Designing & Operating the Wastewater Treatment Plant of the Future Will Require a Paradigm Shift

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Presentation Outline

• Drivers for a Paradigm Shift
• reNEWable (NEW = Nutrient + Energy + Water) Predicament
• Wastewater Management Strategies
• Invention, Innovation & Technology Development
• Closing Thoughts
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Humanity’s Tope Ten Problems for the Next 50 to 100 years

1. Energy
2. Water
3. Food (nutrient)
4. Environment
5. Climate change
6. Poverty
7. Political stability
8. Disease
9. Education
10. Population explosion
Development of World Cities

1950

World Cities exceeding 5 million residents

Data source: U.N. Population Division
2000 World Cities exceeding 5 million residents

Data source: U.N. Population Division
Development of World Cities

2015

World Cities exceeding 5 million residents

Data source: U.N. Population Division
Population Explosion

- 7 Billion (2011)
- 9 Billion (2050)
Our wastewater management approach for a global population of 2 Billion in the 1950s can not be the approach for 10 Billion (2100), mostly urban & living in an increasingly resource & energy constrained world.

It is clear that a paradigm shift is needed in how we design and operate WWTPs.
Key Elements of WEF Position Statement

1. Redefines wastewater treatment plants as water resource recovery facilities (WRRFs)
2. Affirms that energy derived from WRRFs is a renewable energy source
3. States that biosolids should be recognized as biomass under all applicable government and commercial definitions
4. Asserts that state and federal agencies should fully endorse all renewable energy associated with WRRFs
5. Encourages WRRFs to set a goal of becoming energy neutral or net energy producers
6. Encourages more research into emerging technologies on energy recovery from wastewater
7. Encourages continued participation by water sector in traditional energy conservation and recovery at WRRFs
Key Features of the WWTP of the Future

- Water Conservation
- Distributed Stormwater Management
- Water Reclamation and Recycling
- Energy Neutral/Positive
- Carbon Sequestration for Energy Production
- Nutrient Recovery
- Source Separation
- Decentralized treatment
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The Water Predicament
What is the Problem We are Trying to Solve?

Population Growth + Urbanization + Consumption + “Linear System”

Linear System = Take + Treat + Use + Treat + Waste

Water Footprint

- 1 lb beef = 1,900 gal
- 1 cup coffee = 35 gal
- China = 500 gpdpc
- Japan = 800 gpdpc
- USA = 1,800 gpdpc
The Solution

Integrated Water Management

• All water is good water
  ➢ Drinking water
  ➢ Wastewater
  ➢ Stormwater

• Maximize reuse opportunity

• Stream augmentation is part of the solution

Closed System = Use water more than once
Linear to ‘Closed Loop” System
The Energy Predicament
Can WWTPs be Net Zero Energy?

- YES !!

- Research by David Bagley at U of Toronto, 2001:
  - Electricity consumed: 0.2 kWh/m$^3$
  - Potential Energy of Raw Wastewater: 1.8 kWh/m$^3$
  - WW contains ~10 times the electrical energy needed for conventional treatment
Sources of Energy from Waste (Btu/lb Dry)

- Biosolids: 6,000 - 9,000
- Fats, Oils & Grease: 16,700
- Food Wastes: 1,500 - 3,000

Use to reduce fossil fuel source energy at plant or process steam

WRRF

- Thermal Oxidation
- Anaerobic Digestion
  - Solar
  - Algae
  - Wind
  - Hydro

General Energy Balance for WRRF

- Electricity
- Steam
- Fuel Product - Gaseous or Solid

Compare to other fuels (Btu/lb Dry):
- Coal: 7,000 to 11,000
- Wood: 1,500 to 3,000
- Natural Gas: 7,000-9,000

Use for residential or commercial power
Produce electrical energy off-site
Provide “green” fuel for other uses

NBP Webcast, 7 Dec. 2011
Emerging Treatment Concepts for Realizing Energy Savings

• Not your fathers activated sludge system!
• “Everything is everywhere, the environment controls!”
• Design & operate plants differently to take advantage of unique organisms.
  ➢ Mainstream deammonification
  ➢ Microaerobic
  ➢ Anaerobic treatment
Mainstream Deammonification

