Demonstration of the Effect of Particle Size on Design & Performance of Stormwater Quality Systems

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Objective
• Need to define Total Suspended Solids (TSS) removal by:
  – Specifying a particle size distribution (PSD) for the design of stormwater best management practices

Presentation Outline
• What is Total Suspended Solids (TSS)?
• Why is it important?
• Removal Mechanism
• Results / Data
• Recommendation

Definition of TSS
• Defined by Standard Method 2540D
• Weight of solids retained on 1 μm filter
• Often not defined in regulation
  – Definition is subject to interpretation for stormwater design

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**Importance of Defining TSS**

- Impacts Water Quality & Ecology
- Fine particles contain majority of pollutants
  - Disproportional large surface area
  - Nutrients – phosphorous / organics
  - Heavy Metals – Cu, Cd, Pb, Zn
  - Hydrocarbons/ PAHs

**Importance of Defining TSS**

- Must be clearly defined for:
  - Design consistency
  - Protect water resources
  - Evaluate & Compare Lab Performance
  - TSS Removal
  - Scour / Re-suspension Performance

**Presentation Outline**

- What is Total Suspended Solids (TSS)?
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**Removal Mechanism**

- Gravity Separation
  - Waste Water Sedimentation
- Inter-event Settling

**Settling Velocity of Particles**

\[ v_s = \frac{g(\rho_s - \rho_w)d^2}{18\nu} \]

Where

- \( v_s \) = particle settling velocity, ft/s (m/s)
- \( g \) = gravitational constant, ft/s² (m/s²)
- \( \rho_s \) = density of particle, lbs/ft³ (kg/m³)
- \( \rho_w \) = density of water, lbs/ft³ (kg/m³)
- \( d \) = diameter of particle, ft (m)
- \( \nu \) = viscosity of water, lbs/ft·s (kg/ms)

(Stokes, 1851)

**Stoke’s Law**

Settling velocity decreases exponentially as particle diameter decreases

**Removal Mechanism**

- Gravity Separation
  - Waste Water Sedimentation
- Inter-event Settling
MSOffice1 Consider Adding this information before this Slide / Graph
7/21/2006
**Critical Settling Velocity**

\[ v_c = \frac{H}{\theta_H} = \frac{H}{\frac{Q}{WL}} = \frac{Q}{A_s} \]

Where
- \( v_c \) = critical settling velocity, ft/s (m/s)
- \( H \) = tank depth, ft (m)
- \( \theta_H \) = hydraulic detention time, s
- \( W \) = tank width, ft (m)
- \( L \) = tank length, ft (m)
- \( A_s \) = surface area, ft\(^2\) (m\(^2\))

(Tchobanoglous & Shroeder, 1987)

**Gravity Separation**

- **Inlet Zone**
- **Settling Zone**
- **Outlet Zone**
- **Sludge Zone**

**Increase TSS Removal Efficiency**

- Hydraulic Detention Time
- Increase Chamber Dimensions
- Reduce Velocity in Sedimentation Zone
- Increase Design Particle Size (diameter)

**Presentation Outline**

- What is Total Suspended Solids (TSS)?
- Why is it important?
- Removal Mechanism
- **Results / Data**
- Recommendation

**Results / Data**

- Comparison of two different PSDs;  
  - OK-110 PSD  
    - Fine sand ---- D\(_{50}\) = 102 \(\mu\)m  
    - NJDEP  
      - Clay - Fine sand ---- D\(_{50}\) = 97 \(\mu\)m  
  - NJDEP TARP Lab Test Protocol  
    - Stormceptor Model STC-900
### Results / Data

<table>
<thead>
<tr>
<th>Operating Rate</th>
<th>NJ Annual Runoff Weight Factor</th>
<th>NJDEP PSD</th>
<th>DK-110 PSD</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>0.25</td>
<td>87%</td>
<td>99%</td>
</tr>
<tr>
<td>50%</td>
<td>0.30</td>
<td>71%</td>
<td>98%</td>
</tr>
<tr>
<td>75%</td>
<td>0.20</td>
<td>68%</td>
<td>97%</td>
</tr>
<tr>
<td>100%</td>
<td>0.15</td>
<td>74%</td>
<td>96%</td>
</tr>
<tr>
<td>125%</td>
<td>0.10</td>
<td>68%</td>
<td>84%</td>
</tr>
</tbody>
</table>

Weighted TSS Removal: 75% 96%

### Scour / Re-suspension Results

<table>
<thead>
<tr>
<th>Sediment Capacity Fill %</th>
<th>Outlet Concentration (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Product A</td>
</tr>
<tr>
<td></td>
<td>NJDEP PSD</td>
</tr>
<tr>
<td>50%</td>
<td>0</td>
</tr>
<tr>
<td>100%</td>
<td>3</td>
</tr>
</tbody>
</table>

### Conclusion

- TSS removal must be clearly defined
  - for clearly sizing manufactured treatment devices
  - to obtain desired pollutant removal & water quality goals
  - compare laboratory performance data

- Defining TSS by a given Particle Size Distribution needs to be part of design specifications
- Smallest particle diameter will define:
  - removal capability / performance
  - BMP cost

- By not defining TSS within regulations:
  - Inconsistency in BMP performance
  - Irresponsible behavior to designing
  - Generates a BMP "cost" game
    - Leads to misapplication of BMP
  - Compromises water quality & ecology
  - Generates confusion with BMP evaluations / data