The IWA Cities of the Future Approach to Achieving a Resilient Water Supply System - Pursuing Safety, Sustainability and Environmental Friendliness

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We Have a Global Water Crisis Caused by:

- Population Growth
- Increased Living Standard
- Climate Change
- Urbanization
- “Linear System”

Nearly Half of Human Population Will Experience Water Stress by 2025
Scientists* Estimate That We Are Crossing Planetary Boundaries; New Technologies and Approaches Require to Return to Sustainability

- Biodiversity Loss
- Nutrients
  - Nitrogen
  - Phosphorus
- Climate Change
- Chemical Pollution (Not Yet Quantified)

Global Water & Sanitation May be Our Biggest Challenge

- ~3 Billion Without Water at Home or in the Vicinity (45%)
- ~4 Billion Without continuous Access to Water (60%)
- ~4.5 Billion With No Sewerage (70%)
- ~5.5 Billion With No Treatment (80%)
<table>
<thead>
<tr>
<th>Item</th>
<th>Second Half 20th Century</th>
<th>Middle of 21st Century</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>2.5 B Growing to 6 B (World)</td>
<td>Stable at 9 to 10 B</td>
</tr>
<tr>
<td>Urbanization</td>
<td>More Than Half Rural</td>
<td>Nearly Three-Quarters Urban</td>
</tr>
<tr>
<td>Economy</td>
<td>Rapid Growth with Periodic Recession; Based on Material Use</td>
<td>? Based on Knowledge?</td>
</tr>
<tr>
<td>Water</td>
<td>Abundant; Obtaining More is Only a Matter of Money</td>
<td>Scarce and Limited; New Supplies Available Only Through Efficiency</td>
</tr>
<tr>
<td>Energy</td>
<td>Abundant and Inexpensive</td>
<td>Limited and Increasingly Expensive; Related to Climate Change</td>
</tr>
<tr>
<td>Materials</td>
<td>Readily Available and Decreasing Prices</td>
<td>Limited Availability and Increasing Prices</td>
</tr>
<tr>
<td>Food</td>
<td>Increasing Supply and Decreasing Price</td>
<td>Expansion of Supply Not Keeping Up with Demand – Prices to Increase?</td>
</tr>
<tr>
<td>Technology</td>
<td>Expanding at Increasing Rate</td>
<td>Expanding and Diversifying at Increasing Rate</td>
</tr>
<tr>
<td>Climate</td>
<td>Predictable</td>
<td>Wetter and Drier, But How Much?</td>
</tr>
<tr>
<td>Social Stability</td>
<td>Dynamic</td>
<td>?</td>
</tr>
<tr>
<td>Human Well-Being</td>
<td>Improving</td>
<td>?</td>
</tr>
</tbody>
</table>
Can Our “Linear System” That Evolved:

- For Global Population < 2 Billion
- Mostly Rural
- Lacking Modern Technology

Be the Solution When:

- Global Population ~ 10 Billion
- Mostly Urban
- Experiencing Greater Resource Constraints?
Let’s Define the Problem(s) We are Trying to Solve, and Our Goals

Population Growth + Consumption + Urbanization + Climate Change + “Linear System”

= Water + Resource + Nutrient Stress Consumption Dispersal

50 - 70 % Energy Neutral Nutrient Recovery
Less Water

Lack of Support for Urban Water Management Utilities

Financially Stable and Politically Supported
Components of Integrated Urban Water and Resource Management System Include:

- Water Conservation
- Distributed Stormwater Management
  - Low Impact Development
  - Rainwater Harvesting
- Distributed Water Treatment
- Water Reclamation and Recycling
- Heat Recovery
- Organic Management for Energy Production
- Nutrient Recovery
- Source Separation
<table>
<thead>
<tr>
<th>Component</th>
<th>Centralized</th>
<th>Decentralized/Hybrid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stormwater</td>
<td></td>
<td>Permeable Pavements, Green Roofs, Rain Gardens, etc.</td>
</tr>
<tr>
<td>Water Conservation</td>
<td>Wide Variety of Technologies, Along with Behavior Changes</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td>Treatment for Potable Use and Reuse (Direct and In-Direct)</td>
<td>Treatment for Potable Use and Non-Potable Reuse</td>
</tr>
<tr>
<td>Energy Management</td>
<td>Anaerobic Digestion, Thermal, Microbial Fuel Cells</td>
<td>Capture Heat Energy, Microbial Fuel Cells</td>
</tr>
<tr>
<td>Nutrient Recovery</td>
<td>Land Application of Biosolids, Struvite Precipitation</td>
<td></td>
</tr>
<tr>
<td>Source Separation</td>
<td>Treatment of Kitchen, Black and Yellow Water</td>
<td>Supply Potable and Non-Potable; Treatment of Kitchen, Black, and Yellow Water</td>
</tr>
</tbody>
</table>
Guiding Principles and Constraints Guide System Development

Guiding Principles

• Protect & Use Local Water Resources
• Mimic Local Hydrology
• Multiple Barriers for Public Health
• Minimize Resource Consumption and Maximize Recovery

Constraints

• Water Balance (Wet and Dry)
• Salt Balance
• Nutrient Balance
• Manage Residuals
Let’s Look at an Example Integrated System Incorporating Most Tools
What Will These Systems Achieve (Why Would We Do This)?

