
15
20
25
Sep-14 Jun-15 Aug-15

Other
Pharmaceuticals
Pesticides
P flame retardants

Erickson et al. (submitted)
Comparison to MN Ambient Groundwater

- Methyl-1H-benzotriazole (BTA)
- Carbamazepine (CBZ)
- N,N-Diethyl-meta-toluamide (DEET)
- Fluconazole (FLC)
- Lidocaine (LID)
- Sulfamethoxazole (SMX)
- Tris(2-chloroethyl) phosphate (TCEP)
- Tris(dichloroisopropyl) phosphate (TDCPP)

Erickson et al. (submitted)
Prioritization/Screening Assessment

Aquatic Health

- Water quality criteria lacking
- Prioritization scores (Berninger et al., 2016)
  - Scores range 1 to 10
  - Based on adsorption, metabolism, elimination in mammals

Human Health

- MDH Pharmaceutical Rapid Assessment Screening Values (Suchomel et al., 2015)
- Concentration consumed daily with no anticipated health risk
- Not based on toxicological data so lower values = more conservative
Prioritization Assessment - Surface Water

Prioritization rank scores from Berninger et al. (2016)
## Screening Assessment – Human Health

*Screening values (SV) from Minnesota Department of Health (Suchomel et al., 2015)*

<table>
<thead>
<tr>
<th>Pharmaceutical</th>
<th>Common Use</th>
<th>Facility</th>
<th>Average annual discharge, MG</th>
<th>Average Total Sample SV ratio</th>
<th>Concentration/SV ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alprazolam</td>
<td>anti-anxiety</td>
<td>LSTS – D</td>
<td>5.4</td>
<td>0.76</td>
<td>0.02 – 0.08</td>
</tr>
<tr>
<td>Meprobamate</td>
<td>anti-anxiety</td>
<td>LSTS – B</td>
<td>5.1</td>
<td>0.31</td>
<td>0.04 – 0.07</td>
</tr>
<tr>
<td>Warfarin</td>
<td>blood thinner</td>
<td>RIB – F</td>
<td>83</td>
<td>0.55</td>
<td>0.01 – 0.59</td>
</tr>
<tr>
<td>Carbamazepine</td>
<td>anticonvulsant</td>
<td>LSTS – A</td>
<td>2.3</td>
<td>0.08</td>
<td>0.02 – 0.31</td>
</tr>
<tr>
<td>Metformin</td>
<td>antidiabetic</td>
<td>LSTS – C</td>
<td>3.9</td>
<td>0.05</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Glyburide</td>
<td>antidiabetic</td>
<td>LSTS – E</td>
<td>4.2</td>
<td>0.04</td>
<td>0.02 – 2.4</td>
</tr>
<tr>
<td>Fluconazole</td>
<td>antifungal</td>
<td>LSTS – D</td>
<td>5.4</td>
<td>0.76</td>
<td>0.02 – 0.08</td>
</tr>
<tr>
<td>Carisoprodol</td>
<td>muscle relaxant</td>
<td>LSTS – C</td>
<td>3.9</td>
<td>0.05</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Sulfamethoxazole</td>
<td>antibiotic</td>
<td>LSTS – E</td>
<td>4.2</td>
<td>0.04</td>
<td>0.02 – 2.4</td>
</tr>
<tr>
<td>Tramadol</td>
<td>pain reliever</td>
<td>LSTS – E</td>
<td>4.2</td>
<td>0.04</td>
<td>&lt;0.01 – 0.03</td>
</tr>
<tr>
<td>Temazepam</td>
<td>sleep aid</td>
<td>RIB – G</td>
<td>2.1</td>
<td>0.04</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Average Facility Total Concentration/SV ratio range:
- LSTS – D: 0.02 – 0.08
- RIB – F: 0.01 – 0.59
- LSTS – B: 0.02 – 0.05
- LSTS – A: 0.02 – 0.31
- LSTS – C: <0.01
- LSTS – E: 0.02 – 2.4
Objective (b): Determine the occurrence of micropollutants in soil at one land application site.
Objective (b) - Methods

