Design Considerations for High Strength Wastewater

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Presentation Overview
- Wastewater characteristics
- Managing common processes of flocculation, bulking and sloughing
- Building treatment trains for a site specific facility incorporating sustainability & recovery features
- How to work through design/loading challenges

Wastewater Loading
- Wastewater quantity
  - Hydraulic loading
  - Residential 100-150 gallons per bedroom
- Wastewater quality
  - Organic loading
  - Residential < 300 mg/L BOD₅
  - Oxygen demand
- Residential and commercial facilities

Wastewater Quantity
Types of Flow
- Residential
- Commercial
- Design
- Daily Flow
- Average
- Surge
- Peak
- Seasonal
Residential Wastewater Usage
Texas 30 TAC Chapter 285

<table>
<thead>
<tr>
<th>Type of Facility</th>
<th>Usage Rate, Gallons/Day (without water saving devices)</th>
<th>Usage Rate, Gallons/Day (with water saving devices)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single family dwelling (one or two bedrooms) - less than 1,500 square feet</td>
<td>225</td>
<td>180</td>
</tr>
<tr>
<td>Single family dwelling (three bedrooms) - less than 2,500 square feet</td>
<td>300</td>
<td>240</td>
</tr>
<tr>
<td>Single family dwelling (four bedrooms) - less than 3,500 square feet</td>
<td>375</td>
<td>300</td>
</tr>
<tr>
<td>Single family dwelling (five bedrooms) - less than 4,500 square feet</td>
<td>450</td>
<td>360</td>
</tr>
<tr>
<td>Single family dwelling (six bedrooms) - less than 5,500 square feet</td>
<td>525</td>
<td>420</td>
</tr>
<tr>
<td>Greater than 5,500 square feet, each additional 1,500 square feet or increment thereof</td>
<td>75</td>
<td>60</td>
</tr>
</tbody>
</table>
Commercial Wastewater

- **Strength**
  - Usually greater than residential
  - Operation based
    - Food preparation
    - Restrooms
    - Laundry

WASTEWATER QUALITY

- **BOD**
  - Biochemical oxygen demand

- **TSS**
  - Total suspended solids

- **FOG**
  - Fats, oils & grease

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High Strength Wastewater

1) Influent having
   - \( \text{BOD}_5 > 300 \text{ mg/L}, \ (\text{CBOD} > 300 \text{ mg/L} - \text{TCEQ}) \)
   - and/or \( \text{TSS} > 200 \text{ mg/L}, \ (\text{TSS} > 350 \text{ mg/L} - \text{TCEQ}) \)
   - and/or fats, oils, and grease (FOG) \( \geq 50 \text{ mg/L} \) entering a pretreatment component

2) Effluent from a septic tank or other pretreatment component that has:
   - \( \text{BOD}_5 > 140 \text{ mg/L}, \)
   - and/or \( \text{TSS} > 60 \text{ mg/L}, \)
   - and/or (FOG) \( > 25 \text{ mg/L} \) and is applied to an infiltrative surface.

Mass Loading Calculation

**Residential strength**

- Calculate mass loading to a system
  - Concentration in wastewater
  - Volume of wastewater
  - Mass \((\text{lb}) = \text{C (mg/L) x Q (gpd)} \times 0.00000834 \)
  - Mass \(= 0.23 \text{ lbs per day} \)

**Commercial strength**

- Mass \((\text{lb}) = \text{C (mg/L) x Q (gpd)} \times 0.00000834 \)
- Mass \(= 2.5 \text{ lbs per day} \)
Mass Loading

- Calculate mass loading to a system
  - Number of people (capita)
  - Organic loading rate
- Mass (lb) = P (# of people) x OLL (lbs per capita-day)
- Mass (lb) = 5 (# of people) x 0.17 (lbs per capita-day)
- Mass (lb) = 0.85 lbs per day

<table>
<thead>
<tr>
<th>Class</th>
<th>Persons Per Unit</th>
<th>gal/cap/day</th>
<th>Average with Garbage Grinder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subdivisions, Higher Cost</td>
<td>3.5</td>
<td>100</td>
<td>0.17</td>
</tr>
<tr>
<td>Subdivisions, Average</td>
<td>3.5</td>
<td>90</td>
<td>0.17</td>
</tr>
<tr>
<td>Subdivisions, Low Cost</td>
<td>3.5</td>
<td>70</td>
<td>0.17</td>
</tr>
</tbody>
</table>

