THE EVOLUTION OF WASTEWATER TREATMENT

H₂O
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Overview of Presentation

• Evolution of Wastewater Management
• Law of Unintended Consequences
• New Concepts for the Future
• The Sustainability Challenge
Evolution of Wastewater Treatment

Treatment plant located at:
1. Remote locations
2. Flow by gravity

Relatively little concern for:
1. The use of resources
2. The consumption of energy
3. Long-term sustainability
4. The carbon footprint
At $0.03/kWh Energy Efficiency was not an Issue. Example: Excessive Headloss (Energy Loss)
at Primary Sedimentation Tank Weirs
The Law of Unintended Consequences

- Impact of sea level rise on:
  - Plant siting
  - Water reclamation

- Impact of water conservation (e.g., use of low volume toilets) on:
  - Wastewater collection system
  - Wastewater treatment facilities

- Use of purple pipe for recycled water

- Impact of centralized treatment on water reuse
**Impact of Rising Tides on Sewer System**

Historical and Projected High Tides Relative to San Francisco City Datum

- **City Datum (for instance, street grade at The Embarcadero)**
- **Lowest Overflow Weirs**
- **Historical Trend**
- **IPCC High Estimated Projections**

![Image](image.png)

Courtesy City of San Francisco
Wastewater Management Infrastructure
The Law of Unintended Consequences:
The impact of Conservation

- Lateral connection for blackwater and excess greywater
- Existing 8 in. pipe used as protective casing for new plastic pipe
- Plastic pipe (4 to 6 in.) retrofit into annular space
Centralized Facilities
Limit Recycle Potential

Courtesy City of San Diego
New Concepts for the Future

- Significant advances in treatment technologies
- Urine separation
- Satellite water reuse systems will become more common place
- New treatment plant designs will be based on energy recovery
Wastewater Treatment Process Flow Diagrams With Old and New Technologies

(a)

(b)
Advantages of Using Fine Screens in Place of Primary Sedimentation Tanks

• Treatment process flow diagram is simplified

• Particle size and size distribution is altered, leading to enhanced biological treatment kinetics
Stainless Steel Cloth Filter for Filtration of Secondary Effluent
Distribution of Nutrients and Trace Organics in Domestic Wastewater

Examples of Urine Separation Fixtures
Urine Utilization in Indoor System
Use of Satellite Systems in Wastewater Management Infrastructure
Satellite Systems for Reclamation and Reuse
Reclaimed water is used for toilet flushing, landscape irrigation, and cooling water.
Example of Extraction Type Satellite System
(System has been in Operation for 25 Years, Upland, CA)

Courtesy D. Ripley
Wastewater Management Infrastructure

Legend

City of Los Angeles
- Regional facility
- Satellite reclamation facility
- Distributed facility

County Sanitation Districts of Los Angeles County
- Regional facility
- Satellite reclamation facility
- Distributed facility
Satellite Systems for Greywater Reuse

Solar panels for residential use and wastewater treatment

Water for toilet flushing

Low-pressure membrane

To landscape drip irrigation

Greywater treatment unit with storage capacity and effluent recirculation during low water periods

Excess greywater

Existing community collection system

Lateral for blackwater and excess greywater
Long Term Sustainability
For Wastewater Management

1. Reduce use of depleteable natural resources
2. Reuse and recycling of resources
3. Conserve limited resource; namely, petroleum
4. Recover energy from wastewater
5. Recover resources from wastewater
6. Recover potable water from wastewater
Basis for Future Treatment Resource Recovery Processing Facilities

WASTEWATER IS A RENEWABLE RECOVERABLE SOURCE OF ENERGY, RESOURCES, AND WATER
# Constituents in Wastewater