1 agricultural field – irrigates with domestic septage

Soil

- 4 sample locations
- 1 sample event
- Chemical analyses
  - Other wastewater indicators
  - Sterols & hormones
  - Antibiotics & pharmaceuticals
Agricultural Field Results

- 32 micropollutants detected in soil
  - Fragrances, bisphenol A, PAHs, etc.
  - More hormones and sterols detected relative to other analyzed chemicals
  - Carbamazepine, ciprofloxacin, ofloxacin in all samples
  - Ciprofloxacin and ofloxacin in mg/kg range
Agricultural Field Results - Soil

Wastewater indicators

Concentration, micrograms per kilogram

ACET  AHTN  AQ  BaP  BPA  CARB  DNAP  FLU  IND  ISO  MP  OP  PYR  SKAT  TCS

32 number of values
90th percentile
75th percentile
50th percentile
25th percentile
10th percentile
Agricultural Soil

USGS
Summary

- 34 micropollutants detected in groundwater near LSTS/RIB facilities, mostly pharmaceuticals
- Some detections/concentrations of potential concern to aquatic and human health
- Soils receiving wastewater may be a repository for some organic contaminants
- More research on fate & transport needs to be conducted to better understand how these BMPs contribute to contaminant load to environment
Acknowledgements

- **Funding**
  - State of Minnesota Clean Water Fund
  - USGS Cooperative Matching Fund

- **Daniel Morel and Brent Mason, sampling**

- **Facility owners and operators**
Questions?

Sarah Elliott
selliott@usgs.gov
PFAS Trends in Environmental Media and Facility Management Considerations to Limit Future Liabilities

18 October 2017

Shalene Thomas, Amec Foster Wheeler
Hannah Albertus-Benham, Amec Foster Wheeler
Outline

1. Introduction and Background: The Concern
   ► What are Emerging Contaminants?
   ► Why are they different?
   ► PFAS: what are they and where are they used?

2. The Response: PFAS Case Study
   ► Regulatory Landscape and overview
   ► Case Study Summary
   ► Facility Management Considerations

3. Summary
PFAS – General overview

What are Emerging Contaminants?

Why are they different?

What is the concern?

Federal and State Programs
What is an emerging contaminant?

DoD and EPA definitions generally state:

1. Presents potential unacceptable risk
2. Has no published standard
3. New science, detection, or exposure pathway available\(^1,2,3\)

---

1. DoD Instruction 4715.18, *Emerging Contaminants*, June 11, 2009. DUSD (I&E) is Deputy Under Secretary of Defense for Installation and Environment
2. EPA Federal Facilities Restoration and Reuse Office:
   [http://www.epa.gov/fedfac/documents/emerging_contaminants.htm#additional_ec](http://www.epa.gov/fedfac/documents/emerging_contaminants.htm#additional_ec)
List of Emerging Contaminants

Department of Defense Emerging Contaminants

- Naphthalene
- Beryllium
- Hexavalent Chromium (HC)
- Sulfur Hexafluoride (SF₆)
- Phthalate
- Lead
- RDX

EPA Office of Water Contaminants of Emerging Concern

- Pharmaceuticals and Personal Care Products
- Polybrominated diphenyl ethers (PBDEs)
- Perfluorinated compounds (PFCs)

PBDEs
A Moving Target; Why Concerned?

Persistent, Bioaccumulative, Toxic

Use and Contamination is Widespread

Regulatory and Legal Actions Rising

Risk Review, Management, Mitigation
Federal and State EC Programs

- **Safe Drinking Water Act (SDWA)**
- **Unregulated Contaminant Monitoring Rule (UCMR)**
- **Center for Disease Control and Prevention (CDC)**
- **National Health and Nutrition Examination Survey (NHANES)**
- **State Biomonitoring Cooperative Agreement**
- **Seven States with Specific Risk Management Programs Addressing Emerging Contaminants**
  - WA, AZ, MN, NY, ME, VT
What are PFAS?

