Research Update: Nutrient Management and Control

Daniel J. Murray, Jr., P.E., BCEE
Senior Environmental Engineer
U.S. EPA, Office of Research and Development
National Risk Management Research Laboratory
Water Systems Division
Cincinnati, Ohio

June 7, 2018
Presentation Outline

• U.S. EPA, ORD Overview
• Research Plans – Safe and Sustainable Water Program
• Project Examples:
  • Green Infrastructure Performance Monitoring
  • LCA of Nutrient Control Technologies
  • Nutrient Control Design Manual
• Accessing Research Results and Tools
Our Mission

Provide the science, technical support, technology, and tools to inform EPA's mission to protect public health and the environment.
How ORD Develops its Research Programs

1. Strategic Research Action Plans
   - National Research Programs

2. Conduct Research and Develop Products
   - Labs/Centers

3. Deliver Products to Clients

Decision Inputs, Evaluation and Feedback

- EPA Programs and Regions
- EPA Strategic Strategic Plan
- Congressional Mandates
- States, Tribes, Local governments
- Other stakeholders
- External Science Advisors

[Diagram showing flow from Strategic Research Action Plans to Conduct Research and Develop Products to Deliver Products to Clients with feedback loops]
SSWR Research Topics and Projects

- **Watershed Sustainability**: ambient water quality criteria; energy and mineral resources; scalable tools and methods for integrated assessment and management; national water quality benefits.

- **Nutrients**: thresholds and targets for appropriate nutrient levels; management tools and practices; metrics; harmful algal blooms.

- **Water Systems**: current and transformative systems; emerging contaminants in drinking water and sources; technology advances.

- **Green Infrastructure**: models and tools; community benefits; linkage to aquifer storage and recovery.
USEPA Nutrients Research in Cincinnati:
Monitoring GI Performance at sites in the Mill Creek Watershed

Sites, periods of monitoring data collection:

**Lick Run** - St. Francis Apartments Rain Garden, 2012-2015

**Congress Run** - Stream restoration and daylighting, 2016 - present

- Hydrology monitoring by Inter-Agency Agreements with USGS.
- Base-flow sampling (monthly) and storm event sampling (8-10 events per year).
- Flow-proportional and timed sample collection (paired ISCOs), minimum of 8 sample times per location and storm event.
- GCLAS used to estimate storm event load totals.
- Data being used to calibrate and validate GIFMod rain garden module.

Nutrients and methods (by Lachat FIA):

- Total N: AWWA 4500 N$_{org}$D / USEPA 353.2
- Total P: AWWA 4500-P B.5 / USEPA 365.3
- DRP: USEPA 365.1
- NO$_2$-NO$_3$: USEPA 353.2
- NH$_4$: USEPA 350.1

Also: TOC, DOC, TSS, VSS, SSC, COD, Turbidity, pH, Temp., DO, SC, ORP, metals, anions, e. coli, and total coliforms for each sampled time and location at both field sites.
# LCA of 5-Level Nutrient Removal Treatment Train

<table>
<thead>
<tr>
<th>Level</th>
<th>Total Nitrogen, mg/l</th>
<th>Total Phosphorus, mg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>4-8</td>
<td>0.1-0.3</td>
</tr>
<tr>
<td>4</td>
<td>3</td>
<td>0.1</td>
</tr>
<tr>
<td>5</td>
<td>&lt;2</td>
<td>&lt;0.02</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level</th>
<th>Type of Biological Treatment</th>
<th>Phosphorus Precipitation</th>
<th>Fermenter</th>
<th>Sand Filter</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Plug Flow Activated Sludge</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Anaerobic/Anoxic/Oxic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Activated Sludge, 3-Sludge System</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>5-Stage Bardenpho</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>University of Cape Town Process, Modified</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>5-stage Bardenpho</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>Denitrification Filter (100%)</td>
</tr>
<tr>
<td>4</td>
<td>4-stage Bardenpho Membrane Bioreactor</td>
<td>√</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>5-Stage Bardenpho</td>
<td>√</td>
<td>√</td>
<td>√</td>
<td>Denitrification Filter (10%) Ultrafiltration And Reverse Osmosis (90%)</td>
</tr>
<tr>
<td>5</td>
<td>5-stage Bardenpho Membrane Bioreactor</td>
<td>√</td>
<td>√</td>
<td></td>
<td>Reverse Osmosis (85%)</td>
</tr>
</tbody>
</table>
Cumulative Energy Demand

The chart shows the energy demand for various levels of wastewater treatment. The levels are labeled as Level 1, Level 2-1, Level 2-2, Level 3-1, Level 3-2, Level 4-1, Level 4-2, Level 5-1, and Level 5-2. The energy demand is measured in MJ CED/m³ wastewater treated. The categories of energy demand include:

- Preliminary/Primary/Disinfection
- Biological Treatment
- Post-Biological Treatment
- Sludge Processing and Disposal
- Effluent Release
- Total

The total energy demand for Level 5-1 is 23.6 MJ CED/m³, and for Level 5-2 it is 22.8 MJ CED/m³.
Annual Life Cycle Costs
History of Nutrient Control Design Guidance at ORD

• Nitrogen Control
  • Process Design Manual for Nitrogen Control – 1975
  • Manual – Nitrogen Control - 1993

• Phosphorus Control
  • Process Design Manual for Phosphorus Removal – 1971
  • Process Design Manual for Phosphorus Removal – 1976
  • Design Manual – Phosphorus Removal – 1987
  • Handbook – Retrofitting POTWs for Phosphorus Removal in the Chesapeake Bay Drainage Basin - 1987
ORD’s Latest Nutrient Control Technology Design Guidance

- August 2010 – Nutrient Control Design Manual (EPA/600/R-10/100)
Nutrient Control Design Manual Contents

- Need for Nutrient Control
- Principles
  - Phosphorus Removal by Chemical Addition
  - Biological Nitrogen Removal
  - Biological Phosphorus Removal
- Technology Overview
  - Nitrogen Removal
  - Phosphorus Removal
  - Combined N/P Removal
  - Effluent Filtration
Nutrient Control Design Manual Contents (cont’d)

• Design
  • Objectives
  • Process Selection
  • Design Approaches
    – Phosphorus Removal by Chemical Addition
    – Biological Nutrient Removal
    – Effluent Filtration

• Operation and Optimization
• Instrumentation and Control
• Sustainable Nutrient Recovery and Reuse
U.S. EPA’s Science Inventory

https://cfpub.epa.gov/si/
U.S. EPA's Online Publication Warehouse

https://www.epa.gov/nscep