Nitrification/Denitrification

Anammox: Anaerobic Ammonium Oxidation

Typically used for return stream treatment
Mainstream Deammonification

- 63% reduction in oxygen demand (energy)
- Nearly 100% reduction in carbon demand
  - Divert carbon for energy production
- 80% reduction in biomass production
- No additional alkalinity required
- Anammox organisms are slow growing (SRT ~ 25 days)
- Inhibited by oxygen even at very low levels
The Nutrient Predicament
We are Mining P Faster Than The Geologic Cycle
Can Replace It

Michael Mew, 2011
The Fate of Reactive Nitrogen

"new" Nr entering human mouth
- used by body: 5%
- lost to environment: 95%

Environment is also the sink for all of the Nr created by fossil fuel combustion.
Nutrient Recovery Technologies/Approaches

Main Stream
- Direct Reuse (P and N)
  - P – Adsorption
  - N – Stripping
  - N – Adsorption
  - N – Vacuum Distillation

Recycle Stream
- P & N Precipitation/Crystallization
  - P-Adsorption

WAS
- P-Stripping / Recovery

Biosolids
- Wet-chemical
- Direct Reuse

Sludge Ashes
- Wet-chemical
- Thermo-chemical
## Proven P Recovery Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Feed Stream</th>
<th>Product</th>
<th>External Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>PhoStrip</td>
<td>RAS</td>
<td>CaPO$_4$</td>
<td>Lime</td>
</tr>
<tr>
<td>Ostara</td>
<td>Centrate, filtrate</td>
<td>Struvite</td>
<td>MgCl, NaOH</td>
</tr>
<tr>
<td>Ostara</td>
<td>WAS</td>
<td>Struvite</td>
<td>MgCl, NaOH</td>
</tr>
<tr>
<td>Multiform</td>
<td>Centrate, filtrate</td>
<td>Struvite</td>
<td>MgCl, NaOH</td>
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<tr>
<td>Harvest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Procorp</td>
<td>Centrate, Filtrate</td>
<td>Struvite</td>
<td>MgCl, NaOH</td>
</tr>
</tbody>
</table>
## Other Nutrient Recovery Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Origin</th>
<th>Feed Stream</th>
<th>Chemicals Used</th>
<th>End Product</th>
</tr>
</thead>
<tbody>
<tr>
<td>KREPO</td>
<td>Sweden</td>
<td>Centrate</td>
<td>H₂SO₄, NaOH, Fe</td>
<td>FePO₄</td>
</tr>
<tr>
<td>Kemicond</td>
<td>Sweden</td>
<td>Centrate</td>
<td>H₂SO₄, NaOH, H₂O₂</td>
<td>FePO₄</td>
</tr>
<tr>
<td>Seaborne</td>
<td>Germany</td>
<td>Centrate</td>
<td>H₂SO₄, NaOH, Mg(OH)₂</td>
<td>Struvite</td>
</tr>
<tr>
<td>NuReSys</td>
<td>Germany</td>
<td>Anaerobic effluent</td>
<td>NaOH, MgCl₂</td>
<td>Struvite</td>
</tr>
<tr>
<td>PHOSPAQ</td>
<td>Netherlands</td>
<td>Centrate</td>
<td>MgO</td>
<td>Struvite</td>
</tr>
<tr>
<td>Rem-Nut</td>
<td>Italy</td>
<td>Effluent</td>
<td>NaOH, MgCl₂</td>
<td>Struvite</td>
</tr>
<tr>
<td>Phosnix</td>
<td>Japan</td>
<td>Centrate</td>
<td>Mg(OH)₂, NaOH</td>
<td>Struvite</td>
</tr>
<tr>
<td>P-Roc</td>
<td>Germany</td>
<td>Centrate</td>
<td>Tobermorite (Ca source from industrial waste)</td>
<td>Ca₃(PO₄)₂</td>
</tr>
<tr>
<td>BioCon</td>
<td>Denmark</td>
<td>Incinerator ash</td>
<td>H₂SO₄</td>
<td>H₃PO₄</td>
</tr>
<tr>
<td>SEPHOS</td>
<td>Germany</td>
<td>Incinerator ash</td>
<td>H₂SO₄, NaOH, Lime</td>
<td>AlPO₄, Ca₃(PO₄)₂</td>
</tr>
<tr>
<td>SUSAN</td>
<td>Europe</td>
<td>Incinerator ash</td>
<td>H₂SO₄, NaOH, Mg(OH)₂</td>
<td>Fertilizer product</td>
</tr>
</tbody>
</table>