Fluorinated Substances

Perfluoroalkyl substance

i.e. FTOH

i.e. 8:2 FTOH

Polyfluoroalkyl substance

Perfluoroalkyl substance (formerly PFCs)

i.e. PFOA

i.e. PFOS

PFCA

PFSA

Fluorinated Substances

Precurors

Note:
This is a simplified representation of fluorinated substance sub-classes and in no way represents the entire fluorinated substances class

## Uses/Sources

<table>
<thead>
<tr>
<th>Oil and Gas Extraction</th>
<th>Electroplating (mist suppressants)</th>
<th>Manufacturing Processes/Intermediates/By-products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer Products</td>
<td>Semiconductor Industry</td>
<td>Aqueous film forming foams</td>
</tr>
</tbody>
</table>

© Amec Foster Wheeler 2017.
The Response: Perspectives for PFAS

- Regulatory Landscape
- Case Study
- Facility Management
### US Water Criteria

<table>
<thead>
<tr>
<th>Concentration (ug/L, ppb)</th>
<th>PFOA</th>
<th>PFOS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>US EPA</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USEPA</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>0.4***</td>
<td>0.4***</td>
</tr>
<tr>
<td><strong>US by State</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alaska (AK)*</td>
<td>0.40</td>
<td>0.40</td>
</tr>
<tr>
<td>Connecticut (CT)</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Delaware (DE)</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Iowa (IA)*</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Maine (ME)</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td></td>
<td>0.13</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>0.05</td>
<td>1.2</td>
</tr>
<tr>
<td>Michigan (MI)*</td>
<td>0.42</td>
<td>0.011</td>
</tr>
<tr>
<td></td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>Minnesota (MN)**</td>
<td>0.035</td>
<td>0.027</td>
</tr>
<tr>
<td>Nevada (NV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Hampshire (NH)*</td>
<td>0.07</td>
<td>0.07</td>
</tr>
<tr>
<td>New Jersey (NJ)</td>
<td>0.014**</td>
<td></td>
</tr>
<tr>
<td>North Carolina (NC)*</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Oregon (OR)*</td>
<td>24</td>
<td>300</td>
</tr>
<tr>
<td>Texas (TX)*</td>
<td>0.29</td>
<td>0.56</td>
</tr>
<tr>
<td>Vermont (VT)*</td>
<td>0.02</td>
<td>0.02</td>
</tr>
</tbody>
</table>

### NOTES

1= drinking water  
2= groundwater  
3= recreational water  
4= surface water

* = Promulgated rule (AK, IA, MI, NH, NC, OR, TX, VT)  
** = Promulgation anticipated, proposed or recommended (MN, NJ)  
***= Calculated using the EPA RSL calculator

### OTHER NOTABLES

- 70% of the states adopted criteria within the last 2 yrs
- Several states have adopted criteria for other PFAS  
  - CT, DE, MN, NV, NJ, OR, and TX
- CERCLA 5-Year reviews serving as Site “Re-Openers”
- Administrative Orders from EPA despite promulgated rule
- States have adopted Emergency Rules
- Site Clean-Up Goals vary broadly
## International Water Criteria

<table>
<thead>
<tr>
<th>Concentration (ug/L, ppb)</th>
<th>PFOA</th>
<th>PFOS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>International</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>health-based</td>
<td>0.56</td>
<td>0.07</td>
</tr>
<tr>
<td>health-based</td>
<td>5.6</td>
<td>0.7</td>
</tr>
<tr>
<td>Canada</td>
<td></td>
<td></td>
</tr>
<tr>
<td>screening value</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>Denmark</td>
<td></td>
<td></td>
</tr>
<tr>
<td>screening value</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td></td>
</tr>
<tr>
<td>health-based</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>administrative</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Italy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>health-based</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>screening value</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td></td>
<td></td>
</tr>
<tr>
<td>health-based</td>
<td></td>
<td>0.53</td>
</tr>
<tr>
<td>administrative</td>
<td></td>
<td>0.0053</td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
<td></td>
</tr>
<tr>
<td>health-based</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>administrative</td>
<td></td>
<td>0.09</td>
</tr>
<tr>
<td>UK</td>
<td></td>
<td></td>
</tr>
<tr>
<td>health-based</td>
<td>10</td>
<td>0.3</td>
</tr>
<tr>
<td>admin. Level 1</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>admin. Level 2</td>
<td>10</td>
<td>1.0</td>
</tr>
<tr>
<td>admin. Level 3</td>
<td>90</td>
<td>9</td>
</tr>
</tbody>
</table>