• Improved Public Health Protection
  – Greater Isolation and Potential for Treatment of Potable Water

• Less Net Water Abstraction From Environment

• Significantly Reduced Environmental Discharges
  – Volume (Stormwater, Wastewater)
  – Constituents (Organics, Nutrients, Compounds of Concern)

• Reduced Resource Consumption (Energy, Chemicals)

• Easier System Upgrade and Expansion

• Increased System Resiliency

• Enhanced Urban Environment
Wastewater Separation Creates Energy and Nutrient Recovery Options

![Graph showing percentages of BOD5, Nitrogen, Phosphorus, and Potassium in wastewater separated into various categories: Laundry/Bath, Kitchen, Feces, and Urine.]
Many Technologies Enable Non-Revenue Water Reduction in Developed and Developing Countries

- Automated Meter Reading (AMR)
  - Used by Utilities
  - Used by Consumers via Internet and Cell Phones
- Software
  - Leak Detection via Data Mining and Others
  - Optimization
  - Neural Networks for Operation
- Pressure Control
  - Real-Time Operation
  - Energy Recovery
- Condition Assessment
Green Infrastructure and Natural Systems are Key Technologies
NeWater Represents Technology to Reclaim Marginal Quality Water

Microfiltration

Secondary Effluent

Reverse Osmosis

High Quality Product Water

UV
Wastewater Being Viewed as Resource, Rather Than Problem
VFAs Enhance EBPR (no MeOH)

200 micron screen diverts inert VS from activated sludge to energy recovery

Nutrient Recovery (N & P)

Sludge conditioning to increase biogas yield/reduce mass

FOG to increase Biogas

NEW (Nutrients/Energy/Water) Scheme

Biogas-fueled CHP and B2E maximize energy production

Biogas

Reuse Water Hydropower

Ash

B2E

Plant Efluent

CHP

Dewatering

Biosolids

Plant Influent

Ferment

Ferment

N&P Rec

Cond

Short MCRT AAD Process for Biogas Production

VFAs Enhance EBPR (no MeOH)
Direct Anaerobic Treatment of Raw Sewage Converts Carbon Into Biogas
Partial Nitritation and Anammox Saves Oxygen and Carbon

A: Complete Nitrification/Denitrification:
by AOBs, NOBs, Heterotrophs

NH₄⁺ → NO₂⁻ → NO₃⁻ → N₂ + O₂
MeOH

B: Nitritation/Denitritation:
by AOBs, Heterotrophs

NH₄⁺ → NO₂⁻ → NO₂⁻
MeOH

C: Partial Nitritation/Anammox:
by AOBs, Autotrophic Anammox

NH₄⁺ → NO₂⁻ → Anammox → N₂ + NO₃⁻
Partial Nitritation and Anammox Saves Energy, Carbon, and Less Biosolids

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Nit/Anammox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxygen (Kg/Kg NH₃-N)</td>
<td>4.5</td>
<td>0.85</td>
</tr>
<tr>
<td>Carbon (Kg/Kg NH₃-N)</td>
<td>3.0</td>
<td>0.01</td>
</tr>
<tr>
<td>Biosolids (%)</td>
<td>83%</td>
<td>100%</td>
</tr>
</tbody>
</table>

58% Savings

100% Savings

83% Savings
Hydrocyclone Retains Anammox Granular Bacteria
“Legacy Systems” Must be Dealt With In Existing Urban Areas

• Centralized Systems Serve Existing Development
• Distributed Elements Aggressively Incorporated Into New Developments and Redevelopment
  – Allows System to be Converted Over Time
• Existing Water Distribution and Wastewater Collection System Provides Necessary Capacity as Urban Density Increases
  – Avoids Need for System Expansion
  – May be “Downsized” Over Time and “Re-Purposed”
• Centralized Plant Transitions From “Wastewater” to “Organic Matter” Processing Facility

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<thead>
<tr>
<th></th>
<th>Traditional Approach</th>
<th>Revised Approach</th>
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<tbody>
<tr>
<td>Water Supply</td>
<td>What are the Available Surface and Ground Water Sources?</td>
<td></td>
</tr>
<tr>
<td>Wastewater Management</td>
<td>What are the Applicable Discharge Requirements?</td>
<td></td>
</tr>
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</table>
Useful Lives of Facility Components
Indicate Replacement Priorities

<table>
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<tr>
<th>Item</th>
<th>Useful Life (Years)</th>
<th>Comment</th>
</tr>
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<tbody>
<tr>
<td>Structures</td>
<td>50-100</td>
<td>Lifetime of Concrete Structures (Including Rehab)</td>
</tr>
<tr>
<td>Mechanical Equipment</td>
<td>15-40</td>
<td>Rotating Equipment</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>10-20</td>
<td>Determined by Obsolescence</td>
</tr>
<tr>
<td>Treatment Technology</td>
<td>10-20</td>
<td>Determined by Effluent Standards and Evolution of Technology</td>
</tr>
<tr>
<td>I&amp;C Technology</td>
<td>5-15</td>
<td>Determined by Obsolescence</td>
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Rapid Technological Change Means a New Paradigm – Design for Retrofit
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