(Goldstein and Moberg, 1973)

Comparative Biological Loads (BOD$_5$)

<table>
<thead>
<tr>
<th>Waste Source</th>
<th>Pounds per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home (3 Bdrm)</td>
<td>13.67</td>
</tr>
<tr>
<td>Restaurant</td>
<td>17.33</td>
</tr>
<tr>
<td>Supermarket</td>
<td>44.43</td>
</tr>
<tr>
<td>Large Restaurant</td>
<td>32.13</td>
</tr>
</tbody>
</table>

Flow Estimate Using Various References

<table>
<thead>
<tr>
<th>Waste Source</th>
<th>Gallons per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fast Food Restaurant</td>
<td>Actual Data</td>
</tr>
<tr>
<td></td>
<td>M&amp;E (Meals)</td>
</tr>
<tr>
<td></td>
<td>EPA (Meals)</td>
</tr>
<tr>
<td></td>
<td>MSTP (Meals)</td>
</tr>
<tr>
<td>Aqua Test, Inc.</td>
<td>1475</td>
</tr>
<tr>
<td></td>
<td>2040</td>
</tr>
<tr>
<td></td>
<td>851</td>
</tr>
<tr>
<td></td>
<td>2636</td>
</tr>
</tbody>
</table>

BOD$_5$ Load Estimates Using Various References

<table>
<thead>
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<th>Waste Source</th>
<th>Pounds per Day</th>
</tr>
</thead>
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<td>Fast Food Restaurant</td>
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<td></td>
<td>M&amp;E (Meals)</td>
</tr>
<tr>
<td></td>
<td>EPA (Meals)</td>
</tr>
<tr>
<td></td>
<td>MSTP (Meals)</td>
</tr>
<tr>
<td>Aqua Test, Inc.</td>
<td>122</td>
</tr>
<tr>
<td></td>
<td>3.46</td>
</tr>
<tr>
<td></td>
<td>1.87</td>
</tr>
<tr>
<td></td>
<td>4.81</td>
</tr>
</tbody>
</table>
Trimmed Restaurant BOD Data
- N = 284
- Removed 11 values between 4,100 and 20,100 mg/L
- 9 values TSS/FOG

Trimmed Restaurant TSS Data
- N = 312
- Removed 4 values between 15,100 and 91,800 mg/L
- 16 values BOD5/FOG

Trimmed Restaurant FOG Data
- N = 311
- Removed 13 values between 1,129 and 700,000 mg/L
- 7 values BOD5/TSS

Summary Statistics

<table>
<thead>
<tr>
<th></th>
<th>Raw Data</th>
<th>Trimmed Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD5 (mg/L)</td>
<td>Mean</td>
<td>1,584</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>2,902</td>
</tr>
<tr>
<td></td>
<td>Geometric Mean</td>
<td>932</td>
</tr>
<tr>
<td></td>
<td>Geom. Mean + Std Dev.</td>
<td>3,834</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>Mean</td>
<td>1,030</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>7,113</td>
</tr>
<tr>
<td></td>
<td>Geometric Mean</td>
<td>257</td>
</tr>
<tr>
<td></td>
<td>Geom. Mean + Std Dev.</td>
<td>7,370</td>
</tr>
<tr>
<td>FOG (mg/L)</td>
<td>Mean</td>
<td>4,520</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>51,400</td>
</tr>
<tr>
<td></td>
<td>Geometric Mean</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>Geom. Mean + Std Dev.</td>
<td>51,508</td>
</tr>
<tr>
<td>Flow (gal/seat)</td>
<td>Mean</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>Std. Dev.</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Geometric Mean</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Geom. Mean + Std Dev.</td>
<td>26</td>
</tr>
</tbody>
</table>
**Percent of Data Captured**
(28 Restaurants)
(Geometric Mean plus One Std. Dev.)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mg/L)</th>
<th>% Data Covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD&lt;sub&gt;5&lt;/sub&gt;</td>
<td>1523</td>
<td>82</td>
</tr>
<tr>
<td>TSS</td>
<td>664</td>
<td>87</td>
</tr>
<tr>
<td>FOG</td>
<td>197</td>
<td>81</td>
</tr>
</tbody>
</table>

Lesikar et al. (2006)