### NOTES

1= drinking water  
2= recreational water  
3= freshwater

### OTHER NOTABLES

- Most countries adopted criteria earlier than US (2006-2014)
- Several countries have adopted criteria for other PFAS  
  - Australia, Canada, Denmark, Italy, Sweden
- Substantial variability across countries  
- Several countries are re-evaluating criteria  
- Stockholm convention has been a primary driver
The Impetus for Change:

**Driver: DoD Policies**

Guidance established in 2012 with policies published through 2017

---

**Driver: USEPA Health Advisories**

2009 Provisional Health Advisory

2016 Final Lifetime Health Advisory

Outcome:
- Criteria dropped an order of magnitude
- Site Re-openers
- Expanded Plumes

---

**Driver: Social Momentum & Risk Perception**
The Case Study: Data Summary

- Over 100 US DoD Installations in our PFAS program
- TODAY’S FOCUS
  - 22 Installations
  - 125 potential PFAS release areas of AFFF
  - 405 soil borings
  - 769 monitoring wells

AFFF = Aqueous Film Forming Foam
Media and Constituents

7 Media of Concern

- Soil
- Groundwater
- Stormwater
- Porewater
- Sediment
- Surface water
- Fish tissue

3 Functional Groups

- 11 PFCAs
- 2 FTSs
- 3 PFSAs

<table>
<thead>
<tr>
<th>Short name</th>
<th>Formula</th>
<th>PFAS constituent (16)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFBA</td>
<td>C₄HF₇O₂</td>
<td>Perfluorobutanoic acid</td>
</tr>
<tr>
<td>PFPeA</td>
<td>C₅HF₉O₂</td>
<td>Perfluoropentanoic acid</td>
</tr>
<tr>
<td>PFBS</td>
<td>C₄F₉SO₃H</td>
<td>Perfluorobutanesulfonic acid</td>
</tr>
<tr>
<td>PFHxA</td>
<td>C₆HF₁₁O₂</td>
<td>Perfluorohexanoic acid</td>
</tr>
<tr>
<td>PFHpA</td>
<td>C₇HF₁₃O₂</td>
<td>Perfluoroheptanoic acid</td>
</tr>
<tr>
<td>PFHxS</td>
<td>C₆F₁₃SO₃H</td>
<td>Perfluorohexanesulfonic acid</td>
</tr>
<tr>
<td>6:2 FTS</td>
<td>C₈H₅F₁₃SO₃</td>
<td>6:2 Fluorotelomer sulfonate</td>
</tr>
<tr>
<td>PFOA</td>
<td>C₈HF₁₅O₂</td>
<td>Perfluorooctanoic acid</td>
</tr>
<tr>
<td>PFOS</td>
<td>C₈F₁₇SO₃H</td>
<td>Perfluorooctanesulfonic acid</td>
</tr>
<tr>
<td>PFNA</td>
<td>C₉HF₁₇O₂</td>
<td>Perfluoronanoic acid</td>
</tr>
<tr>
<td>PFDA</td>
<td>C₁₀HF₁₉O₂</td>
<td>Perfluorodecanoic acid</td>
</tr>
<tr>
<td>8:2 FTS</td>
<td>C₁₀H₅F₁₇SO₃</td>
<td>8:2 Fluorotelomer sulfonate</td>
</tr>
<tr>
<td>PFUnA</td>
<td>C₁₁HF₂₁O₂</td>
<td>Perfluoroundecanoic acid</td>
</tr>
<tr>
<td>PFDoA</td>
<td>C₁₂HF₂₃O₂</td>
<td>Perfluorodecanoic acid</td>
</tr>
<tr>
<td>PFTrDA</td>
<td>C₁₃HF₂₅O₂</td>
<td>Perfluorotridecanoic acid</td>
</tr>
<tr>
<td>PFTeDA</td>
<td>C₁₄HF₂₇O₂</td>
<td>Perfluorotetradecanoic acid</td>
</tr>
</tbody>
</table>
## Data Summary