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Unit</th>
<th>Value (typical)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solids, total (TS)</td>
<td>mg/L</td>
<td>390 - 1230 (720)</td>
</tr>
<tr>
<td>Dissolved, total (TDS)</td>
<td>mg/L</td>
<td>270 – 860 (500)</td>
</tr>
<tr>
<td>Suspended solids, total (TSS)</td>
<td>mg/L</td>
<td>120 – 400 (210)</td>
</tr>
<tr>
<td>Biochemical oxygen demand (BOD) 5-d, 20°C</td>
<td>mg/L</td>
<td>110 – 350 (190)</td>
</tr>
<tr>
<td>Total organic carbon (TOC)</td>
<td>mg/L</td>
<td>80 – 260 (140)</td>
</tr>
<tr>
<td>Chemical oxygen demand (COD)</td>
<td>mg/L</td>
<td>250 – 800 (430)</td>
</tr>
<tr>
<td>Oil and grease</td>
<td>mg/L</td>
<td>30 – 90 (60)</td>
</tr>
</tbody>
</table>
# Energy Content of Wastewater

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater, heat basis</td>
<td>MJ/10°C•10³ m³</td>
<td>41,900</td>
</tr>
<tr>
<td>Wastewater, COD basis</td>
<td>MJ/kg COD</td>
<td>12 - 15</td>
</tr>
<tr>
<td>Primary sludge, dry</td>
<td>MJ/kg TSS</td>
<td>15 - 15.9</td>
</tr>
<tr>
<td>Secondary biosolids, dry</td>
<td>MJ/kg TSS</td>
<td>12.4 - 13.5</td>
</tr>
</tbody>
</table>
**Required and Available Energy for Wastewater Treatment, Exclusive of Heat Energy**

- Energy required for secondary wastewater treatment
  
  1,200 to 2,400 MJ/1000 m$^3$

- Energy available in wastewater for treatment, using previous data

  \[Q = (430 \text{ kg COD/1000 m}^3) (1000 \text{ m}^3) (13 \text{ MJ/kg COD})\]

  \[5,590 \text{ MJ/1000 m}^3\]

- Energy available in wastewater is 2 to 4 times the amount required for treatment
What is the Key Question – What is Best Way to Recover and Use Energy?

- Anaerobic digestion and power generation
- Ambient temperature anaerobic treatment and power generation
- Complete treatment without biological processing with heat drying and power generation
- Upstream recovery of heat and chemical energy
New Concept for the Treatment and Recovery of Energy from Wastewater

• Replace primary and secondary sedimentation tanks with cloth screens

• Use “plant adsorbent (e.g., Kenaf)” to adsorb organics and ammonia

• Recover heat energy for drying solids

• Generate energy from dried solids
Wastewater Treatment Process Flow Diagram Without Biological Treatment

Untreated wastewater → Screening → Fine screen → Processed Kenaf core (Adsorbent) → Fine screen → micro- or ultrafilter → UV disinfection → Effluent reuse and/or dispersal

- Coarse screenings dried and combusted
- Fine screenings to digester, gasification, or combustion after heat drying with energy recovered from wastewater
Fine Screen for Solids Removal

Adelanto, California

Fontana, California

Squeezed (dewatered) solids

200 micron cloth screen
Recovery of Constituents from Wastewater Collection System

(a) Collection main or trunk
 Untreated wastewater

(b) Untreated wastewater
 Remote pump station
 Fine screen (200 micron) with auger press
 Screened wastewater returned to collection system
 Solids to drying and combustion or gasification
Takeaway Message

• As new projects and technologies are developed greater attention must be paid to unintended consequences.
• With new concepts, technologies, and processes configurations, it will be possible to recover energy, resources, and potable water from wastewater.
• Ultimately, wastewater treatment facilities could become exporters of energy and resources.
THANK YOU
FOR LISTENING
Recovery of Energy Within
Wastewater Management Infrastructure

Satellite treatment system
for non-potable urban uses

Satellite treatment system

Satellite treatment system

Individual onsite
treatment with drip
irrigation system
for water reuse

Development type
decentralized
water reclamation
and reuse system

Residual flow to centralized
wastewater treatment facility

Homes with greywater reuse
systems and curbside collection
of recovered urine, blackwater
discharged to collection system

