CHALLENGES FOR SUSTAINABLE ONSITE
AND SMALL SYSTEM WASTEWATER
MANAGEMENT IN THE 21ST CENTURY

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George Tchobanoglous
Department of Civil and Environmental Engineering
University of California Davis
Some Important Challenges For Centralized Systems

- Science Versus Regulations
- Wastewater Collection Infrastructure Issues
- Wastewater Treatment Issues
- Biosolids Reuse and Disposal
- Effluent Reuse
- Effluent Disposal Issues
- Purple Pipe: A Bad Investment?
Some Important Challenges For Decentralized Systems

• Science Versus Regulations
• Wastewater Collection Infrastructure Issues
• Wastewater Treatment Issues
• Biosolids Reuse and Disposal (Indirectly)
• Effluent Reuse
• Effluent Disposal Issues
• Purple Pipe: A Bad Investment?
• Effective Management
Science Versus Regulations

Pre 1880s
Physical observations - No Science - Common sense practices (regulations)

Enlightenment 1880-1980s
Science develops - Semi-scientific, observational, and empirical regulations follow

Post 1980s
Science leaps ahead - Science based regulations have evolved, but have not kept pace - Semi-empirical and empirical regulations persist, especially in the implementation of onsite systems
Wastewater Treatment Issues
For the 21st Century

- Removal of Traditional Constituents
- Removal of Trace Constituents
- New Compliance Requirements
- Sustainable Energy Use and Management
- Design of Treatment Facilities in light of Sustainability and Homeland Security
Wastewater Constituents Of Concern In The 20th Century

- Organic matter (e.g., dissolved and particulate BOD)
- Suspended and colloidal solids
- Pathogenic microorganisms (e.g., bacteria, virus, protozoa, helminthes)
- Nutrients (e.g., nitrogen, phosphorus)

Onsite Systems Are Almost Here
Wastewater Constituents Of Concern In The 21st Century

• Organic matter (e.g., dissolved and particulate BOD)
• Suspended and colloidal solids
• Pathogenic microorganisms (e.g., bacteria, virus, protozoa, helminthes)
• Nutrients (e.g., nitrogen, phosphorus)
• TRACE CONSTITUENTS

Trace constituents are a new challenge for onsite and small systems
Trace Constituents Of Concern
Now Found In Wastewater

- Veterinary and human antibiotics
- Human prescription and prescription drugs
- Industrial and household wastewater products
- Sex and steroidal hormones (also EDs)
- Endocrine disrupters (EDs)
- N-nitrosodimethylamine (NDMA)
- Disinfection byproducts (DBPs)
Removal of Trace Constituents

- Ability to remove trace constituents depends on chemical structure, physiochemical properties, reaction condition, nature of chemical matrix (e.g. wastewater), and type of treatment process

- The principal removal mechanisms include: (1) absorption, (2) biological degradation, (3) chemical transformation, and (4) volatilization

- Because the various classes of compounds respond differently to the removal mechanisms, current designs for most wastewater treatment plants are not optimized for their removal

- Clearly, new operating strategies, technologies, and treatment process flow diagrams are needed

- Adapted from April Z. Gu
Removal of Trace Constituents In Centralized Systems
Removal of Trace Constituents In Decentralized Systems

Source control of problematic constituents

Modification of existing septic tank designs for enhanced removal of trace constituents

For constituent biotransformation and optimization of water quality for removal of trace constituents in soil

Optional disinfection process for improved reliability

Lightly loaded soil for removal of residual carbon, nutrients, pathogens, and trace constituents

Domestic wastewater → Modified septic tank → Biological treatment → Disinfection → Soil system

Domestic wastewater → Modified septic tank → Membrane bioreactor → Disinfection → Soil system

Domestic wastewater → Modified septic tank → Membrane bioreactor → Nanofiltration or reverse osmosis → Soil system or reuse
New Compliance Requirements

• Definition of not to exceed discharge limits
• Variability in wastewater treatment
• Statistical approach to selection of design values
**Definition of Not to Exceed Discharge Limits**

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<th>Exceedances per year</th>
<th>Probability, percent</th>
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<td>98.3</td>
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<tr>
<td>3</td>
<td>99.2</td>
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<tr>
<td>0.33*</td>
<td>99.9</td>
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</tbody>
</table>

*Recommended average frequency for acute and chronic criteria*
Variability in Wastewater Treatment

• Variability of influent wastewater characteristics
• Inherent variability in wastewater treatment processes (for reasons cited previously)
• Mechanical process reliability
Performance of Textile Filter Over Time Management Is Important
Importance of Variability in Selection of Design Values

- Monthly data
- Monthly standard (15 mg/L at 99% reliability)
- Weekly standard (20 mg/L at 99.9% reliability)

<table>
<thead>
<tr>
<th>Concentration TSS, mg/L</th>
<th>Percent of values equal to or less than indicated value</th>
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<tbody>
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<td>10.5 mg/L</td>
<td>99%</td>
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<td>12 mg/L</td>
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<tr>
<td>10.5 mg/L</td>
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<td>99%</td>
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<tr>
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<td>99.9%</td>
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<td>99.99%</td>
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</tbody>
</table>
Design of Treatment Facilities In light Of Sustainability and Homeland Security

With a clean piece of paper the location and design of wastewater treatment facilities to meet sustainability and homeland security concerns would be quite different

- More satellite treatment facilities
- Multiple distributed (decentralized) wastewater treatment facilities
Utilization of Satellite and Distributed Wastewater Treatment Facilities
Decentralized Wastewater Reuse
In Metropolitan Areas