### Summary data for 22 installations

<table>
<thead>
<tr>
<th>Samples</th>
<th># of samples</th>
<th>PFOS detects</th>
<th>Median / Maximum (ppb)</th>
<th>PFOS &gt;HA</th>
<th>PFOA detects</th>
<th>PFOA detectd (ppb)</th>
<th>Median / Maximum (ppb)</th>
<th>PFOA &gt;HA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil samples</td>
<td>1562</td>
<td>60%</td>
<td>32.4 / 108,000</td>
<td>NA</td>
<td>45%</td>
<td>0.514 / 697</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>GW samples</td>
<td>1381</td>
<td>75%</td>
<td>0.050 / 7150</td>
<td>34%</td>
<td>67%</td>
<td>0.011 / 21.5</td>
<td>30%</td>
<td></td>
</tr>
<tr>
<td>Stormwater samples</td>
<td>80</td>
<td>96%</td>
<td>0.231 / 3.70</td>
<td>55%</td>
<td>68%</td>
<td>0.013 / 0.033</td>
<td>16%</td>
<td></td>
</tr>
<tr>
<td>Porewater samples</td>
<td>40</td>
<td>98%</td>
<td>0.052 / 4.30</td>
<td>83%</td>
<td>93%</td>
<td>0.011 / 0.052</td>
<td>85%</td>
<td></td>
</tr>
<tr>
<td>Sediment samples</td>
<td>123</td>
<td>76%</td>
<td>8.64 / 984</td>
<td>NA</td>
<td>47%</td>
<td>0.289 / 24.4</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Surface water samples</td>
<td>119</td>
<td>97%</td>
<td>0.138 / 2.40</td>
<td>67%</td>
<td>91%</td>
<td>0.0028 / 0.037</td>
<td>35%</td>
<td></td>
</tr>
<tr>
<td>Fish tissue samples</td>
<td>17</td>
<td>100%</td>
<td>59.1 / 457</td>
<td>NA</td>
<td>35%</td>
<td>0.576 / 1.28</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>

*High frequency of detections for PFOS and PFOA*
All installations compound highlights

- PFSAs account for most of the mass
- Accumulated mass resides at GW-SW interface in pore water and sediment
- Some PFAS bioaccumulate in fish filet
All Installations- Aqueous Media

**Groundwater**
- 6:2 FTS highest in groundwater

**Stormwater**
- PFHxS and PFOS dominate in ST, PW SW

**Porewater**
- Low and mid-range C chain lengths dominate

**Surfacewater**
- Widespread low-level detections in SW

© Amec Foster Wheeler 2017.
All installations SO, SD, FT

- Longer chain compounds present in solid media
- PFOS, PFHxS dominate SO and SD
- PFOS 100X other PFAS in fish tissue
Managing and Mitigating Liability

- **Active Remediation Considerations**
  - Oxidation of precursors
  - Soil excavation
  - Reinjection

- **Construction/Demolition**
  - Soil management
  - Air translocation
  - Dewatering considerations

---

<table>
<thead>
<tr>
<th>Sampled Media</th>
<th># of samples</th>
<th>PFOS Frequency of Detects</th>
<th>PFOS Median / Maximum (ppb)</th>
<th>PFOA Frequency of Detects</th>
<th>PFOA Median / Maximum (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil samples</td>
<td>1562</td>
<td>59.70%</td>
<td>32.4 / 108,000</td>
<td>44.60%</td>
<td>2.60 / 1,450</td>
</tr>
<tr>
<td>Groundwater samples</td>
<td>1363</td>
<td>74.50%</td>
<td>0.050 / 7150</td>
<td>66.30%</td>
<td>0.05 / 3,820</td>
</tr>
</tbody>
</table>