Anaerobic digesters for energy
recovery from biosolids and other
urban organic waste streams

To indirect
potable reuse

Tertiary and/or
advanced treatment

Facilities for urine
processing and grease
conversion to biodiesel

Residual flow processed at
regional wastewater facility
Advantages of Using Fine Screens Within Wastewater Collection System

• Significant reduction in influent organic loading to existing WWTPs
• The useful life of existing facilities can be increased
• Reduce the need for new treatment facilities
Wastewater Treatment Process Flow Diagrams Without and With Influent and Effluent Screens
**New Filtration Technologies**

- **Downflow and upflow sand filters**
  5 to 15 m/h (2 to 6 gal/ft$^2$·min)
  Backwash water, 8 to 20%

- **Cloth media filters**
  15 to 25 m/h (6 to 10 gal/ft$^2$·min)
  Backwash water, 1 to 4%

- **Stainless steel cloth screen filter**
  15 to 25 m/h (6 to 10 gal/ft$^2$·min)
  Backwash water, 1 to 4%

- **Compressible medium filter**
  Up to 98 m/h (40 gal/ft$^2$·min)
  Backwash water, 1 to 4%
New Filtration Technologies

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Enhanced Wastewater Management and Enhanced Reuse Through Urine Separation

- Maximum recovery of nutrients
- Removal of trace organics (EDCs, etc.)
- Enhanced treatment with respect to residual nutrients and trace organics with less treatment complexity
- Reduced energy requirements
- Use of soil for advanced treatment of residual trace organics and unknown pathogens
- Enhanced protection of the environment
The Sustainability Challenge

In closing, we must all continue to seek new concepts and technologies to change the status-quo with respect to how the energy and resources in wastewater are recovered to develop a more sustainable future – a challenge worthy of the attendees at this workshop.
THANK YOU
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Non-Membrane Processes for Dissolved Constituents

Evaluation of the performance of the biologically active carbon (BAC) process for the removal of specific constituents and electrodialysis reversal (EDR) for TDS control
Technologies for the Removal of TDS, Trace Constituents, and Unknowns

Adapted from OCWD
Technologies for the Removal of Trace Constituents and Unknowns

Adapted from Sundaram et al., 2009
Goreangab Water Reclamation Plant
Windhoek, Namibia

(a) Treatment process upgrade (1997)

(b) New treatment process flow diagram (ca 2005)
Assess the risk of reducing or eliminating the residence time constraint now included in the DHS regulations.

Evaluate the legal and regulatory issues at both the state and federal levels that may limit the implementation of indirect potable reuse, and the development of model legislation that can be used to overcome regulatory impediments.
### Draft California Regulations for Groundwater Recharge into Potable Aquifers

<table>
<thead>
<tr>
<th>Quality limits</th>
<th>Treatment required</th>
<th>Other requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 5 mg/L total N</td>
<td><strong>Spreading</strong></td>
<td>≥ 80% dilution for spreading (to start)</td>
</tr>
<tr>
<td>≥ 5 log virus inactivation</td>
<td>• Secondary</td>
<td>≥ 50% dilution for injection</td>
</tr>
<tr>
<td>≤ 2.2 total coli/100 mL</td>
<td>• Filtration</td>
<td>6-month retention time underground</td>
</tr>
<tr>
<td>≤ 2 NTU</td>
<td>• Disinfection</td>
<td>Monitor reclaimed water and monitoring wells for unregu-</td>
</tr>
<tr>
<td>≤ 0.5 mg/L TOC of wastewater origin</td>
<td>• SAT</td>
<td>lated constituents specified by CDPH</td>
</tr>
<tr>
<td>Drinking water MCLs</td>
<td>Injection</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Secondary</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Filtration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Reverse osmosis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• AOP* ({H}_2{O}_2 + UV)</td>
<td></td>
</tr>
</tbody>
</table>

*AOP must reduce NDMA and 1,4-dioxane by at least 1.2 logs and 0.5 logs, respectively.