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**Soil Organic Loading**

<table>
<thead>
<tr>
<th>Soil Classification</th>
<th>Hydraulic Loading (g/ft&lt;sup&gt;2&lt;/sup&gt;-d)</th>
<th>Organic Loading Rate lb/ft&lt;sup&gt;2&lt;/sup&gt;-d</th>
</tr>
</thead>
<tbody>
<tr>
<td>I&lt;sub&gt;b&lt;/sub&gt;</td>
<td>0.38</td>
<td>0.00044</td>
</tr>
<tr>
<td>II</td>
<td>0.25</td>
<td>0.00029</td>
</tr>
<tr>
<td>III</td>
<td>0.20</td>
<td>0.00023</td>
</tr>
<tr>
<td>IV</td>
<td>0.10</td>
<td>0.00012</td>
</tr>
</tbody>
</table>

Organic loading rate based on the assumption of BOD<sub>5</sub> = 140 mg/L

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**Infiltrative surface area based on organic loading**

1st approach

\[ A_{OL} = \frac{[(BOD_{Eff} / 140) \times (Q / Ra)]}{0.77} \]

Where:
- \( A_{OL} \) = Infiltrative surface area (For high strength wastewater based on organic loading) – ft<sup>2</sup>
- \( BOD_{Eff} \) = Facility BOD – mg/L
- \( Q \) = Flow - gpd
- \( Ra \) = hydraulic acceptance rate - gpd/ ft<sup>2</sup>
- 0.77 = Safety factor

Note: This equation uses an example assumed value for septic tank effluent of 140. If the local code Ra values are based on an assumed BOD<sub>5</sub> other than 140 mg/L, use that value instead.
Infiltrative surface area for high strength wastewater

Example Cont.
Area based on hydraulic loading rate:
\[ \text{Area} = Q / R_a \]
Area = 500 gallons per day / 0.25 gallons per ft²-day
Area = 2000 ft²

Infiltrative surface area for high strength wastewater

Example Cont.
Area based on organic loading rate (Method 1):

Organic loading rate:
\[ A_{OL} = \left( \frac{\text{BOD}_{\text{Eff}}}{140} \right) \times \left( \frac{Q}{R_a} \right) / 0.77 \]
\[ A_{OL} = \left( \frac{300 \text{ mg/L}}{140} \right) \times \left( \frac{500 \text{ gallons/day}}{0.25 \text{ gallons/ft}^2-\text{day}} \right) / 0.77 \]
\[ A_{OL} = \left( 2.14 \times 2000 \text{ ft}^2 \right) / 0.77 \]
\[ A_{OL} = 6114 \text{ ft}^2 \]

Required area: 5558 ft²
*more than 2.5 times as large as calculated with hydraulic loading

Question

What would the life expectancy be for a system operating at both maximum flows and waste strengths?

Physical Treatment: Separation

Stokes law in action
Settling
- Floatation
- Discrete particle settling
- Flocculent development
- Hindered particle settling
- Particle compression
All systems will do one or more of three things which may influence physical treatment

- Bulking
- Sloughing
- Emulsification

Resulting in Flocculent

Bulking

- What is bulking?
- What is the impact on a system that has bulked?
  - Reduction in the solids contained in a treatment tank
  - Can resettle
- Naturally occurring bulking
  - Black in color
Emulsification

What is emulsification?
- Discrete particles in suspension
- Loss of stratification

Causes
- Temperature
  - Example: FOG emulsified by high temperature
- Chemical Emulsification
  - Brownish or yellow in color
  - Fabric softeners and wax releasing agents

Effects
- Homogeneous mass of solids that is not contained in the septic tank
- Will not settled back out

Healthy septic tank
- Scum and sludge normal
- Some carryover to second compartment
- Limited flocculent in clear zone

Chemical emulsification near completion
- Homogeneous mixture
- No clear zone
- Solids carryover definite

Solids carryover from this chemically upset system

Statistics –
- Estimated 150 gpd
- Family of 2 adults
- 1000 gallon septic tank
- System less than 3 years old
- Excessive liquid fabric softener was used
- Other chemicals likely

After drying, this remaining material was fibrous in nature showing a definite texture.
**Sloughing**

- **What is sloughing?**
  - Loss of accumulated organic material / biological growth from surfaces
- **Where does it occur?**
  - Media, trickling filters, pipe interiors
- **When does sloughing occur?**
  - When gas develops between organic / biological growth and surface it is attached to
  - Gas causes solids to lose grip on surface and solids become unattached and mobile.
  - Scouring velocity passing through a pipe.
- **What impact does sloughing have on a system?**
  - Naturally occurring
  - Advanced treatment system designs usually account for this
  - Sludge return pumps in trickling filters
  - Largely responsible for orifice clogging