---

Managing and Mitigating Liability

➢ Wastewater and Management
  • Water treatment, containment, reuse/discharge
  • Biosolids management/ reuse

➢ Water reuse
  ✓ Source?
  ✓ Construction (compaction, dust suppression)
  ✓ Irrigation (grounds, golf course)

5 Xindi C. Hu et al. Detection of Poly- and Perfluoroalkyl Substances (PFASs) in the U.S. Drinking Water Linked to Industrial Sites, Military Fire Training Areas, and Wastewater Treatment Plants, Environmental Science and Technology Letters (August 2016), 3, 344-350, DOI: 10.1021/asc.astlett.6b00260
6 U.S. Environmental Protection Agency FACT SHEET, Perfluorochemical (PFC) Contamination of Biosolids Near Decatur, Alabama, March 2011
7 http://www.afcec.af.mil/News/Article-Display/Article/466187/air-force-earth-day-2013-emphasis-on-water-conservation
Managing and Mitigating Liability

- **Stormwater**
  - >95% detection across samples collected
  - Non-point source contribution
  - Management via
    - passive treatment
    - collection and treatment
    - retention

- **Investigation-Derived Waste (IDW) Management**
  - Currently being maintained on property
  - Staged until later date
  - Liabilities minimized by storing on-site
  - Some disposal facilities refusing to accept.

- **AFFF Foam**
  - Consider entire life cycle
    - Procurement
    - Management of wastewater during testing and flushing
    - Disposal practices

<table>
<thead>
<tr>
<th>Sampled Media</th>
<th># of samples</th>
<th>PFOS Frequency of Detects</th>
<th>PFOS Median / Maximum (ppb)</th>
<th>PFOA Frequency of Detects</th>
<th>PFOA Median / Maximum (ppb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater samples</td>
<td>80</td>
<td>96.30%</td>
<td>0.140 / 3.70</td>
<td>67.50%</td>
<td>0.040 / 0.940</td>
</tr>
</tbody>
</table>
The “take-home messages”…

1. Keep one eye open- the PFAS regulatory framework is evolving quickly

2. Science is not always driving decisions

3. Evaluate and manage liabilities proactive to avoid unintended consequences
Upcoming Conferences
- AEHS, Amherst MA- Oct 16-19
- SETAC Annual Conference, Minneapolis MN- Nov 16-18
- Battelle Chlorinated Conference, Palm Springs, CA –April 8-12

Industry Publications
- NGWA: Groundwater and PFAS: State of Knowledge and Practice- due out Fall 2017
- ITRC: PFAS Fact Sheets- 6 in total before the end of 2017
Questions?

Thank you

Shalene Thomas, MS, PMP
Emerging Contaminants Program Manager
Wood dba Amec Foster Wheeler
800 Marquette Avenue, #1200
Minneapolis, MN 55402
T – 612-252-3697
M – 612-490-7606
shalene.thomas@amecfw.com
www.amecfw.com/ec

Hannah Albertus-Benham,
Water Resources & Environmental Engineer
Wood dba Amec Foster Wheeler
800 Marquette Avenue, #1200
Minneapolis, MN 55402
T – 612-252-3657
M – 605-222-7609
hannah.albertus@amecfw.com
Pollutant Stress in the Maumee River: Impacted Physiology and Reproduction in Fathead Minnow (*Pimephales promelas*) and Sunfish (*Lepomis* spp.)

Nicholas Cipoletti, Heiko L. Schoenfuss
St. Cloud State University
Aquatic Toxicology Laboratory

In collaboration with US Fish & Wildlife Service and US Geological Survey
Maumee River

Land use - agricultural to urban gradient.