Courtesy Dr. J. Crook
Indirect and Direct Potable Reuse, along with New Approaches to Infrastructure, Represents the Future

San Diego, CA (Proposed), Singapore, Australia

OCWD

Windhoek, Namibia ~30%
Direct Potable Reuse

Assess the comparative risk of adding highly treated reclaimed water to the raw water supply immediately upstream of a water treatment plant or downstream of a water treatment plant.

Develop a guidance manual that can be used to determine the blend requirements to maintain water quality when reclaimed water is to be introduced into existing potable water supply distribution systems.
Closing Thought: Try It - you'll like it
Reuse Market Size and Growth 2008

Source: GWI Global Water Market 2008
**Disinfection**

Identification of the fundamental mechanisms of inactivation, destruction, and the selectivity for microorganisms using existing, combined, and emerging disinfection processes.

Develop new disinfection guidelines for chlorine for treatment processes that produce a fully nitrified effluent

Current Ct value of 450 mg-min/L is a legacy regulation
Onsite Wastewater Characteristics with Urine Separation (US) (190 L/capita-d)

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Typical, g/capita-d</th>
<th>Typical, mg/L</th>
<th>g/capita-d with US</th>
<th>Typ., mg/L with US</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD$_5$</td>
<td>85</td>
<td>450</td>
<td>85</td>
<td>~450</td>
</tr>
<tr>
<td>COD</td>
<td>200</td>
<td>1050</td>
<td>200</td>
<td>~ 1050</td>
</tr>
<tr>
<td>TSS</td>
<td>95</td>
<td>500</td>
<td>95</td>
<td>~500</td>
</tr>
<tr>
<td>NH$_4$-N</td>
<td>7.8</td>
<td>42</td>
<td>0.5</td>
<td>2.6</td>
</tr>
<tr>
<td>Organic N</td>
<td>5.5</td>
<td>30</td>
<td>3.0</td>
<td>15.9</td>
</tr>
<tr>
<td>TKN</td>
<td>13.3</td>
<td>72</td>
<td>3.5</td>
<td>18.5</td>
</tr>
<tr>
<td>Total P</td>
<td>3.3</td>
<td>17</td>
<td>1.6</td>
<td>8.8</td>
</tr>
</tbody>
</table>
Nutrient Separation, Storage, and Recovery with Curbside Collection
The Sustainability Challenge

In closing, we must all continue to seek new concepts and technologies to change the status-quo with respect to how the energy in wastewater is recovered to develop a more sustainable future – a challenge worthy of the attendees at this seminar.
THANK YOU
FOR LISTENING
Literature Review Categories

1. Source Control of Specific Constituents (8)
2. Water Quality Monitoring and Constituent Detection (14)
3. Decentralized and Satellite Systems for Water Reuse (8)
4. Conventional Treatment Processes (10)
5. Biological and Tertiary Membrane Treatment Processes (13)
6. Disinfection (6)
7. Oxidation Processes for Organic Constituents (7)
Recovery of Energy Within Wastewater Management Infrastructure

Satellite treatment system with fine screen for recovery of particulate matter for energy recovery

Pump station with fine screen for recovery of particulate matter for energy recovery

Centralized wastewater treatment facility with reduced hydraulic and organic loading

Satellite treatment system with fine screen for recovery of particulate matter for energy recovery

Reuse

Tertiary and/or advanced treatment
NEW CONCEPTS FOR ENERGY IN THE FUTURE

- New treatment plant designs will be based on energy recovery (discussed previously)
- Satellite systems for wastewater treatment and reuse
- Significant advances in treatment technologies
- Urine separation
New Concepts for the Future

- Significant advances in treatment technologies
- Urine separation
- Satellite water reuse systems will become common place
- New treatment plant designs will be based on energy recovery