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**Chemical Emulsification**

**Recoverable Trench**

- Facilitate sludge removal
- Clean out pipe at bottom of trench
- Clean out & Inspection port at ends connected to the clean out pipe

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**ATU Working Properly – sloughing should happen according to design**
FLOCCULENT

- What is flocculent?
  - Neutrally buoyant organic material aggregating together
  - Often composed of fibrous materials
  - Can be sparse or dense

- Where is flocculent present?
  - Primary, recirculation, processing, and clarifier tanks or compartments

**Treatment Trains**

- “Treatment train” refers to the series of components functioning together in a wastewater treatment system to remove contaminants from wastewater.
- Order and specific component selection important
- Must understand:
  - How each component operates
  - How the train functions as a whole
  - The limitations of each component within the train
  - The treatment processes occurring
Flow Equalization Tanks

- Makes the flow introduced to the treatment system more consistent.
- Flow equalization is important if:
  - The average flow is $\geq 70\%$ of the design capacity
  - Water use habits or facility operations are variable—Example church only open on Sun.
  - Frequent peaks exceed system capacity
    - Wash day: cleaning service

Flow Equalization/Surge Tank

- Moderates flow from facility
- Determine peak/surge to be moderated:
  - Daily
  - Weekly
- Improves treatment by ALL DOWNSTREAM components
- Up stream sized for peak

Time-Dosed / Pumping Systems

- It is a soft malfunction

Diversity of Flows from a Supermarket
Separation of Businesses

- Strip Mall
  - Multiple stores
  - Different sources
- Initial tank for each facility
- Rental contract tied to wastewater quality & quantity

Water Tightness

- Critical for treatment
  - Water entering
  - Water exiting
- Hydraulic overloading flushes system
  - Partially treated wastewater exits
  - Solids carryover
  - Dilutes microbial population

Operation and Maintenance

- Defined activities
- Designer specified
  - O&M activities
  - Troubleshooting
- Data contained in reports
- Mechanism in place to ensure they are occurring
- Lack of O&M leads to malfunction

Flexibility - Spacing & Elevation of Components

Initial tank for each facility
Rental contract tied to wastewater quality & quantity
Flexibility -- Spacing & Elevation of Components
Water Tightness
Critical for treatment
Water entering
Water exiting
Hydraulic overloading flushes system
Partially treated wastewater exits
Solids carryover
Dilutes microbial population

Operation and Maintenance
O&M requirements **MUST** be included in plans
- Defined activities
- Designer specified
  - O&M activities
  - Troubleshooting
- Data contained in reports
- Mechanism in place to ensure they are occurring
- Lack of O&M leads to malfunction
Accessibility for Maintenance

- Manufacturers guidance
- Risers to surface
- Appropriate size openings
- Appropriate depth
- Connections to components

All Systems NEED O&M

- O&M Frequency is a function of:
  - Regulations
  - Site conditions
    - Risk associated with soil type
    - Dispersal method (surface requires more O&M because of greater risk)
  - Wastewater loading to the environment
    - Watershed loading rate (subdivision on small lots—greater load—higher risk)
  - Technology—system complexity
    - Manufacturer recommendations
  - Wastewater source or use
    - Operating at >70% of design requires more O&M

Monitoring Frequency

- Who sets the monitoring frequency?
- State requirements!
- Local regulators!
- What factors?
  - Residential systems
  - Commercial systems
  - Site conditions
  - Wastewater loading to the area
  - Human and Environmental risk factors
  - Technology used

Operational Data

- All commercial systems must record flow
- Flow recording
  - Flow meter—high quality effluent
  - Elapse time meter
  - Cycle counter
  - Potable water meter
- Amber alarm
  - Add to flow equalization tank to water level in tank
- Communication with owner
System Upgrades

- A good business will grow
- How will we deal with the extra wastewater?
- Centralized sewers have a set/accepted schedule
- Performance based systems can be required to upgrade treatment system – tied to food permit
- Flexibility is key to future system upgrades
- Waste minimization

Summary

- Wastewater characteristics
- Managing common processes of flocculation, bulking and sloughing
- Building treatment trains for a site specific facility incorporating sustainability & recovery features
- Owner responsibility and good data are essential to working through design/loading challenges