Identified as a heavily polluted tributary to the Great Lakes.

Thomas et al., 2017
Study Objective

How do differing aquatic inputs across a gradient of land use impact the physiological, organismal, and population level of the Fathead Minnow and Sunfish?

Upstream (Agricultural)  ➔  Downstream (Urban)
Upstream Sampling Sites
Downstream Sampling Sites
Maumee

- 21 day FHM exposure - static daily water renewal
- Resident sunfish collection and caged sunfish deployment (14 day)
- 21 day larval FHM exposure
- ELISA hormone analysis
Sites ranked by mean concentration for each detected chemical (1 lowest concentration to 9 highest concentration).
Water Chemistry

Sites most influenced by wastewater effluent.

Contaminant Rank vs. Treatment

BLK GRM BCR FMP PBG USC SCR TWP MIX

Upstream Downstream

http://www.toledoblade.com/image/2014/08/09/10n1plant-4.jpg
Fathead Minnow Fecundity

FATHEAD MINNOW FECUNDITY - MAUMEE 2016

CUMULATIVE MEAN # EGGS SPAWNED/FEMALE/DAY

TREATMENT DAY

0 5 10 15 20 25 30

0 5 10 15 20 25 30

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Upstream Sites

Downstream Sites
Larval Fathead Minnow

Predator Avoidance Behavior:
- Latency
- Escape Velocity
- Escape Angle
- Total Escape Response

Apical Endpoints:
- Feeding Efficiency
- Growth
- Survival

No significant effects for all variables.
Sunfish: Blood Glucose
Caged Sunfish

Mean Glucose vs. Treatment (Caged Sunfish)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>GRM</th>
<th>BCR</th>
<th>FMP</th>
<th>PBG</th>
<th>USC</th>
<th>SCR</th>
<th>TWP</th>
<th>BLN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
<td>140</td>
</tr>
</tbody>
</table>

Statistically different means indicated by differing letters.

Resident Sunfish

Mean Glucose vs. Treatment (Resident Sunfish)

<table>
<thead>
<tr>
<th>Treatment</th>
<th>GRM</th>
<th>BCR</th>
<th>FMP</th>
<th>PBG</th>
<th>USC</th>
<th>SCR</th>
<th>TWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>0</td>
<td>20</td>
<td>40</td>
<td>60</td>
<td>80</td>
<td>100</td>
<td>120</td>
</tr>
</tbody>
</table>

Statistically different means indicated by differing letters.

Upstream → Downstream
Sunfish: Hepatosomatic Index

Caged Sunfish

Resident Sunfish

Statistically different means indicated by differing letters.
Resident Sunfish: Gonadosomatic Index

Mean GSI vs. Treatment (Resident Sunfish)

Statistically different means indicated by differing letters.

Upstream  →  Downstream
Male Fathead Minnow: Condition Factor

<table>
<thead>
<tr>
<th>Treatment</th>
<th>BLK</th>
<th>GRM</th>
<th>BCR</th>
<th>FMP</th>
<th>PBG</th>
<th>USC</th>
<th>SCR</th>
<th>IWP</th>
<th>MIX</th>
</tr>
</thead>
<tbody>
<tr>
<td>BCF</td>
<td>0.00</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Statistically different means indicated by differing letters.

Upstream → Downstream
Discussion

Varied water chemistry depicts a system with multiple inputs from both known (effluent) and unknown (runoff) sources.

Alterations to FHM fecundity and body condition factor represent a complex river system with varying inputs.

Sunfish indices (glucose, HSI, GSI) detail the importance of entire life-cycle exposure due to strong upstream to downstream trends (glucose) and individual site effects (HSI, GSI)
Impacts

Potential improper re-direction of energy stores at a critical energy-intensive period of reproduction.

Alterations to reproduction and reproductive indices could lead to population dynamic changes.

Most pronounced effects observed on resident sunfish, those which were exposed their entire life.
Acknowledgements

Thanks to our collaborators:
St. Cloud State University – Aquatic Toxicology Laboratory