The Importance of Particle Size Distribution in Determining BMP Efficiency

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Outline

- Stormwater Runoff Overview
- Detention Basin Study (2005-2006)
  - Particle Size Distribution
  - Metals Data
- Rational Design
Stormwater Runoff
Stormwater Runoff Problems

- Runoff Volume
- Runoff Water Quality
Stormwater Runoff Problems

Ballona Creek

Normal Conditions

Photos: Michael Stenstrom
Stormwater Runoff Problems

Ballona Creek

Normal Conditions

During a Storm

Photos: Michael Stenstrom
Stormwater Runoff Problems

Ballona Creek

Normal Conditions

During a Storm

Photos: Michael Stenstrom
Stormwater Runoff Problems

- Runoff Volume
- Runoff Water Quality

**Goal:** Estimate Performance of Treatment Units
Removal Rates

- Removal Rates are easy to understand
- The BMP Database Project Team has a list with 15 reasons not to use percent removal
Removal Rates

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Percent removal is primarily a function of influent quality.

Removal Rates

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BMPs with high percent removal may have unacceptably high concentrations of pollutants in effluent

Removal Rates

- Removal Rates are easy to understand

- The BMP Database Project Team has a list with 15 reasons not to use percent removal

Range of expected effluent quality concentrations is a much better planning and design tool than percent removal estimates.

Performance

Data Source: Overview of Performance by BMP Category and Common Pollutant Type [1999-2008]
Removal Rates

- By knowing the particle size distribution of the solids in the runoff, removal rates can be used in the selection process of a treatment unit.

- We will show this using a detention basin as a case study.
Caltrans Study
(2005-2006)

Storm Water Retrofit Pilot Study
A Scientific Study to Treat Storm Water Runoff
by Retrofitting Caltrans Right-of-Way using
Best Management Practice (BMP) Technologies

Technology Type:
Extended Detention Basin

An Effort Undertaken by:
Caltrans, NRDC, EPA, San Diego Baykeeper,
Santa Monica Baykeeper

213-897-8636
www.dot.ca.gov/hq/Environmental/stormwater
Detention Basin
Detention Basin
Detention Basin
Detention Basin
Detention Basin

Photos: Google
Detention Basin
Site Characteristics

- Catchment: 4,000 m²
- Vehicles Daily: 220,000
- Impervious Cover: 100%
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- Catchment: 4,000 m²
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INFLUENT

EFFLUENT
Site Characteristics

Catchment: 4,000 m²
Vehicles Daily: 220,000
Impervious Cover: 100%

Length: 30 m
Inside width: 3.3 m
Side Slope 1:2.8 m

INFLUENT

EFFLUENT
Traditional Efficiency Study
Total Suspended Solids

Mean of influent TSS is 127.25 mg/L Mean of effluent TSS is 25.17 mg/L

80% removal of solids
Total Suspended Solids

Mean of influent TSS is 127.25 mg/L Mean of effluent TSS is 25.17 mg/L
Particle Size Distribution Data
Particle Size Distribution

Nicomp Particle Sizing Systems – AccuSizer 780

- Autodilution
- Sensor Range: 0.5 – 500 µm
- Light Obscuration
- Measures voltage pulse, which is proportional to the particle maximum cross-sectional area
- Sample volume: 0.5 ml
Particle Size Distribution
Particle Size Distribution

Feb 27

Influent
Effluent

Particle Counts (#/ml)

Diameter (μm)
## Particle Removal

<table>
<thead>
<tr>
<th>Diameter Range (μm)</th>
<th>Percent Removal (%)</th>
<th>All Storms (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27-Feb</td>
<td>17-Mar</td>
</tr>
<tr>
<td>0.5-5</td>
<td>62</td>
<td>15</td>
</tr>
<tr>
<td>5-10</td>
<td>83</td>
<td>75</td>
</tr>
<tr>
<td>10-20</td>
<td>90</td>
<td>85</td>
</tr>
<tr>
<td>20-30</td>
<td>90</td>
<td>84</td>
</tr>
<tr>
<td>30-40</td>
<td>86</td>
<td>82</td>
</tr>
<tr>
<td>40-100</td>
<td>78</td>
<td>93</td>
</tr>
</tbody>
</table>
Metals Data
Concentration ($\mu$g/L)

mass of constituent by volume of runoff filtered

26 Measured Constituents

17 Constituents Above Detection Limit

Welch t-test comparison for influent and effluent concentrations for each size fraction: statistically significant with exception of the dissolved phase for 4 constituents
Concentration (µg/L)
mass of constituent by volume of runoff filtered

Pb

Zn

Cu

Ni

K

Na

< 0.45µm  0.45-8 µm  8-20 µm  >20 µm
Rational Design to Runoff Treatment Unit Performance
Removal Efficiencies

- For discrete particle settling, we can construct removal efficiency chart based on overflow rate.

- Assuming laminar flow, spherical particles with density 2.65 g/cm$^3$, and temperature 20$^\circ$C.

$$\eta = \frac{V_p}{V_o} = \frac{g(sg_p - 1)d_p^2}{18\mu}$$
Sedimentation Removal Efficiencies

Overflow Rate

0.1 m/h
1 m/h
10 m/h
100 m/h

0.5 - 8 μm
8 - 20 μm
> 20 μm
### Sedimentation Removal Efficiencies

<table>
<thead>
<tr>
<th>Storm Date</th>
<th>Rainfall (m)</th>
<th>Drainage Area (m²)</th>
<th>Volume (m³)</th>
<th>Length of storm (h)</th>
<th>Flow through device (m³/h)</th>
<th>Assumed volume (m³)</th>
<th>Retention time (h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>27-Feb</td>
<td>0.0475</td>
<td>4000</td>
<td>190.0</td>
<td>22</td>
<td>8.64</td>
<td>30</td>
<td>3.5</td>
</tr>
<tr>
<td>17-Mar</td>
<td>0.0048</td>
<td>4000</td>
<td>19.3</td>
<td>5</td>
<td>4.06</td>
<td>30</td>
<td>7.4</td>
</tr>
<tr>
<td>28-Mar</td>
<td>0.0168</td>
<td>4000</td>
<td>67.1</td>
<td>16</td>
<td>4.19</td>
<td>30</td>
<td>7.2</td>
</tr>
<tr>
<td>14-Apr</td>
<td>0.0109</td>
<td>4000</td>
<td>43.7</td>
<td>7</td>
<td>6.24</td>
<td>30</td>
<td>4.8</td>
</tr>
</tbody>
</table>

![Graph showing particle removal efficiency versus particle diameter for different storms.](image)

**Overflow Rate:**
- 0.02 m/h
- 0.06 m/h
- 0.29 m/h
Summary

- PSD is characteristic of each site
  - in certain locations, season might play a role

- We cannot talk removal rates without knowing PSD
  - we also need to know the chemistry and size fractionation of the pollutants of interest