- Diversion structure
- Screened raw wastewater
- Treatment unit (e.g., membrane separation unit, membrane bioreactor)
- Separated suspended solids
- Local reuse applications (e.g., toilet flushing, median strip watering, golf course watering, park watering, car washing)
- Existing wastewater collection system
Disk Screen Used for Primary Treatment
Membrane Bioreactor
For Buildings With Dual Plumbing
Effluent Reuse

- Turbidity – A questionable surrogate
- Easy to measure, but the wrong organism
- Chlorine or UV – Which is it?
- Advance treatment – brine management
- Assessment of Risk: Epidemiology – A crude tool?
- Is purple pipe a bad investment?
Turbidity A Questionable Surrogate
Turbidity A Questionable Surrogate
Consider Title 22 Regulations For Reclaimed Water
(NTU ≤ 2, MPN ≤ 2.2, Virus Removal ≥ 5 logs)

• With chlorine, with an approved effluent filter, a $C_Rt$ value of 450 mg•min/L is assumed to provide 5 logs of poliovirus removal

• With UV irradiation, with an effluent filter, a UV dose of 100 mJ/cm² is assumed to provide 5 logs of poliovirus removal (based on MS2)

• Because poliovirus is difficult to work with, MS2 a bacteriophage is used as a surrogate measure

• Although easy to measure, MS2 may be the wrong organism
Inactivation of MS2 Coliphage and Poliovirus With UV Irradiation
Inactivation of MS2 Coliphage and Polio Virus With Combined Chlorine

![Graph showing the inactivation of MS2 coliphage and polio virus with combined chlorine. The graph plots log reduction (\(-\log (N/N_0)\)) against \(C_{Rt}\) (mg•min/L). The data points for MS2 in buffer and effluent, as well as polio virus in buffer and effluent, are shown.]
Chlorine or UV – Which is it?

- What microorganisms need to be disinfectected?
- How should disinfection be accomplished – with chlorine, UV or something else?
- Should treated effluent be disinfected?
Epidemiology: A Crude Tool?

• Epidemiology, defined literally, is the study of epidemics in humans.

• Epidemiology in its broadest sense is the study of disease patterns in human populations.

  Dr. John Snow is famous for the suppression of an 1854 outbreak of cholera in London's Soho district. He identified the cause of the outbreak as a public water pump in Broad Street, and had the handle removed, thus ending the outbreak.

• Many agencies want to employ epidemiology to justify the use of onsite systems by demonstrating their safety.
**Epidemiology: A Crude Tool?**

- Consider flying into Los Angeles on a clear night.
- If one or two lights are out, there is no way of knowing.
- The same is true if one or two people got sick drinking either potable or reclaimed water.
- If, however, the lights of an entire neighborhood were out, it would be noticeable.
- Thus, epidemiology is really only useful for a cluster or massive events.
- Clearly, a Beaufort type approach is needed.
Effluent Disposal Issues

• De-facto indirect potable reuse is increasing as greater quantities of treated wastewater are discharged to streams and rivers (e.g. Mississippi, Colorado, and Sacramento Rivers)

• Presence of extremely low concentrations of endocrine disruptors and related compounds of concern can cause sex reversal in fish

• The ramifications of many of these constituents in trace quantities are not well understood with respect to long-term health effects
Use of Soil In Reuse And Dispersal Applications

- To remove residual organics
- To remove pathogens
- To remove nutrients
- To remove trace constituents
Effluent Application To Soil

- Conventional deep trenches (Old)
- Absorption beds (Old)
- Shallow gravel-less pressure dosed reuse systems (New)
- Drip irrigation (New)
- Surface application (New)
Flow from Conventional Leachfield Trench

- Traditional leachfield trench
- Effluent distribution pipe
- Assumed idealized flow pattern
- Actual flow moves through preferential flow channels
Flow from Conventional Leachfield Trench
Shallow Subsurface Dosing (circa 1900)
Subsurface Application Of Treated Effluent In Shallow Dosing Chamber
Subsurface Drip Application of Small Dose of Treated Effluent Over Wide Area
Removal of Coliphage in Soil Filter

- Effluent applied uniformly at 24 dose/d
- Soil filter constructed with Yolo Loam soil (cation exchange capacity 26.5 meq/100g)
- Average of 4 sampling events for each HLR
- At low HLR, no coliphage detected below 12 in
**Groundwater Accretion Issue**

(200 gal/home\* d)(365 d/yr) = 73,000 gal/home\* yr  
(73,000 gal/yr)/(10,000 ft\(^2\)) = 7.3 gal/ ft\(^2\)\* yr  
\[\sim 1.0 \text{ ft/ ft}^2\* \text{ yr}\]

Rainfall = 1.25 ft/ft\(^2\)* yr  
Evapotranspiration = 6 ft/ft\(^2\)* yr  
Field capacity = 25 % by volume

**Conclusion:** little or no groundwater accretion

What is important is holdup time
Maximum Onsite Reuse Combined
With off Site Treatment

Residence

Diversion valve

Maximum onsite reuse

Off site treatment and reuse of excess flow
Research Needs For Sustainable Onsite Development

1. Need to understand how to optimize the application of a high quality effluent to:
   - Reduce residual organics
   - Control nutrients
   - Reduce pathogenic microorganisms
   - Reduce trace constituents

2. Hydraulic model to predict actual groundwater accretion to establish soil loading rate
Closing Thoughts

- Research must be conducted that can be used to resolve issues related to the disconnect between existing standards and regulations, scientific findings, and public perception.

- Although much has been accomplished in the field of wastewater management since the passage of the *Clean Water Act*, dealing with new treatment requirements, reuse and dispersal issues in the context of public health, sustainability, cost-effectiveness, and homeland security is a challenge worthy of the attendees of this conference.
THANK YOU
FOR LISTENING