* Article in next issue of the Buckeye Bulletin  
* WERF Study
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Centralized Treatment

- Foremost of the last century, this was the only viable approach to safe, dependable & cost-effective treatment
- Focus on environmental protection – meet limits
- Favored by technology development & economics - off-grid development generally discouraged
- Local needs ignored
- Linear system
- Greater similarity in treatment approach
Decentralized Treatment

• Focus on environmental enhancement – go beyond meeting limits

• New technologies allow high-level treatment at decentralized facilities

• Offers opportunities for
  • Integrated water management based on local needs & opportunities
  • Site specific solution
Optimum Strategy Includes Both Centralized & Decentralized Approaches

• Centralized – large urban areas
• Decentralized - smaller communities & cluster developments
• Centralize solids processing to maximize energy & resource recovery
• The issues are political, administrative, & regulatory. NOT technical
Source Separation Takes Advantage of Wastewater Characteristics

- New terminology for the industry
  - Grey water: Shower, washing, and bathwater
  - Black water: Toilet water
  - Yellow water: Urine
- Urine contains more than 70% of the N and 60% of the TP in less than 1% of raw sewage flow
- Feces contains most of the organic mater

Urine Separation

• Advantages over the traditional wastewater system are:
  - Separate collection & treatment
    • Yellow water (urine) – Nutrient & water recovery
    • Black & grey water - Organics/solids removal, & recovery of energy & water
  - Reduced emissions to the environment
  - More efficient handling of flows due to less dilution

• Many barriers exist
  • Social
  • Operational
  • Economic
It is Already Happening at HRSD’s New Operations Center Complex

Urine will be separated and trucked to the Ostara Facility at the Nansemond Treatment Plant to produce struvite

- 85% P recovery
- Up to 40% N recovery

Courtesy, Dr. Charles Bott, HRSD
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Technology Life-Cycle

Technology development is a 1000 to 1 game!

- Acclimation
- Growth
- Stability (Maturation)
- Lag
- Loss of Technology

10 Years (average)

Next Generation

Level of Innovation & Application

Knowledge

Time
We Need those 1000 Ideas!
Invention & Innovation

• Invention: New ideas/concepts. Often resulting from fundamental research. Limited or no direct benefit.
• Innovation: Extraction of value from ideas/concepts. Commercialization stage.
• Both invention & innovation are important in finding solutions to the challenges we face.
• Role of WEF & WERF: Forum for exchanging ideas & facilitate open-innovation. Plant the seed for the next innovation.
The world will not evolve past its current state of crisis by using the same thinking that created the situation.

- Albert Einstein
Closing Thoughts

• Population explosion and rapid urbanization is forcing us to go from a comfortable position of abundant resources to a stressful position of scarcity.

• Wastewater management of the future will continue to remain true to its core principles of public health and environmental protection.

• However, in order to remain sustainable, current practices must evolve to cope with the practical realities of the 21st century and beyond.

• Invention, innovation, and technology development are all crucial for the paradigm shift to occur.

• Major elements of the WWTP of the future include energy positive, water reuse, and nutrient recovery. Complementing practices include decentralized treatment and source separation.
Closing Thoughts

• Wastewater professionals need to collaborate with city planners in designing livable & sustainable cities of the future.

• We need to promote rebranding to align with the principles of WWTP of the future:
  – ‘Resource Recovery Facility’ vs. WWTP
  – ‘Used Water’ vs. ‘Wastewater’

• The limiting factor is not technology but our willingness to effect change.

• Wastewater treatment in the 21st century will depend on 2 types of organisms:
  – Those within the basin
  – Those outside: operators, engineers, researchers, regulators, etc.
Learning is like rowing upstream; not to advance is to drop back.

Chinese proverb
Questions?

So near, yet so far!
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